Comments on the Channel Modeling Document

- **Section 2.3 - Ray-Tracing Model:** In ray tracing models, the exact locations of primary scatterers is not sufficient to fully describe the channel. Location of primary scatterers will only determine the resolvable path delays. Not only do we need the exact location but the physical characteristics of the scatterer itself, e.g. surface roughness, reflection coefficients etc. Ray tracing is OK in situations like channel modeling in a pretty well defined area, e.g. indoor channels.

  Suggested Text:

  In this approach, exact locations of the primary scatterers, their physical characteristics, as well as the exact location of the transmitter and receiver are assumed known. The resulting channel characteristics are then predicted by summing the contributions from a large number of the paths through the simulated environment from each transmit antenna to each receive antenna. This technique provides fairly accurate channel prediction by using site-specific information, such as building databases of architectural drawings. However, this method is only useful for indoor channel modeling since it is too complex for modeling outdoor environment because of the difficulty in obtaining detailed terrain and building databases.

- **Section 2.5.1 – BS Antenna Topologies:** This paragraph specifies three values for the element spacing. Specifying element spacing is not sufficient to fully determine the antenna topology. One need also to specify how these elements are arranged, e.g. as a linear array or as a circular array. In the case of a circular array, the spacing between every pair of antenna elements need to be specified in order to completely specify the BS antenna topology.

  Suggested Text:

  Option 1: *At the BS, a linear antenna array is assumed. Three values for reference antenna element spacing are defined as:* 0.5λ, 4λ, *and* 10λ.

  Option 2: *At the BS, antenna arrays can be either arranged as a linear or circular array. In the case of a linear antenna array, Three values for reference antenna element spacing are defined as:* 0.5λ, 4λ, *and* 10λ. *In the case of a circular array, an extra array parameter representing the "radius" of the array is specified* <u>*(Need to state an appropriate value).*</u>

- **Section 2.5.2 - BS Angle spread:** "The individual path powers are defined in the temporal ITU SISO channel models". The ITU SISO models specify the main or resolvable paths not the sub-chip or un-resolvable paths. We need to be specific about this

  Suggested Text:

  Option 1: *The individual resolvable path powers are defined in the temporal ITU SISO channel models.*

  Option 2: *Remove the sentence*

- **Section 2.5.2 - BS Angle spread:** The base station angle spread is defined here with respect to the receiving antenna array. Hence, it is not obvious what is the role of angle of departure AoD. This should read angle of arrival AoA. Also the definition of AoA needs to be aligned with the definition of AoD in Section 2.5.3

  Suggested Text:
  "Two values of BS angle spread (each associated with a corresponding mean angle of arrival, AoA) are considered in this document: …. Attention should be paid when comparing the link level performance between the two angles spread values since the BS antenna gains for the two corresponding AoAs are different."

- **Section 2.5.3 – Angle of Departure:** The section is supposed to define the angle of departure. However, the text here seems to define both AoA and AoD.

  Suggested Text:
  "The Angle of Departure (AoD) is defined to be the mean angle with which a departing ray's power is transmitted by the BS array with respect to the broadside. The two values considered are: …"

- **Section 2.5.3 – BS Azimuth Power Spectrum:** This section defines the azimuth power spectrum of a ray arriving at the BS MEA. However, the parameter $\bar{\theta}$, is defined as an AoD, where as it should correspond to an AoA.
  Suggested Text:
  Replace "AoD" with "AoA" throughout this section

- **Section 2.6.1 – MS Antenna Topology:** The text here assumes that the MS will have enough "real estate" to have an antenna array. However, due to the limited area in the terminal or the MS, antenna elements may not be necessarily placed in a regular pattern. Hence, in defining the MS antenna topology, we need to define the spacing between every pair of elements. *"We need to specify antenna spacing values for this case".*

- **Section 2.6.4: MS Azimuth Power Spectrum**: The limits on the laplacian distribution are not defined (although the become clearer later when the normalization constant N_o is defined)

  Suggested Changes:
  1. **Change title of section to** *"MS Azimuth Power Spectrum"*
  2. **Add the limits on the Laplacian distribution**

$$P(\theta,\sigma,\overline{\theta}) = N_o \exp\left[\frac{-\sqrt{2}\left|\theta-\overline{\theta}\right|}{\sigma}\right] \quad \theta\in\left[-\pi,\pi\right]$$

- **Section 2.6.5 – MS Direction of Travel:** In the light of the comment on section 2.6.1 and the fact that we are assuming that each antenna element at the MS is omni directional, the direction of travel is linked to the MS antenna topology. In fact if no antenna pattern is assumed then, the direction of travel will also depend on the antenna pattern as well. *"In the case of irregular antenna placement at the MS, a different definition of the MS direction of travel DoT is required."*

