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Title: Link-Level Simulation of Isotropic Channel Model with SCME Temporal Characteristics

Agenda Item: 7.4

Document for: Discussion

1 Introduction

We describe LTE link-level simulations using the geometrical description in [1] of the isotropic channel model with SCME temporal characteristics. The LTE transmitters and receivers are modeled in SystemVue [2]. The over-the-air portion of the simulation, including the transmitting and receiving antennas, is performed with SystemVue's Matlab interface. Hence, SystemVue performs the LTE throughput calculations with Matlab providing the fading channel. We also show preliminary results for multicluster and single cluster methods.

2 Isotropic channel model based on SCME

Figure 1 shows the schematic for the isotropic channel model with SCME temporal characteristics described in [1]. The channel model has the temporal characteristics of the SCME model and is spatially isotropic. The full specification of the SCME model can be found in [3]. The isotropic environment in [1] has been used to compute capacity curves [4]-[9], which subsequently have been shown to agree with experimental results obtained with a reverberation chamber [10].

We repeat the important features of the isotropic channel model based on SCME here. The complete description can be found in [1]. An SCME channel model is connected to the isotropic test environment through a set of relay antennas. On the input side, the SCME channel model is connected to a base station. On the output side, the SCME model is connected to a set of uncorrelated relay antennas. With the base station antennas and the relay antennas selected, the SCME model specification [3] allows us to compute the output of the relay antennas from the base-station input signals.

We let the input port index be denoted s, with $s = 1, ..., S$, where S is the number of base station ports. Similarly, the relay antenna index is denoted by u, with $u = 1, ..., U$, where U us the number of relay antennas. In Figure 1 we have $S = 2$ and $U = 4$. Then the

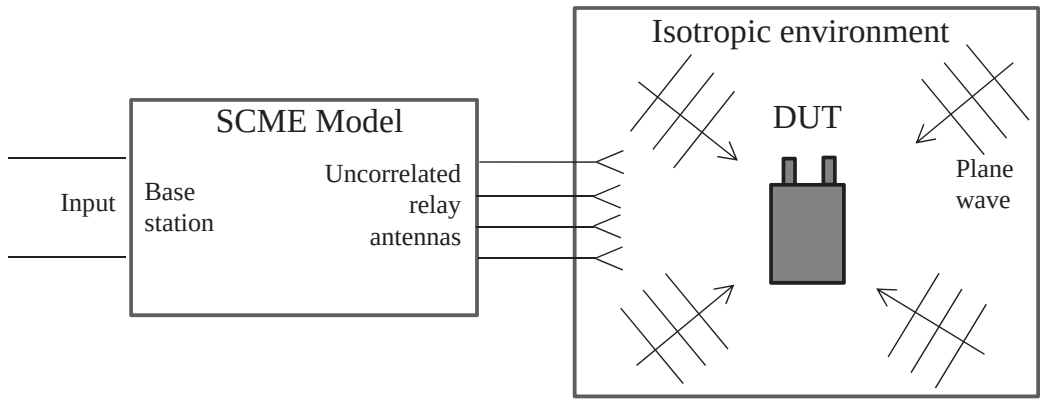

Figure 1: *Schematic of isotropic channel model based on SCME. A base station broadcasts into a standard 2D SCME model environment. A set of relay antennas act as the output of the SCME model. The relay antennas broadcast into an isotropic environment in which the DUT is placed.*

SCME model [3] determines the channel coefficients $h_{u,s}^{(SCME)}(t,n)$, where t is time and n is the tap number. We let $V_u^{(relay)}(t)$ denote the output of relay antenna u and have

$$V_u^{(relay)}(t) = \sum_{s=1}^{S}\sum_{n=1}^{N} h_{u,s}^{(SCME)}(t,n)V_s(t-t_n) \tag{1}$$

where t_n is the tap delay for tap $\#n$, and $V_s(t)$ is the input signal from port $\#s$ of the base station. Matlab software required to compute the SCME channel coefficients $h_{u,s}^{(SCME)}(t,n)$ can be found in [11], [12].

The isotropic channel model based on SCME operates with the isotropic environment locked in a particular state for an extended period of time. In other words, the SCME model is run over an extended period of time for each of the isotropic states $j = 1, 2, .., J$. Hence, for given relay antenna outputs $V_u^{(relay)}(t)$, we need to compute the DUT antenna outputs for each state j separately.

