Beam width assessment of a Linear Array for MaMIMO applications at 3.5 GHz using measurements and raytracing

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Abstract

The width of a beam produced by MaMIMO arrays will affect a user's exposure to RF-EMFs. We performed measurements in an anechoic chamber using a virtual arrays and successfully assessed this beamwidth. We validated our measurements with simulations.

1 Introduction

In the fifth generation of telecommunication networks, Massive Multiple-input-multiple-output (MaMIMO, [1]) base stations (BSs) will produce narrow RF-EMF beams aimed at each specific user device they service. Knowledge on the widths of these beams is essential to evaluate a user's exposure to RF-EMFs. The aim of this study is to assess this beam width via measurements in an anechoic chamber and to validate the used setup with free-space simulations.

2 Materials and Method

2.1 Measurement setup

Figure 1 shows a schematic top view of the measurement setup in the anechoic chamber. Two vertically polarized dipole dual cone broadband antennas, a transmitting (TX) and receiving (RX) antenna, are connected to a vector network analyzer (VNA) performing measurements at 3.5 GHz. The TX antenna is fixed on a linear positioning system, moving along the y-axis. The RX antenna is placed on a 2D positioning system, consisting of two orthogonally oriented linear positioners moving along the y- and x-axis. Positioning systems are co-planar, such that the antennas stay in the same xy-plane as they move.
The TX grid has 17x1 locations, with the interspacing chosen to be δTx=4.28 cm, which is about half the wavelength. This results in an array aperture L of 68 cm. The TX-RX distance D is chosen to be 68 cm as well. The RX grid has 33x17 locations (33 elements along the y-axis per 17 elements along the x-axis) with an interspacing half of the TX interspacing (δRx=2.14 cm). We measure the channel transfer function h_{kn},measured between each Tx-position k (k=1…17) and each Rx-position n (n=1…561), resulting in the channel matrix $\mathbf{H}_{\mathbf{measured}}$.

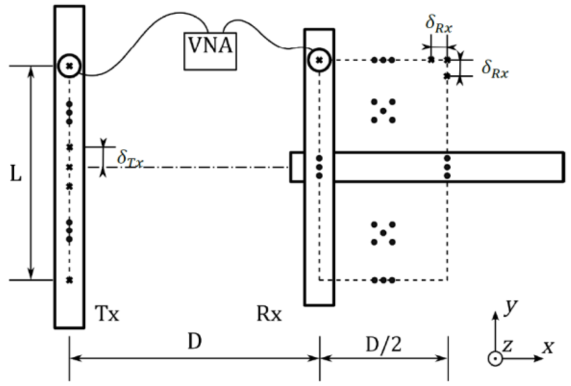


Figure 1: Schematic overview of the measurement setup.

To validate the measurement results, we estimate the wireless channel between the TX and RX virtual arrays using a Line-of-Sight (LOS) propagation model. This is suitable for calculating propagation in the anechoic chamber with virtual arrays, as it only takes into account direct propagation paths between TX-RX pairs and neglects mutual coupling effects of the arrays' antennas. This results in the simulated channel matrix $\mathbf{H}_{\mathbf{model}}$.

2.2 Post processing

The channel correlation matrix (CM) is commonly used for the analysis of the performance of MaMIMO systems is defined as:

$$G = H^* H. \quad (1)$$

This results in two 561x561 CMs: $\mathbf{G}_{\mathbf{measured}}$ and $\mathbf{G}_{\mathbf{model}}$ which are complex valued with real values on the main diagonal. To simplify the analysis we take the average of the results in each of the 17 Rx-rows along the x-axis. This way we calculate the average beam width over the distance x=[68cm 102cm]. This results in the 33x33 averaged CMs $\mathbf{G}_{\mathbf{avg,measured}}$ and $\mathbf{G}_{\mathbf{avg,model}}$. These are normalized.
To assess the beamwidth, we define the spatial correlation function (CF) ρ(G_avg,i) as the average over the ith diagonal of $\mathbf{G}_{\mathbf{avg}}$:

$$\rho(\mathbf{G}_{\mathbf{avg}}, \mathrm{i}) = \frac{\sum_{k=1}^{33-i} \left| g_{k,k+i} \right|}{33 - \mathrm{i}}, \quad (2)$$

with glm an element of $\mathbf{G}_{\mathbf{avg}}$. ρ can be treated as a function of the distance in the y-direction between the receivers.