- **Table 2.1:** In the light of Section 2.6.1 comment above, *we need to use the proper definition of MS antenna topology in this table.*
- **Section 2.7.2:** The text in this section states that "all paths are assumed independent". This is fine as long as we are only considering the physical propagation channel, i.e. the channel from the transmitting antenna to the receiving antenna. However, this is not true when the pulse shaping is taken into account, i.e. when the transmitting pulse shaping and transmit filters as well as the receive filter are taken into account. In this case, the equivalent channel model will have taps or paths that are generally correlated. These models describe the physical propagation channel. To illustrate this point, Let us consider the channel impulse response

$$h(t) = \sum_{i=1}^{P} \alpha_i \cdot \delta(t-\tau_i) \tag{1.1}$$

  Let $g(t)$ represent the overall pulse shaping and transmit filter response and $f(t)$ represent the overall receiving filter response. The transmitted discrete time signal is

$$s(t) = \sum_{n} s_n g(t-nT) \tag{1.2}$$

  The corresponding received signal is

$$r(t) = h(t)*s(t)*f(t) = h(t)*(s(t)*f(t)) = h(t)*x(t) \tag{1.3}$$

$$
\begin{aligned}
x(t) &= f(t) * s(t) \\
&= \sum_n s_n (f * g)(t - nT) \\
&= \sum_n s_n \tilde{g}(t - nT)
\end{aligned} \tag{1.4}
$$

where $\tilde{g}(t)$ is the overall response due to the transmit and receive filters. Then the received signal can be written as

$$
\begin{aligned}
r(t) &= h(t) * x(t) \\
&= \left\{ \sum_{i=1}^{P} \alpha_i \cdot \delta(t - \tau_i) \right\} * \left\{ \sum_n s_n g(t - nT) \right\} \\
&= \sum_n s_n \sum_{i=1}^{P} \alpha_i \int_\beta \delta(\beta - \tau_i) \tilde{g}(t - \beta - nT)\, d\beta \\
&= \sum_n s_n \sum_{i=1}^{P} \alpha_i \tilde{g}(t - \tau_i - nT)
\end{aligned} \tag{1.5}
$$

Let us assume that the received signal is over sampled by a factor Q. The sampling times are

$$
t = kT + \frac{qT}{Q} \qquad k = 0,1,2,\ldots \qquad q = 0,1,2,\ldots,Q-1 \tag{1.6}
$$

Then the received signal at those sampling instant is given by

$$
\begin{aligned}
r\left(kT + \frac{qT}{Q} \right) &= \sum_n s_n \sum_{i=1}^{P} \alpha_i \tilde{g}\left(kT + \frac{qT}{Q} - nT - \tau_i \right) \\
&= \sum_n s_n \sum_{i=1}^{P} \alpha_i \tilde{g}\left(kT + \frac{qT}{Q} - nT - \tau_i \right) \\
&= \sum_n s_n \sum_{i=1}^{P} \alpha_i \tilde{g}\left((k-n)T + \frac{qT}{Q} - \tau_i \right)
\end{aligned} \tag{1.7}
$$

Let $m = k - n$. A reasonable assumption is that the overall pulse response $\tilde{g}$ has a finite duration. Hence we can rewrite the received signal at the sampling instants as

$$
\begin{aligned}
r\left(kT + \frac{qT}{Q} \right) &= \sum_{m=0}^{L} s_{k-m} \sum_{i=1}^{P} \alpha_i \tilde{g}\left(mT + \frac{qT}{Q} - \tau_i \right) \\
&= \sum_{m=0}^{L} s_{k-m} h_m(q)
\end{aligned} \tag{1.8}
$$

where

$$
h_m(q) = \sum_{i=1}^{P} \alpha_i \tilde{g}\left(mT + \frac{qT}{Q} - \tau_i \right) \tag{1.9}
$$

is the equivalent “digital” channel response. Let us now consider the symbol rate channel ($q = 0$)

$$
\begin{bmatrix} h_0(0) \\ h_1(0) \\ h_2(0) \\ \vdots \\ h_L(0) \end{bmatrix} = \begin{bmatrix} \tilde{g}(-\tau_1) & \tilde{g}(-\tau_2) & \tilde{g}(-\tau_3) & \cdots & \tilde{g}(-\tau_P) \\ \tilde{g}(T-\tau_1) & \tilde{g}(T-\tau_2) & \tilde{g}(T-\tau_3) & \cdots & \tilde{g}(T-\tau_P) \\ \tilde{g}(2T-\tau_1) & \tilde{g}(2T-\tau_2) & \tilde{g}(2T-\tau_3) & \cdots & \tilde{g}(2T-\tau_P) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{g}(LT-\tau_1) & \tilde{g}(LT-\tau_2) & \tilde{g}(LT-\tau_3) & \cdots & \tilde{g}(LT-\tau_P) \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \vdots \\ \alpha_P \end{bmatrix} \tag{1.10}
$$

$$
\mathbf{h} = \tilde{\mathbf{G}}(\tau) \cdot \boldsymbol{\alpha}
$$

Let us now consider the digital channel vector $\mathbf{h}$. The correlation matrix of the digital channel is

$$
\begin{aligned} \mathbf{R}_h &= E\left\{\mathbf{h} \cdot \mathbf{h}^*\right\} \\ &= \tilde{\mathbf{G}}(\tau) \cdot E\left\{\boldsymbol{\alpha} \cdot \boldsymbol{\alpha}^*\right\} \cdot \tilde{\mathbf{G}}^*(\tau) \\ &= \tilde{\mathbf{G}}(\tau) \cdot \mathbf{R}_\alpha \cdot \tilde{\mathbf{G}}^*(\tau) \end{aligned} \tag{1.11}
$$

From the above equation, we can easily see that even the paths are assumed independent, the equivalent digital channel will be correlated and its correlation matrix will be a function of the overall filter response, the physical channel complex gains, and time delays.

We can leave this section as is, however, it has to be made clear that it is for the physical channel only. when integrating this model with an actual transmitter/receiver proposal, the effect of any addition filtering, e.g. pulse shaping and receive filtering, must be taken into account.

- **Table 2.1:** Why these values of the phase of the complex correlation were chosen? *Need an explanation*.