Let the output ports of the DUT be indexed by g, with $g = 1, 2, ..., G$. Moreover, let $V_{g,j}^{(DUT)}(t)$ denote the output of DUT port g when the relay antenna outputs are $V_u^{(relay)}(t)$ and the isotropic environment is in state j. With $\boldsymbol{\mathcal{R}}_g(\theta,\phi)$ denoting the plane-wave receiving characteristic for DUT port g, we find from [1, eq.(10)] that

$$V_{g,j}^{(DUT)}(t) = \frac{1}{D_0}\sum_{u=1}^{U}\sum_{p=1}^{P}\left[\alpha_p^{(j,u)}\hat{\boldsymbol{\theta}}_p\cdot\boldsymbol{\mathcal{R}}_g(\theta_p,\phi_p) + \beta_p^{(j,u)}\hat{\boldsymbol{\phi}}_p\cdot\boldsymbol{\mathcal{R}}_g(\theta_p,\phi_p)\right]V_u^{(relay)}(t) \tag{2}$$

where $\alpha_p^{(j,u)}$ and $\beta_p^{(j,u)}$ can be determined from [1, eqs.(2)-(3)], and (θ_p,ϕ_p) with $p = 1, 2, ..., P$ are the plane-wave directions of the isotropic environment. Inserting (1) into (2) gives the output of DUT antenna port $\#g$ in terms of the input signals $V_s(t)$ of the base station antennas when the isotropic environment is in state $\#j$.

Introducing the DUT antenna response constants for the isotropic environment

$$\mathcal{D}_{g,u,j} = \frac{1}{D_0} \sum_{p=1}^{P} \left[\alpha_p^{(j,u)} \hat{\boldsymbol{\theta}}_p \cdot \boldsymbol{\mathcal{R}}_g(\theta_p, \phi_p) + \beta_p^{(j,u)} \hat{\boldsymbol{\phi}}_p \cdot \boldsymbol{\mathcal{R}}_g(\theta_p, \phi_p) \right] \tag{3}$$

and the channel coefficients $h_{s,g,j}^{(ISCME)}(t,n)$ for the isotropic model with SCME temporal characteristic

$$h_{g,s,j}^{(ISCME)}(t,n) = \sum_{u=1}^{U} \mathcal{D}_{g,u,j}\, h_{u,s}^{(SCME)}(t,n) \tag{4}$$

the output of the DUT antennas can be expressed simply as

$$V_{g,j}^{(DUT)}(t) = \sum_{s=1}^{S} \sum_{n=1}^{N} h_{g,s,j}^{(ISCME)}(t,n) V_s(t - t_n). \tag{5}$$

To ensure that isotropy is achieved, we must repeat the experiment for all states $j = 1, 2, ..., J$, as described in [1].

The DUT antenna response constants $\mathcal{D}_{g,u,j}$ in (3) are seen to be the DUT output when the incident field consists of P plane waves with amplitudes $\alpha_p^{(j,u)}$ and $\beta_p^{(j,u)}$ propagating in the directions (θ_p, ϕ_p). The channel coefficients $h_{g,s,j}^{(ISCME)}(t,n)$ in (4) for the isotropic model with temporal SCME characteristics is seen to have the same number of taps as the underlying SCME model.

Finally, we note that the isotropic model with temporal SCME characteristics (5) has the same structure as the standard SCME model (1). The difference between the two models lies in the direction of propagation of the incoming plane waves. In the standard SCME model the incoming plane waves emerge from clusters located in a plane. For the isotropic model with temporal SCME characteristics, the incoming plane waves come from P direction (θ_p, ϕ_p) evenly distributed on a sphere; see [1] for details.

3 Implementation in SystemVue

As shown in Figure 2, the LTE transmitters and receivers are modeled in SystemVue [2], and the fading channel (including the transmitting and receiving antennas) is modeled in Matlab. Specifically, SystemVue provides the inputs $V_s(t)$ to the base station antennas (denoted $V_1^{in}(t)$ and $V_2^{in}(t)$ in Figure 2), and Matlab computes the outputs $V_{g,j}^{(DUT)}(t)$ of the DUT antennas (denoted $V_1^{out}(t)$ and $V_2^{out}(t)$ in Figure 2).

