Diversity gains of multiport mobile terminals in multipath for talk positions on both sides of the head

Diversity Gains of Multiport Mobile Terminals in Multipath for Talk Positions on Both Sides of the Head

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***Abstract*—The paper studies the over-the-air (OTA) performance of a mobile terminal. A practical two-port mobile terminal model on the left side and the right side of the head for both standard cheek position and standard tilt position is used to study the diversity gains. The diversity gain has been determined by measurements in a reverberation chamber as well as by simulations using the far field patterns from CST Microwave Studio, and then exposing these patterns to rich isotropic multipath (RIMP) environment in a ray-based simulation tool.**

***Index Terms*—diversity gain; multiport; terminal, multipath**

I. Introduction

With the advancement in cellular technology, Long Term Evolution (LTE) has emerged out as the latest communication standard, which has been widely spread and implemented nowadays around the world. The LTE standard has been developed by the successful specifications of the 3rd Generation Partnership Project (3GPP). According to these specifications LTE over-the-air (OTA) terminals include Multiple-input Multiple-output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) to support higher data rates.

We will present measured and simulated 2×2 MIMO diversity gains when the user is holding a MIMO terminal model on the right and the left sides of the head as shown in Fig. 1, over a frequency range of 0.7-1.0 GHz and 1.7-3.2 GHz. The two standard talk positions, i.e. standard cheek position and standard tilt position, are used to locate the terminal on both sides of the head [1]. The motivation of this research is to study similarities between performance on left and right sides of the head in rich isotropic multipath (RIMP) environment. The feature article in [2] describes RIMP as an important reference environment for testing MIMO OTA devices. The present study is based on numerical simulations, which are validated by measurements in RIMP emulated by a reverberation chamber. The reverberation chamber was used for several years to characterize the performance of MIMO antenna systems as shown in [3]-[4]. The focus of the last years has been to perform active measurements, and then the diversity gains at 1% CDF level as defined and used in [3]-[4] becomes an important performance parameter that directly relates to the improvement of data-rate throughput at 99% level, as explained in [2]. This fact is a result of the ideal digital threshold receiver model introduced in [5]. Active throughput measurements can even be used to characterize the OFDM frequency diversity for different time delay spreads, which can be changed by loading the chamber as shown in [6].

Section II will discuss about CST simulations of MIMO mobile terminal on right and left sides of the head phantom. Section III will discuss about ViRM-lab simulations and measurements to calculate diversity gains in RIMP environment. Section IV will show some results with discussion. Section V will conclude the paper.

II. Simulations of MIMO Terminal on Both Sides of the Head Phantom Using CST MWS

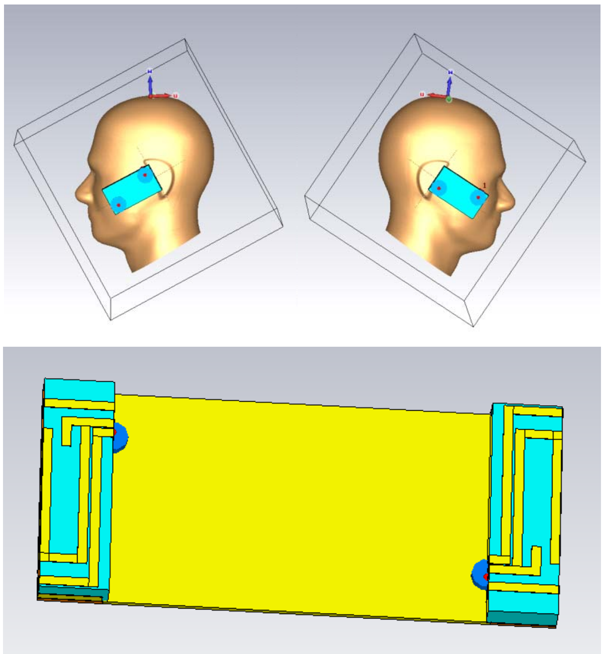

Figure 1. CST model of a two-port antenna terminal on right side (upper right) and left side of the head phantom (upper left). The mock-up phone with its two antennas are shown in the lower figure.

Several studies e.g. [7]-[8] have shown that the effect of head and hand close to the user-terminal can be large depending on how the antenna is designed and placed in the chassis and the user practices of holding the terminal. A planar inverted F-antenna (PIFA) is mostly used in mobile terminals. In this study, we also use two PIFA antennas placed on each end of the terminal i.e. top and bottom. A head phantom is used

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together with this two-port antenna terminal model in CST Microwave Studio (MWS) to simulate S-parameters and far field patterns. The two-port mobile terminal model is located on either right or left side of the head as shown in Fig. 1, using the defined standard talk positions in [1], i.e. cheek position and tilt position. The simulated S-parameters from CST and the Cumulative Distribution Function (CDF) from ViRM-lab are shown in Fig. 2 and Fig. 3, respectively, both for cheek positions. The material properties of the head phantom used in the CST simulations is given below in Table I.

