Extension of ITU IMT-A Channel Models for Elevation Domains and Line-of-Sight Scenarios

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Abstract—In this contribution, the 3-dimensional (3D) channel characteristics, particularly in the elevation domains, are extracted through measurements in typical urban macro and micro environments in Xi’an China. Stochastic channel model parameters are obtained based on the high-resolution multi-path parameter estimates. In addition, a modified spatial channel model (SCM) for the line-of-sight (LoS) scenario is proposed where the LoS polarization matrix is parameterized in accordance with the reality. Measurement results justify the reasonability of the proposed model. These works significantly improve the applicability of the ITU SCM models in realistic 3D channel simulations.

Index Terms—3-dimensional channel models, elevation of arrival, elevation of departure, line-of-sight, and polarization matrix

I. INTRODUCTION

Multiple-input Multiple-output (MIMO) enhancements are proposed in the 3rd Generation Partnership Project (3GPP) Releases 10 and 11 to support eNodeB (eNB) antenna configurations capable of adaptation in azimuth. Recently researches in enhancing system performance through the use of antenna systems having a two-dimensional array structure has been paid lots of attention in order to provide more spatial degree of freedom in both elevation and azimuth domains. Additional control in the elevation dimension enables new transmission techniques by using the 3-dimensional (3D)-beamforming or with the massive MIMO, such as the sector-specific elevation beamforming (e.g., adaptive control over the vertical pattern beamwidth and/or downtilt), advanced sectorization in the vertical domain, and user-specific elevation beamforming techniques. In order to evaluate the performance of the systems utilizing these techniques, new channel models characterizing channels in both vertical and horizontal dimensions in various environments with different user locations are necessary.

Existing directional channel models as proposed in 3GPP TR25.996\textsuperscript{2}, the IMT-Advanced standards\textsuperscript{3} and in the WINNER reports\textsuperscript{4} have been widely adopted for development of wireless communication systems. However, with respect to the elevation characteristics of the radio channel, these models are considered to be insufficient. For example, in the WINNER+ project\textsuperscript{5}, 3D channel modeling methodology and parameters were proposed based on literature survey rather than extensive measurements. Thus, the applicability of the models suggested are questionable due to some obvious errors, such as that the cross-correlation matrix of large scale parameters (LSPs) is non-positive definite. The elevation characteristics, such as mean elevation angular spread (MEAS), extracted based on measurements have also been reported in literature\textsuperscript{6}, \textsuperscript{7}, \textsuperscript{8}. However, these models focus on the marginal elevation characteristics, rather than the joint characteristics in both azimuth and elevation, and thus, are lack of applicability for 3D MIMO system-level evaluation.

In this contribution, 3D channel measurement campaigns conducted by Huawei Propagation Research Group are described, which have been performed in different urban scenarios with the objective of extracting the full 3D channel characteristics particularly at the eNB. New measurement results for the statistics of the LSPs, and the cross-correlation matrix thereof are elaborated. Furthermore, a questionable setting specified in the WINNER+ SCM models for the polarization matrix of the line-of-sight (LoS) path is corrected and verified with measurement data.

The rest of the paper is organized as follows. Section II introduces the measurement setup and the environments where the measurements were carried out. In Section III the channel characteristics extracted for the urban macro (UMA) and urban micro (UMI) scenarios are described and the updated values for the ITU IMT-A model parameters are reported. In Section IV a mistake in the SCM, WINNER+, and ITU IMT-Advanced models for the LoS scenario is discussed, and the correction is proposed. Finally conclusive remarks are provided in Section V.

II. MEASUREMENT SETUP AND ENVIRONMENTS

A diagram for the measurement setup is illustrated in Figure 1, where the Agilent E4438C signal generator is applied as an eNB, generating a pseudo-noise signal with 35MHz...
bandwidth and center frequency of 2.6 GHz. Figure 2 depicts the photographs of the antennas used in the eNB and the user equipment (UE). The eNB was equipped with a planar antenna array with 32 antenna elements configured as 16 patches, each consisting of two antennas with ±45° polarizations, 7 dBi gain and 90° beamwidth on both horizontal and vertical planes. A crown-shaped antenna array is used in the UE, which has 50 antenna elements allocated on 25 patches with the structure similar with those on the eNB antenna array. The horizontal and vertical spacings between the nearest neighboring antennas are 0.5 wavelength. The down-tilting angle of the eNB antenna array is approximately 7°.