Agilent provided the template SystemVue workspace shown in Figure 3 where Matlab is accessed through a Matlang block. Noise is added after the signal has reached the output of the DUT antennas, as indicated in Figure 3. Throughput is computed for each of the isotropic states and each of the selected noise levels, thus producing a throughput curve for each isotropic state. The final throughput curve is obtained by averging over all isotropic states.

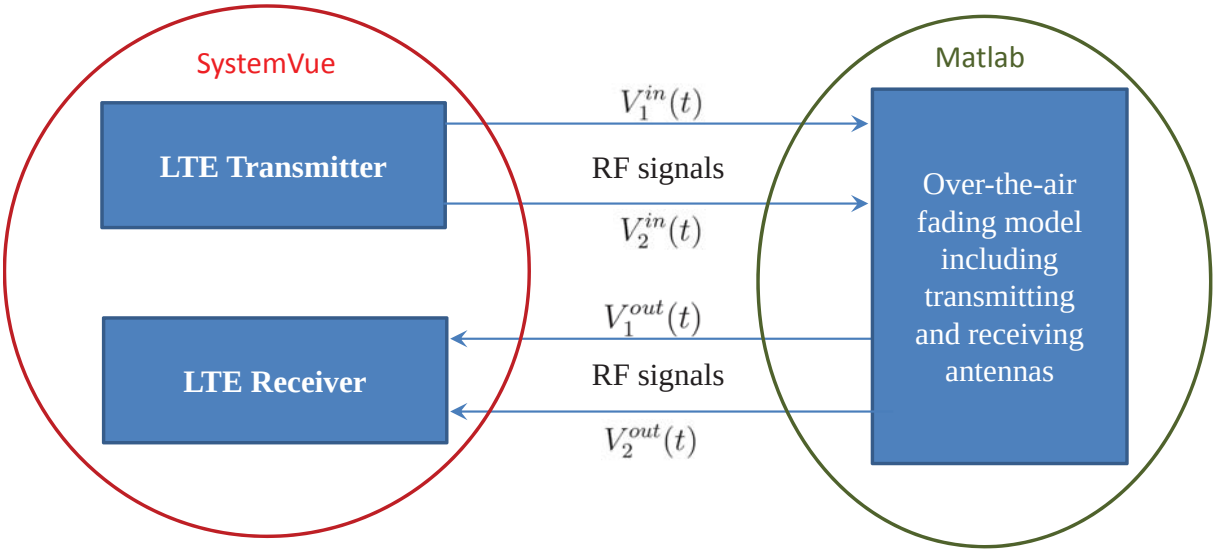

Figure 2: *Schematic of the implementation of the isotropic channel model with SCME temporal characteristics for a 2X2 MIMO simulation. The fading model and transmitting and receiving antennas are implemented in Matlab. The rest is implemented in SystemVue.*

