3GPP TSG RAN WG 1 ***TSGR1#15 R1-00-1067***
Berlin, Germany, August 22-25, 2000

Agenda Item:

Source: Siemens[1]

Title: Channel model for Tx diversity simulations using correlated antennas

Document for: Discussion

---

1. Introduction

The current simulation parameters for Tx diversity assume that the cross correlation factor between antennas of the Node B is zero. This presumes that the antennas can be placed apart from each other with large enough distance. In real scenarios this may not be the case due to limitations at the site of the Node B. Therefore, we extend the simulation description in [1] by specifying spatial correlation between antenna elements. This extension can be easily applied to the different ITU channels (1-path Rayleigh, Ped. A and Veh. A).

2. Correlated antenna channel model

The current channel model is extended by incorporating (long-term) spatial correlations between the signals from antennas *m* and *n* of the base station, denoted by $r_{m,n}$, which are general complex numbers. The corresponding matrix capturing all correlation coefficients is denoted by $R = [r_{m,n}]$ of size $M \times M$ when *M* antennas are used. Assuming Rayleigh fading for each antenna, the receive vector $\underline{x}(t)$ at the UE can be expressed by an overlay of *M* independent and normalized complex Gaussian fading processes $\underline{g}(t) = [g_1(t) \quad g_2(t) \quad \ldots \quad g_M(t)]^T$, with Jakes power density spectrum, i.e.,

$$\underline{x}(t) = \sqrt{P}\,\underline{h}(t)\,u(t) \tag{1}$$

where

$$\underline{h}(t) = R^{1/2}\,\underline{g}(t) \tag{2}$$

is the *M*-dimensional channel vector. Here, *u(t)* and *P* denote the transmitted signal and the transmit power per antenna, respectively. Figure 1 shows the applied model.

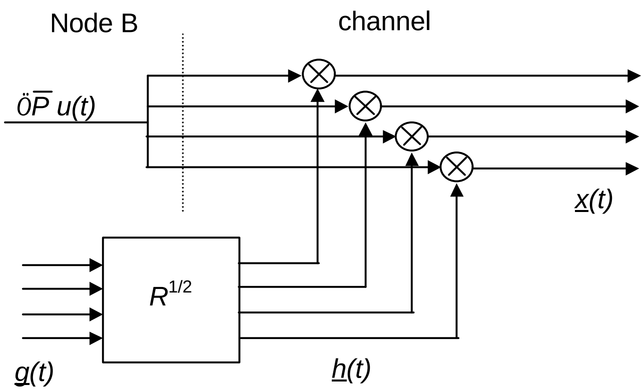

Figure 1: Correlated channel model. Here, the Node B does not apply channel weights to the antennas.

---

[1] In cooperation with the Institute for Circuit Theory and Signal Processing of Technische Universität München, Germany

By taking the expected value of the receive vector, we can easily verify $E\{\underline{x}\underline{x}^H\}/P = R$ as required (Note: $R^{1/2}R^{1/2H} = R$).

If the channel is frequency-selective, *N* separate sets of independent fading processes and spatial covariance matrices are used, i.e.,

$$\underline{x}(t) = \sum_{n=1}^{N} \sqrt{P_n}\; \underline{h}_n(t)\, u(t - t_n) \qquad (3)$$

where t_n denotes the delay of the *n*-th tap and $\underline{h}_n(t) = R_n^{1/2}\,\underline{g}_n(t)$ is the corresponding time-variant (*M*-dimensional) channel vector.

Assuming antenna weights $\underline{w}^H$ are applied to the signal prior to transmission on the antennas, the combined signal received at the UE can be written as

$$x_{UE}(t) = \sum_{n=1}^{N} \underline{w}^H R_n^{1/2}\,\underline{g}_n(t)\, u(t - t_n) \qquad (4)$$

3. Comparison to propagation environment

Figure 1 shows a propagation environment for subsequent discussion.

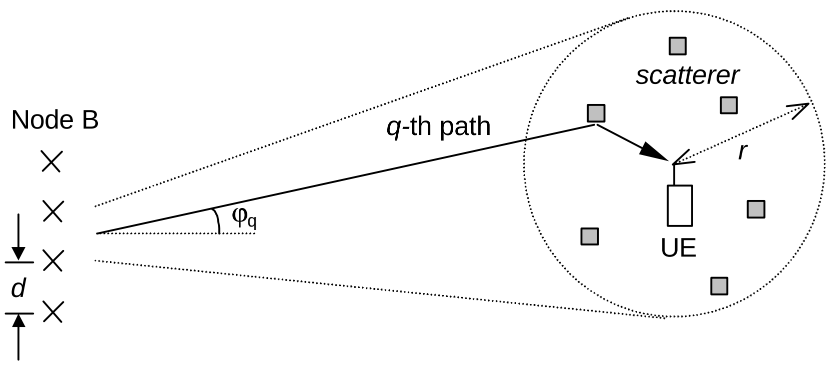

Figure 2: Propagation Environment

The cell shall have 4 antennas, with spacings *d* between adjacent antenna elements. We assume local scattering around the UE, and there are many scattering points distributed within an effective scattering radius *r*. If *Q* is the number of propagation paths arriving at the UE due to scattering, the receive vector can be expressed as

$$\underline{x}(t) = \sum_{q=1}^{Q} \sqrt{p_q}\, \exp(j2pf_{D_q} t)\,\underline{a}(j_q)\,u(t) \qquad (5)$$

where $\sqrt{p_q}$, j_q, and f_{D_q} denote the *q*-th path amplitude, angle of departure, and Doppler shift, respectively. Moreover, the steering vector for the four antenna case is denoted by