The measurement was conducted emulating the downlink scenarios, i.e. the eNB and the UE were considered as the transmitter (Tx) and the receiver (Rx) respectively. The high-resolution channel parameter estimation algorithm Space-Alternating Generalized Expectation-maximization (SAGE) algorithm [9] was applied to estimation of 14 parameters for individual paths, i.e. the delay, Doppler frequency, direction (azimuth and elevation) of departure (DoD), direction of arrival (DoA) and polarization matrix.

The measurements were conducted in the “High-tech” district of Xi’an, China. The UE was moving along two routes in the area A and area B as indicated in Figure 3 and 4 respectively. The photographs taken in the eNB side for the area A and B are shown in Figure 3 and 4. It can be observed that the area A and B are close to the definition of UMA and UMI scenarios specified in the WINNER modeling [4] receptively. The heights of the eNB antenna in area A and area B were 40 m and 14 m above the ground respectively. Notice that considering the limited effective radiation of the antenna array in the eNB, the estimation range of azimuth of departure (AoD) and elevation of departure (EoD) are confined to be [−180°, 0°] and [0°, 180°], respectively. Furthermore, the AoD and EoD of the direction normal to the array plane are −90° and 90° respectively.

### III. Verification of the parameter estimation

To ensure that the path parameters are correctly estimated, the angular estimates obtained in the LoS scenario in the case 4 in the area B are compared with their counterparts calculated geometrically based on the map information and the antenna heights. It can be observed from Figure 4 that...
in the measurement case 4, the UE started from the location A, moving to the location B, then back to A, and finally arrived at the location C. The theoretical AoD and EoD for the LoS path at the start and the end point of this measurement route are illustrated in Figure 4. Figure 5 (a) depicts the AoD estimates for the LoS path, which is selected to be the strongest path estimated by using the SAGE algorithm, versus the measurement snapshots. It can be seen that the AoD estimate increases gradually from $-85^\circ$ to $-98^\circ$ when the UE arrived at the location A, and then increase again up to $-70^\circ$ when the UE arrived at the location C. This variation is consistent with the AoD’s trajectory calculated theoretically based on the UE displacement. It can also be observed from Figure 5 (a) that there is a sudden change of the AoD at the 180th measurement snapshot. This is due to the fact that the orientation of the Tx antenna array was adjusted manually at that moment in order to make sure that the UE can be covered by the array’s main lobe. The array was tuned back to its original position finally. Figure 5 (b) depicts the estimated EoDs of the LoS path versus the snapshots, which also fits well with the theoretically calculated EoDs. In addition, it is worth mentioning that the estimated trajectories of AoDs and EoDs are not smooth due to the limited intrinsic resolution of the measurement equipment in both delay and angular domains.

IV. Measurement results

A. Measurement-based 3D channel parameters

The measurements were conducted with the objective of extending the ITU channel model [11] to include the elevation dimension in order to generate the 3D channel model for system level simulations. Table I reports the statistical channel parameters extracted for both the elevation and azimuth domains at the eNB and UE sides, as well as the delay domains. In the table, DS, ASD and ASA represent the delay spread, azimuth spread for departure and for arrival, respectively. These parameters can be used to update the corresponding entries of the table A1-7 in [3] for ITU channel model standards for the environments considered in the measurements.
The 3D MIMO performance evaluation also requires the power elevation spectrum and elevation spread at the eNB. Table I reports the mean azimuth angular spread (MAAS) and mean elevation angular spread (MEAS) at the eNB. Figure 6 depicts the EoA distributions for the UMA and UMI LoS scenarios. It can be observed from Figure 6 that the Laplacian distributions can be used to fit the empirical distribution derived from measurements.

Table III reports the cross-correlation coefficients between different large-scale parameters (LSPs) based on the measurement results. Here, the cross-correlation coefficient of two random variables, say \( a \) and \( b \), are calculated as

\[
C(a, b) = \frac{\sum_{i=1}^{N} (a_i - \bar{a})(b_i - \bar{b})}{\sqrt{\sum_{i=1}^{N} (a_i - \bar{a})^2 \sum_{i=1}^{N} (b_i - \bar{b})^2}},
\]

where \( \bar{a} \) and \( \bar{b} \) denote the mean of \( a \) and \( b \) respectively.

