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Re:	*Response to the call for technical proposal regarding IEEE Project 802.16m*	
Abstract	*We present a suggested text for a submission by IEEE 802.16m to the ITU-R group 8F on channel modeling.*	
Purpose	*To provide general information on channel modeling to IEEE 802.16m.*	
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Text proposal for 802.16m channel modeling submission to ITU-R 8F

1. Introduction

The ITU is currently in the process of establishing performance evaluation criteria for IMT-Advanced that specify minimum capabilities and process and items for the test evaluation. As part of the process, channel models have to be defined. Due to the enhanced capabilities, increased bandwidth, and increased variety of envisioned deployment scenarios, existing channel models cannot be used.

In order to achieve the spectral efficiency demanded by IMT-Advanced, multiple-input – multiple-output (MIMO) systems will be required. Therefore, in addition to the traditional description of delay dispersion, any channel model for IMT-advanced will have to adequately describe MIMO propagation channels. It furthermore has to incorporate polarization properties of the channel.

This contribution gives an overview of possible channel modeling methodologies, and then suggests a stochastic double-directional characterization of the channel as the most suitable modeling methodology.

2. Deterministic versus stochastic channel models

In general, models for propagation channels can be divided into *deterministic* and *stochastic* channel models.

2.1 Deterministic channel models

The deterministic category encompasses all models that describes the propagation channel for a specific transmitter location, receiver location, and environment.

The most realistic deterministic models are based on measurement results. Measuring and storing the channel impulse responses or equivalent quantities is, however, a considerable effort. Furthermore, the impact of noise and interference on the measurement results has to be carefully assessed.

Another category of deterministic channel models is based on describing the geometry and electromagnetic properties of the "relevant" environment and then solves Maxwell's equations or an approximation thereof (e.g., ray tracing) for the electromagnetic boundary value problem established by this environment. This modeling method allows to more easily obtain channel impulse responses. On the downside, it is often not established how inaccuracies of the environment model, and of the numerical approximation of Maxwell's equations, influence the final results.

Deterministic channel models are site-specific, as they clearly depend on the location of transmitter, receiver, and the properties of the environment. They are therefore most suitable for network planning and deployment.

2.2 Stochastic channel models

In many cases, it is not possible or desirable to model the propagation channel in a specific environment. Especially for system testing and evaluation, it is more appropriate to consider channels that reflect “typical”, “best case”, and “worst case” propagation scenarios. A stochastic channel model thus prescribes *statistics* of the channel impulse responses (or their equivalents), and during the actual simulation, impulse responses are generated as *realizations* according to those statistics.

The simplest example of this approach is the Rayleigh-fading model: it does not attempt to correctly predict the fieldstrength at each location, but rather attempts to correctly describe the pdf of the fieldstrength over a large area.

3. Modeling approaches for MIMO channels

In general, MIMO channels can be modeled either as double-directional channels [12] or as vector (matrix) channels [13]. The former method is more related to the physical propagation effects, while the latter is more centered on the effect of the channel on the system.

3.1 Double-directional characterization

The *deterministic double-directional channel* is characterized by its double-directional impulse response. It consists of N propagation paths between the transmitter and the receiver sites. Each path is delayed in accordance to its excess-delay τ_ℓ, weighted with the proper complex amplitude $a_\ell e^{j\phi_\ell}$. Note that the amplitude is a two-by-two matrix, since it describes the vertical and horizontal polarizations and the cross-polarization; neglecting a third possible polarization direction is admissible in macro- and microcells. Finally, the paths are characterized by their direction-of-departure (DOD) $\Omega_{T,\ell}$ and direction-of-arrival (DOA) $\Omega_{R,\ell}$.[1] The channel impulse response matrix $\underline{h}$, describing horizontal and vertical polarization is then

$$\underline{h}(t,\tau,\Omega_T,\Omega_R) = \sum_{\ell=1}^{N} \underline{h}_\ell(t,\tau,\Omega_T,\Omega_R) = \sum_{\ell=1}^{N} \underline{a}_\ell e^{j\phi_\ell}\delta(\tau-\tau_\ell)\delta(\Omega-\Omega_{T,\ell})\delta(\Psi-\Omega_{R,\ell}) \qquad (1)$$