The average relative difference σ_{avg} between $\mathbf{G}_{avg,measured}$ and $\mathbf{G}_{avg,model}$ is calculated as:

$$\sigma_{avg,lm} = \left| \frac{\left|g_{avg,model,lm}\right| - \left|g_{avg,measured,lm}\right|}{\frac{\left|g_{avg,model,lm}\right| + \left|g_{avg,measured,lm}\right|}{2}} \right| \qquad (3)$$

with $\sigma_{avg,lm}$ an element of σ_{avg}.

3 Results and Discussion

Figure 2 compares $\rho(\mathbf{G}_{avg,model})$ and $\rho(\mathbf{G}_{avg,measured})$. A very good agreement is observed. Both functions have maximum at $\delta y=0$ and decrease rapidly within a 1-wavelength distance (8.57 cm). After minor oscillations they flatten-out at around 4% of their maximum value for $\delta y>0.5$ m ($\approx 6*\lambda$). The distance between the maximum and half the maximum $\delta_{hm}y=6.5$ cm, the beam width is thus $2*\delta_{hm}y=13$ cm.

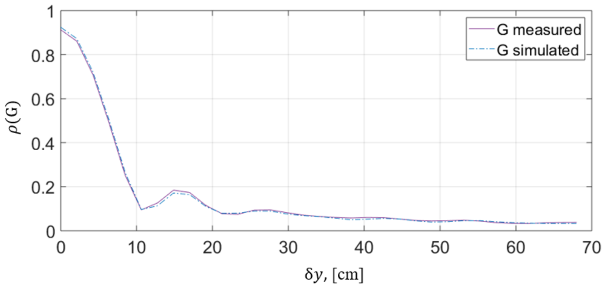
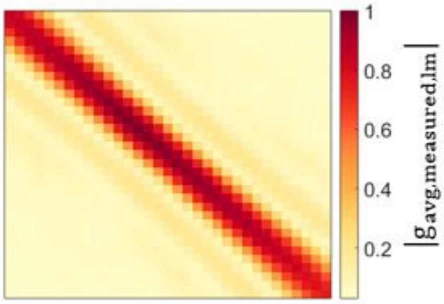
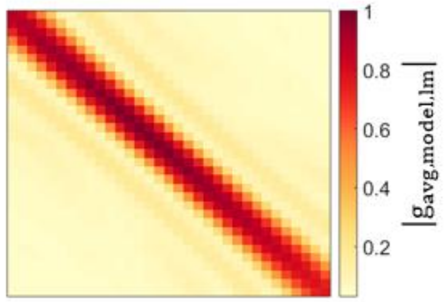


Figure 2: Spatial correlation function of $G_{avg,measured}$ and $G_{avg,model}$ in terms of the distance between their rows.

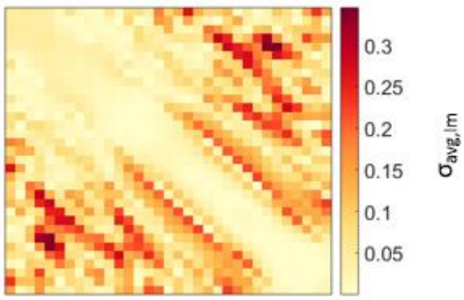
In Figure 3 the normalized CMs $G_{avg,measured}$ (3a), $G_{avg,model}$ (3b) and their difference σ_{avg} (3c) are shown. The main diagonal dominance is apparent in both averaged CMs. The same result has been obtained in measurement campaigns [2] and using geometry-based models [3]. σavg, does not exceed 5% on the main diagonal. This implies a good agreement between measurements and simulations. However, some of the out-of-diagonal elements exceed 30%. The reason for that are the low absolute correlation values observed at large RX separation distances, which are shown in the top-right corner of the CMs. Even a small variation of the received signal (due to e.g. reflections by the positioners and support structures, alignment errors, radiation pattern variation) results in a relatively high simulation error.
This measurement setup can now be used to evaluate exposure from MaMIMO systems in other environments, such as a room without absorbing materials, with obstructed line-of-sight conditions, etc.



(a)



(b)



(c)

Figure 3: The normalized correlation matrices $G_{avg,measured}$ (a), $G_{avg,model}$(b), and their relative difference σ_{avg} (c).

4 Conclusions

We measured and simulated the beam width of a MaMIMO array and found $2*\delta_{hm}y=13$ cm. A good agreement between measurements and simulations was observed.

5 Acknowledgements

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6 References

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