TABLE I. MATERIAL PROPERTIES OF HEAD PHANTOM

Material	Material Properties		
	ε'	ε''	μ
Head Phantom (Shell)	3.7	0.028	1
Head Phantom (Fluid)	41.33	16.91	1

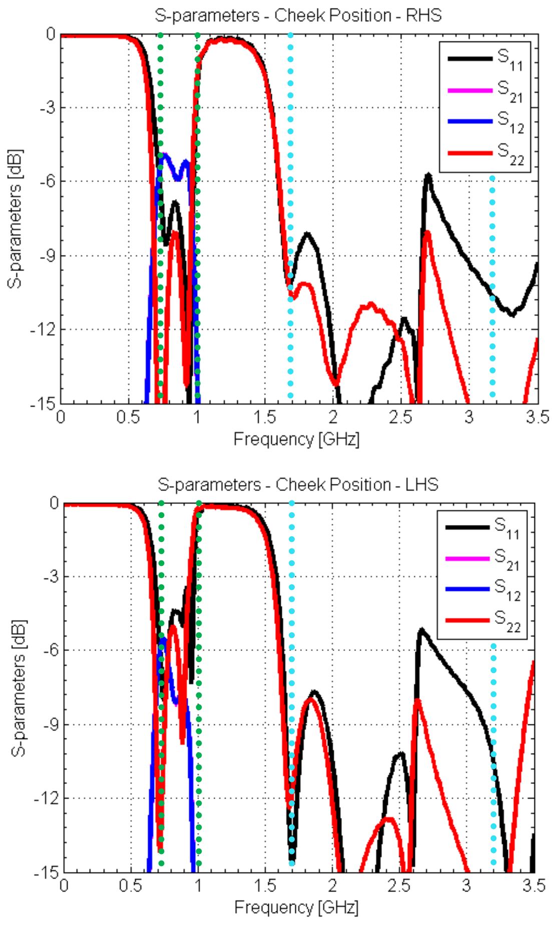

Figure 2. Simulated S-parameters of two-port antenna terminal in CST located on right (top) and left sides of the head (bottom) in the standard cheek position. The two useful frequency bands are 0.7-1.0 GHz & 1.7-3.2 GHz.

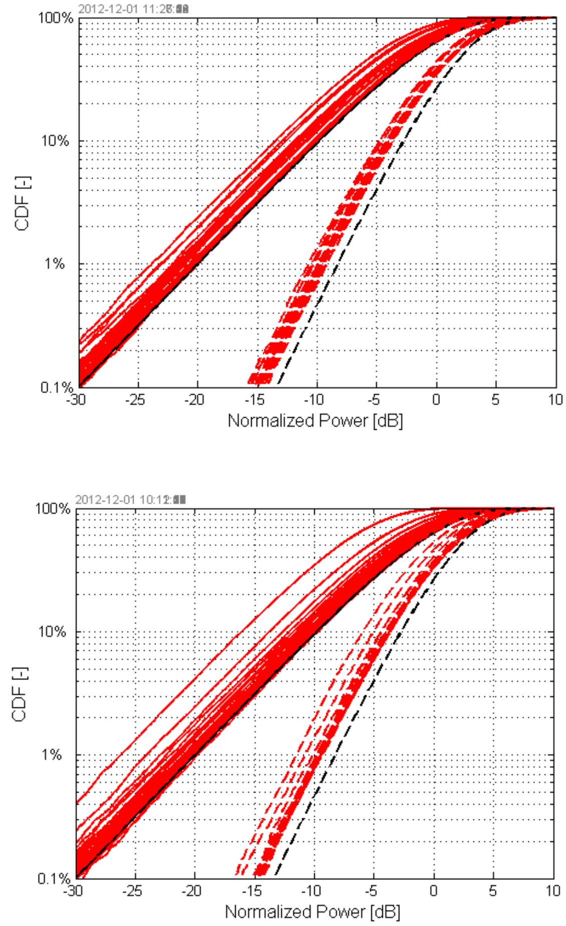

Figure 3. Simulated CDFs of voltages recevied at both antenna ports (solid lines) and CDFs of the MRC-combined diversity channel (dashed lines) when the terminal is on the right (top) and the left side of the head (bottom) following standard cheek position. The different curves are CDFs for 20 frequency points in the two frequency bands.