V. GENERATING CHANNEL COEFFICIENT FOR LOS PATH

In the case where the elevation domain is taken into account, the contribution of the \( n \)th cluster in the narrowband coefficients of the channel between the \( n \)th Tx antenna and the \( m \)th Rx antenna can be calculated as

\[
H_{m,n}(t) = \frac{1}{K_k + 1} H'_{m,n}(t) + \delta(n-1)H'_{m,n}^{\text{NLoS}}(t),
\]

where \( H'_{m,n}(t) \) represents the NLoS component and can be written as

\[
\Phi_{\text{LoS}}^{\Phi_{\text{LoS}}} = \phi_{\text{LoS}}^{\text{LoS}} = \phi_{\text{LoS}},
\]

which is different from the settings in the existing ITU and 3GPP geometry-based channel models that \( \Phi_{\text{LoS}} \) and \( \phi_{\text{LoS}} \) are generated independently. This revision is important since in the case where the LoS path is of free-space propagation, the polarization status of the transmitted EM wave shall be unaffected, which occurs if and only if the diagonal elements of the LoS path polarization matrix do not introduce extra phase difference to the vertical and horizontal polarized components being transmitted. The conventional setting of independent \( \Phi_{\text{LoS}} \) and \( \phi_{\text{LoS}} \) results in a consequence that the polarization status of received LoS component is different from that of the transmitted signal, which is inconsistent with the common experience in reality.

To justify the amendment suggested, a measurement campaign was conducted to check the variability of polarization status for the signals received from the LoS path. Figure 7 depicts the premises of the measurement in the open rooftop environment with clear LoS between the Tx and Rx separated by 40 meters. The Tx was equipped with a patch consisting of two antennas transmitting \( \pm 45^\circ \) polarized waves respectively. By feeding different phases into the input signals at radio frequency of the two Tx antennas, the transmitted wave may have desirable polarizations, such as the linear, elliptical or circular polarizations, which is consistent with the common experience in reality.

Figure 8 reports the received power at the output of the Rx with linear polarizations from \( 0^\circ \) to \( 360^\circ \). Notice that the polarization slant angle of \( 0^\circ \) is referred to the vertical
In this contribution, the stochastic channel characteristics scenarios in Xi’an, China have been reported with emphasis in extracted based on measurements for urban macro and micro generated by using the updated model parameters yield non-
Advanced channel models for urban scenarios. The channels compared with the existing 3-dimensional (3D) ITU IMT-
with other large-scale channel parameters were calculated and
obtain by using the existing models. In addition, modification were proposed for the conventional settings of the LoS-
spatial channel models. Measurement results justified the reasonability of the changes for real LoS cases.

VI. Conclusions

In this contribution, the stochastic channel characteristics extracted based on measurements for urban macro and micro
scenarios in Xi’an, China have been reported with emphasis in the elevation of arrival and of departure domains. The elevation
angular spreads and the cross-correlation coefficients thereof with other large-scale channel parameters were calculated and
compared with the existing 3-dimensional (3D) ITU IMT-
Advanced channel models for urban scenarios. The channels generated by using the updated model parameters yield non-
egative definite correlation matrices which is difficult to obtain by using the existing models. In addition, modification
were proposed for the conventional settings of the LoS-
path polarization matrix defined in the WINNER+/ITU/3GPP

\[ H_{\text{LoS},u}(t) = \sqrt{K_U} \left[ \frac{F_{\text{LoS},u}^h(\bar{\phi}_{u,m})}{F_{\text{LoS},u}^h(\bar{\phi}_{u,m})} \right] \exp(j \phi_{u,m}) \] 

\[ H_{\text{LoS},r}(t) = \frac{K_R}{K_R + 1} \left[ \frac{F_{\text{LoS},r}^v(\bar{\phi}_{r,m})}{F_{\text{LoS},r}^v(\bar{\phi}_{r,m})} \right] \exp(j \phi_{r,m}) \] 

\[ \begin{bmatrix} \frac{F_{\text{LoS},r}^h(\bar{\phi}_{r,m})}{F_{\text{LoS},r}^h(\bar{\phi}_{r,m})} & \exp(j \phi_{r,m}) \end{bmatrix} \exp(j 2\pi (\bar{\lambda}_r \cdot \bar{\phi}_{r,m}/\lambda_0 + \bar{\lambda}_n \cdot \bar{\phi}_{n,m}/\lambda_0 + \bar{\phi}_{n,m}/\lambda_0) \right) \] 

(2)

(3)

Figure 7. Measurement in a LoS environment. The antennas marked by the red and blue ellipses are for the Tx and Rx respectively.

Figure 8. Power of the received signal when the Rx polarization varies from 0° to 360° polarizations

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