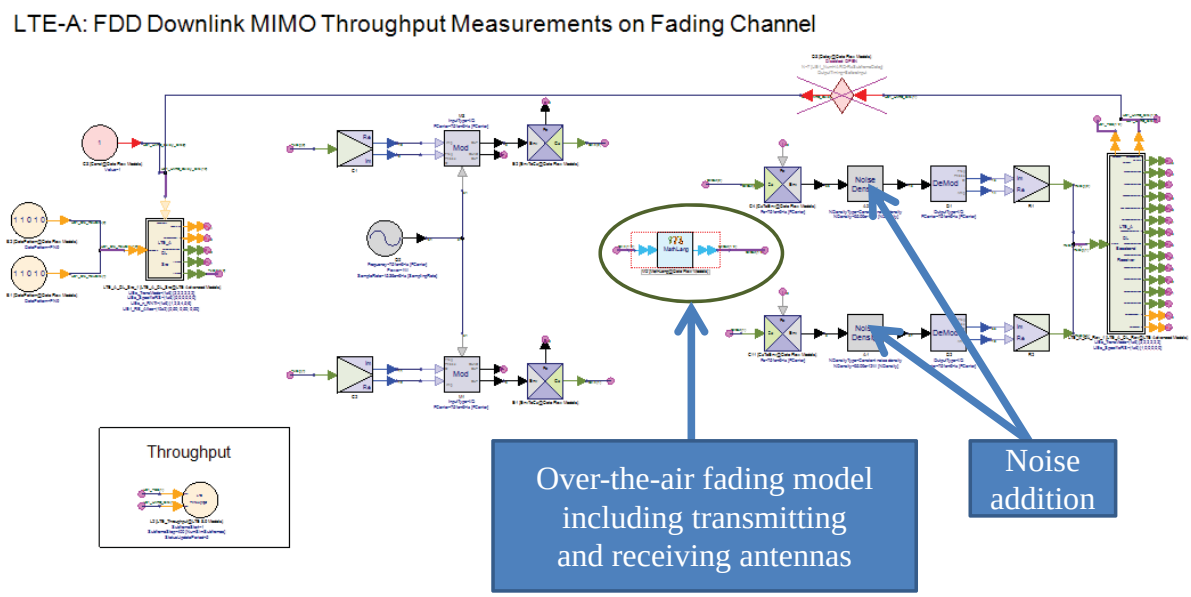

Figure 3: *Screen capture of SystemVue work-space architecture. The Matlab code is incorporated in a Matlang block. Noise is added after the signal has reached the output of the DUT antennas.*

4 Numerical results

We next present results for the isotopic model with SECM temporal characteristics in Section 4.1 and for single and multicluster models in Section 4.2

4.1 Isotropic model with SCME temporal characteristics

Figure 4 shows the throughput curves obtained with a 16QAM SystemVue LTE simulation for the good and bad band 13 CTIA reference antennas. The SCME model is UMi. For each value of the noise level and each isotropic state, 1000 subframes were transmitted. Each thin

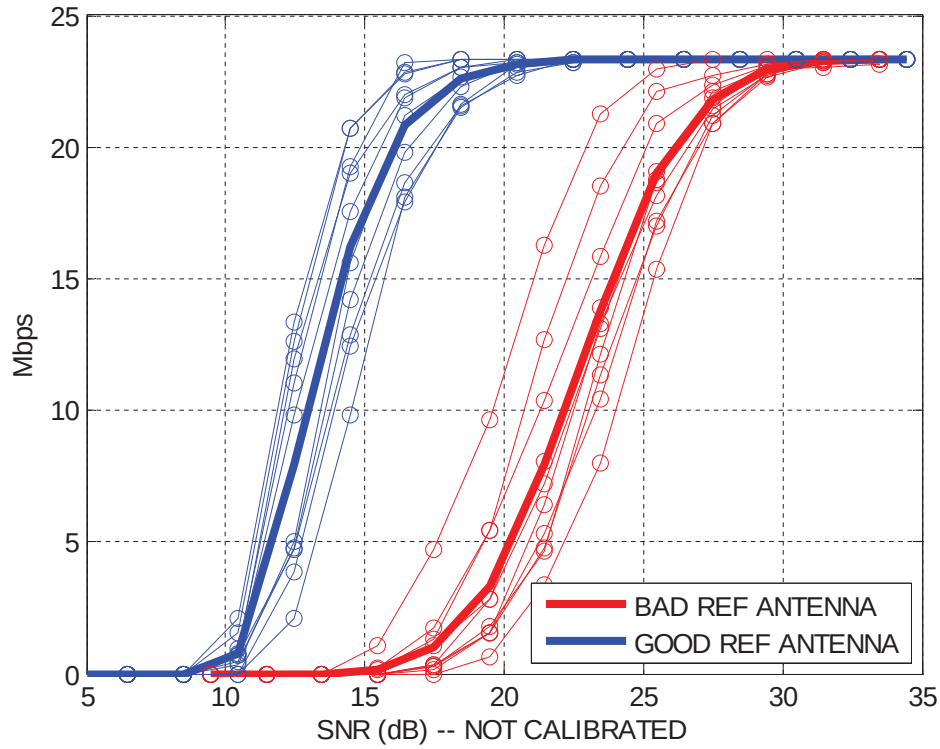

Figure 4: *Throughput curves obtained with a 16QAM SystemVue LTE simulation for the good and bad band 13 CTIA reference antennas. 1000 subframes were transmitted for each noise level and each isotropic state. The isotropic model with SCME temporal characteristics uses a UMi model. The thin lines correspond to particular isotropic states. The fat lines are obtained by averaging over isotropic states. We observe 7dB to 10dB separation between good and bad reference antenna.*

line corresponds to a particular isotropic state. The two fat lines are obtained by averaging over isotropic states. We observe 7dB to 10dB separation between good and bad reference antenna. The separation is largest for high throughput values.