The number of paths N can become very large if all possible paths are taken into account; in the limit, the sum has to be replaced by an integral. For practical purposes, paths that are significantly weaker than the considered noise level can be neglected. Furthermore, paths with similar DOAs, DODs, and delays can also be merged into ”effective” paths. Note that the parameters of those paths must be similar enough so that over the distances of interest for the simulation, no fading is created by the superposition of the subpaths.

In general, all multipath parameters in (1), $\tau_\ell, \Omega_{R,\ell}$, $\Omega_{T,\ell}, \underline{a}_\ell$, and $e^{j\phi_\ell}$ will depend on the absolute time t; also the set of multipath components (MPCs) contributing to the propagation will vary, $N \rightarrow N(t)$. The variations

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[1] We stress that the (double-directional) channel is reciprocal. While the directions of multipath components at the base station and at the mobile station are different, the directions at one link end for the transmit case and the receive case must be identical. When we talk in the following about DOAs and DODs, we refer to the directions at two different link ends.

with time can occur both because of movements of scatterers, and movement of the mobile station MS (the BS is assumed fixed). Without restriction of generality, the reference coordinate (center) of the base station antenna array is chosen to coincide with the origin of the coordinate system. We furthermore assume that the antenna arrays both at the BS and MS are small enough so that the MPC parameters do not change over the size of this array.

The above *double-directional* description seems rather straightforward. However, a straightforward *stochastic* description of the involved parameters involves a multi-dimensional probability density function that could only be described or saved as a huge file. Note that in general, the statistics of MPC delays, DOAs, DODs, amplitudes and phases are not separable, and thus have to be described by their *joint* probability density function. It is thus often preferable to base the MPC parameters (DOA, delay,...) on another set of parameters. While the number of parameters in that different set is large, the pdfs of those parameters are more compact. This will be discussed in Section 4.

3.2 Channel transfer matrix

The *deterministic* wideband *matrix* channel response describes the channel from a transmit to a receive antenna array. It is characterized by a matrix $\underline{H}$ whose elements H_{ij} are the (non-directional) impulse responses from the $j-$th transmit to the i-th receive antenna element. They can be computed for any antenna constellation as

$$H_{i,j} = h(\tau, \vec{x}_{R,i}, \vec{x}_{T,j}) = \sum_{\ell=1}^{N} \vec{g}_R(\Omega_R) \cdot \underline{h}(\tau_\ell, \Omega_{R,\ell}, \Omega_{T,\ell}) \cdot \vec{g}_T(\Omega_T) \cdot e^{j\langle \vec{k}(\varphi_{R,\ell})\vec{x}_{R,i}\rangle} e^{j\langle \vec{k}(\varphi_{T,\ell})\vec{x}_{T,j}\rangle}, \qquad (2)$$

where where $\vec{x}_R$ and $\vec{x}_T$ are the vectors of the chosen element-position measured from an arbitrary but fixed reference points $\vec{x}_{R,0}$ and $\vec{x}_{T,0}$ (e.g., the centers of the arrays) and $\vec{k}$ is the wavevector so that

$$\langle \vec{k}(\Omega) \cdot \vec{x} \rangle = \frac{2\pi}{\lambda}(x \cos\vartheta \cos\varphi + y \cos\vartheta \sin\varphi + z \sin\vartheta). \qquad (3)$$

where ϑ and φ denote elevation and azimuth, respectively. The functions $\vec{g}_R(\Omega_R)$ and $\vec{g}_T(\Omega_T)$ are the antenna patterns at transmitter and receiver, respectively, where the two entries of the vector $\vec{g}$ describe the antenna pattern for horizontal and vertical polarization.