III. DIVERSITY GAIN SIMULATIONS & MEASUREMENTS

Rich Isotropic Multipath (RIMP) environment is emulated by a reverberation chamber as explained in [2]. We simulate such an environment by using a ray-based simulation tool called ViRM-lab [9]. The radiation patterns from CST MWS are then exposed to RIMP environment in ViRM-lab. We plot the resulting CDFs of voltages received on each antenna port for all frequencies of operation in Fig. 3. We also plot CDFs of the MRC-combined diversity gains as well, presented as dashed lines in Fig. 3. The diversity gains are plotted in Fig. 5, being calculated at 1% CDF-level.

To validate our simulated results we perform measurements of this two-port mobile terminal inside reverberation chamber together with head phantom. The terminal is located on right and lift sides of the head according to the standard talk positions i.e. cheek position and tilt position. A photo of measurements inside reverberation chamber is shown below:

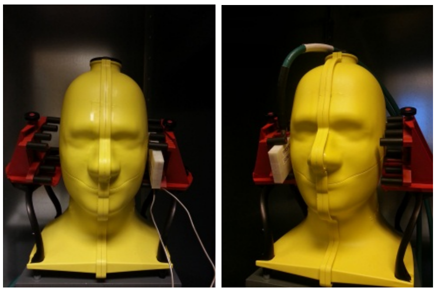

Figure 4. Photos of two-port mobile terminal on right side (right) and left side (left) of the head phantom during measurements inside reverberation chamber.

IV. RESULTS & DISCUSSION

We can already see from S-parameters in Fig. 2 that there are only minor differences when user is holding the phone on right side compared to when user is holding the phone on the left side of the head. Similarly, we can see some minor differences for the two sides in the CDFs and diversity gains in Fig. 3 and Fig. 5 respectively.

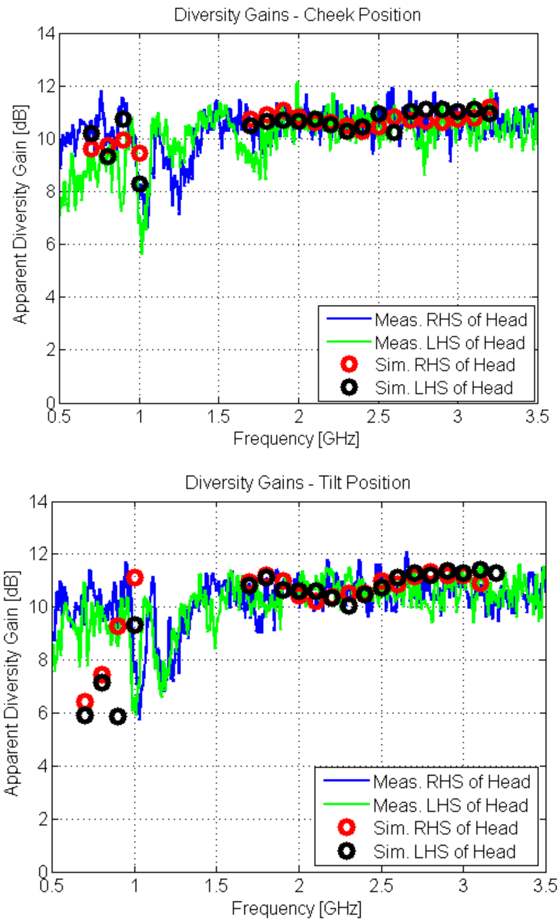

Figure 5. Measurements and simulations of diversity gains at different frequencies when user-terminal is on the right and left side of the head for cheek position (top) and tilt position (bottom).

There is a major discrepancy between measured (good) and simulated (poor) values for the diversity gain at the tilt position in the lower frequency band. This degradation is also seen in the simulated S-parameters and CDFs of the tilt-position when compared to the cheek position, although these results are not included in the present paper. This degradation in the simulated performance is due to a small shift of the lower frequency band of the S-parameters when we move from cheek to tilt position. There is no corresponding frequency band shift observed in the measured S-parameters inside the reverberation chamber.

V. CONCLUSION

We can conclude that for this specific two-port mobile terminal mockup model the diversity gain performance in rich isotropic multipath (RIMP) will be quite similar when the mobile terminal is located on either side of the head for both standard talk positions i.e. cheek and tilt positions. This conclusion is a result of both simulations and measurements which generally are in good agreement. There is a discrepancy between measured and simulated diversity gain in the lower frequency band for tilt position, but this appears almost in the same way at both sides of the head.,

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