4.2 Single and multicluster models

Figure 5 shows two 2D configurations for evaluating the DUT. One is the SCME multicluster method (UMi) [3], the other is the corresponding single cluster method with all clusters in the same direction.

The evaluation is repeated for different DUT orientations indicated by the azimuthal angle ϕ. Each DUT orientation is thus analogous an isotropic state in the isotropic channel model. Tilt is not yet included.

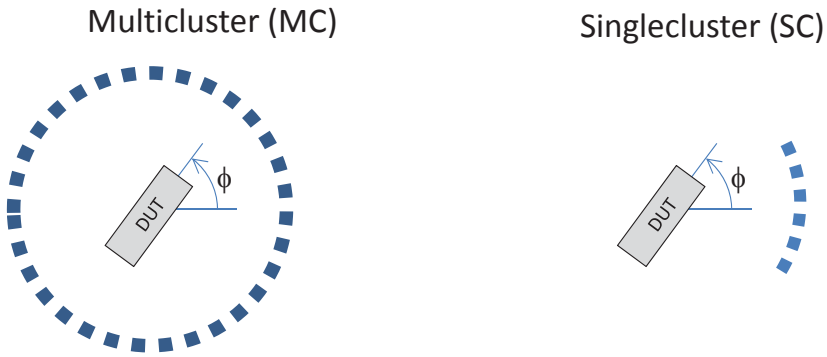

Figure 5: *Two 2D configurations for evaluating the DUT: (i) the SCME multicluster method, and (ii) the corresponding single cluster method with all clusters in the same direction. The DUT orientation is determined by the angle ϕ.*

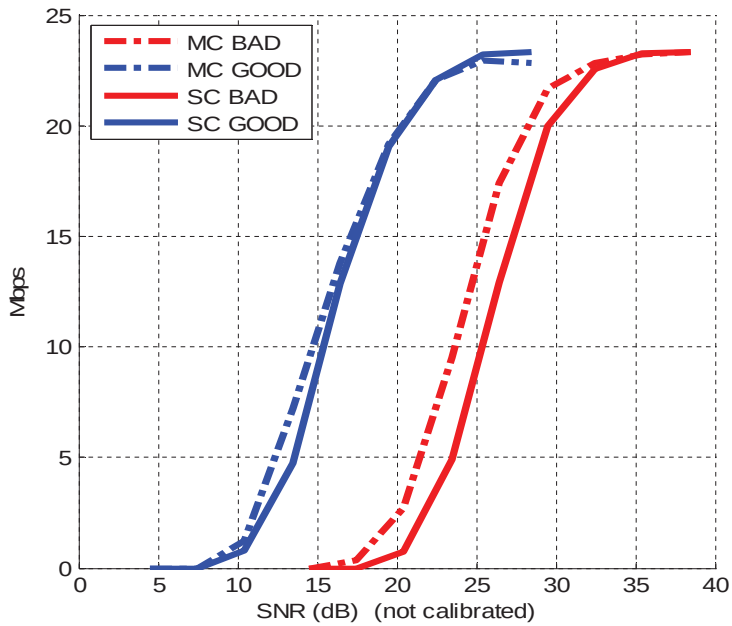

Figure 6: *The average (with respect to DUT orientation ϕ) throughput curves for multicluster (MC) and singlecluster (SC) obtained with a 16QAM SystemVue LTE simulation for the good and bad band 13 CTIA reference antennas. For each value of the noise level and each isotropic state, 1000 subframes were transmitted and 2 instantiations were used.*

Figure 6 show the average (with respect to DUT orientation ϕ) throughput curves for multicluster (MC) and singlecluster (SC) obtained with a 16QAM SystemVue LTE simulation for the good and bad band 13 CTIA reference antennas. For each value of the noise level and each isotropic state, 1000 subframes were transmitted and 2 instantiations were used. We observe 8dB to 10dB separation between good and bad reference antenna. There is a slight difference between the average MC and SC throughput curves for the bad antennas.

NIST [13] computed capacity curves with different channel models and averaged over all

three Euler angles. We are currently working on Euler-angle averaging within the framework of LTE link-level simulations.

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