$\underline{a}(j_q) = [1 \quad \exp(jm) \quad \exp(j2m) \quad \exp(j3m)]^T$ with $m = \frac{2p}{l} \cdot d \cdot \sin(j_q)$.

The Doppler frequencies per path are determined by the maximum Doppler shift max(f_D) and the cosine of the angle between the mobile velocity vector $\underline{v}$ and the incoming path. If there is a large number of propagation paths and the directions of arrival are omnidirectional at the UE, fading of the signal from each antenna element at UTRAN exhibits a Rayleigh-type of amplitude distribution and a Jakes-shaped Doppler power density function. We note that in this model, the bulk (long-term) properties (magnitudes, angles-of-departure) remain unchanged during all times of observation.

Using the above signal model, the normalized (long-term) correlation matrix is given by

$$R = 1/P \sum_{q=1}^{Q} p_q \underline{a}(j_q)\underline{a}^H(j_q) \quad (6)$$

since any cross-terms vanish due to distinguishable Doppler shifts between each two paths. For given wave geometries, equation (6) can be used to generate the long-term covariance matrix *R*. From *R* are produced partially correlated fadings according to the respective wave environment. If, moreover, the fading processes exhibit Jakes Doppler power density, the omnidirectional wave arriving at the UE is properly modelled.

4. Special cases for the covariance matrix R

There are two special cases for the covariance matrix R:

- The antennas are assumed to be uncorrelated, which is the current assumption for the simulation parameters in [1].

$$R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

  This would correspond to a scenario where the antennas are large enough apart from each other, which probably cannot be the case in realistic situations.

- The antenna paths are all fully correlated and consequently the elements of the covariance matrix have all an absolute value of one. If in addition the angle of departure is zero and a uniform linear array is assumed, this yields

$$R = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}.$$

  This would correspond to a spatial coherent channel. In this case we have one macropath with vanishing angular spread. This again is not a typical scenario.

5. Recommended channel parameter

To combine realistic antenna spacing with various macropaths and angular spread let us assume a scenario characterized by a large number of planar waves with power uniformly distributed on an angular region of 45° and centered around 60°. The spacing between the antenna elements is approximately 0.5 of the carrier wavelength (see Fig. 3).

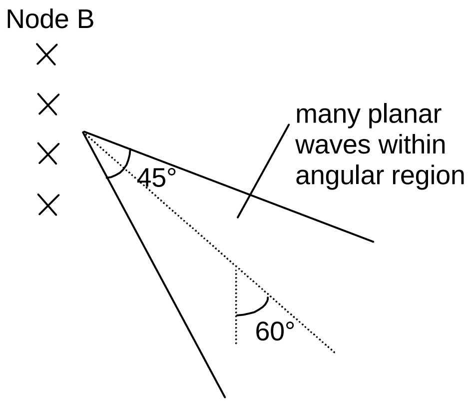

Figure 3. Partly correlated scenario

The spatial covariance matrix corresponds to

$$R = \begin{bmatrix} 1 & a & b & c \\ a^* & 1 & a & b \\ b^* & a^* & 1 & a \\ c^* & b^* & a^* & 1 \end{bmatrix}, \qquad \text{where } [a,b,c] = \left[0.7e^{-j2.2}, \quad 0.1e^{j1.2}, \quad 0.2e^{-j3.0}\right] \qquad (7)$$

As this leads to a partial correlation between antenna elements it is a realistic scenario in between the two extreme cases considered in Section 4. Thus, this channel model is recommended for simulations when smaller distances between antennas need to be considered.
Note that this model combines radio channel propagation characteristics as well as antenna geometry in a compact matrix description.

This spatial model can be applied to all three path models (1-path Rayleigh, modified ITU Ped A, modified ITU Veh A). In the scenarios with more than one tap (Ped A, Veh A) for simplicity we assume that the spatial covariance matrices are equal for each tap ($R_n = R$).

6. Conclusion

We propose to extend the simulation parameters in [1] by a channel model using the spatial covariance matrix *R* of equation (7) for simulations where correlated antennas need to be taken into consideration. The extended model can be applied to the path models1-path Rayleigh, Ped. A and Veh. A.

In this contribution the long-term properties of the channel were assumed to remain unchanged over time. However, we will provide a further extension of this model that also takes into consideration changes of the long-term parameters.

7. Reference

[1] Nokia. Recommended simulation parameters for Tx diversity simulations. TSG-R WG 1 document, TSGR1#14(00)0867, 4-7th, July, 2000, Oulu, Finland.