The *stochastic* description of the *matrix channel* also seems simple at first glance. It requires the average powers of the entries of the transfer matrix (from each transmit to each receive antenna), as well as the correlation between the matrix entries. Especially for small antenna array sizes, a description of the H-matrix seems desirable. However, we have to keep the following point in mind:

1. The fading at the different antenna elements can be Rayleigh, Rician, or ”double-Rayleigh”. Thus, we have to define those statistics and its associated parameters.
2. The number of involved correlation coefficients increases quadratically with the number of antenna elements. Their number might be reduced in periodic structures, as can be usually found at base stations (BSs) (Toeplitz structure of the correlation matrix for antenna arrays), but not necessarily for diversity arrangements as found at the mobile station (MS). Approximate description methods have been suggested to reduce the number of involved parameters, including the Weichselberger model [14,15], and the more simplified Kronecker model [16].
3. The whole description is dependent on the used antenna arrangement. Generalizations to larger (or just different) antenna arrays are not easily possible.
4. In delay-dispersive environments, we have to define different correlation factors for each delay,

because different propagation mechanisms (which induce different correlation factors) have different delays.

5. The correlation matrices change, depending on the realizations of the position (and therefore realization of large-scale fading etc.) of the mobile station in the cell. Actual modeling of those changes is significantly more difficult than modeling of the changes of the MPC parameters in a double-directional model.

3.3 Geometry-based stochastic channel models

An alternative stochastic description of MIMO channels is a *geometry-based stochastic channel model* (GSCM). This model is a way of efficiently describing and implementing a double-directional channel characterisation, by stochastically prescribing scatterer locations. The actual channel impulse response is then found by a simplified RAY TRACING procedure.GSCM were originally devised for channel simulation in systems with multiple antennas at the base station (diversity antennas, smart antennas) [17], [18,19,20,21,22], taking only single-scattering processes into account. The single-scattering assumption makes ray tracing extremely simple: apart of the LoS, all paths consist of two subpaths connecting the scatterer to the Tx and Rx, respectively. These subpaths characterize the DoD, DoA, and propagation time (which in turn determines the overall attenuation, usually according to a power law).

A GSCM has a number of important advantages [23]:

- it has an immediate relation to physical reality; important parameters (like scatterer locations) can often be determined via simple geometrical considerations;
- many effects are implicitly reproduced: small-scale fading is created by the superposition of waves from individual scatterers; DoA and delay drifts caused by MS movement are implicitly included;
- all information is inherent to the distribution of the scatterers; therefore, dependencies of power delay profile (PDP) and angular power spectrum (APS) do not lead to a complication of the model;
- Tx/Rx and scatterer movement as well as shadowing and the (dis)appearance of propagation paths (e.g. due to blocking by obstacles) can be easily implemented.

Using the assumption of single-scattering, the position of a scatterer completely determines DoD, DoA, and delay. However, many environments (e.g., micro- and picocells) feature multiple-bounce scattering for which DoD, DoA, and delay are completely decoupled. If the directional channel properties need to be reproduced only for *one* link end (i.e., multiple antennas only at the Tx or Rx), multiple-bounce scattering can be incorporated into a GSCM via the concept of *equivalent scatterers* - virtual single-bounce scatterers whose position is chosen such that they mimic multiple bounce contributions in terms of their delay and DoA [7]. In a MIMO system, the equivalent scatterer concept fails since the angular channel characteristics are reproduced correctly only for one link end. As a remedy, [9] suggested the use of double scattering where the coupling between the scatterers around the BS and those around the MS is established by means of a so-called illumination function (essentially a DoD spectrum relative to that scatterer). Another approach to incorporate multiple-bounce scattering into GSCM models is the twin-cluster concept pursued within COST 273 [11].

3.4 Structure of existing models

It is noteworthy that all currently standardized MIMO channel models are double-directional stochastic channel models. COST 259, COST 273, 3GPP-SCM, and IEEE 802.11n all fall into this category. Some of those models explicitly allow for an implementation as a geometry-based stochastic channel model (COST 259, COST 273), other models like IEEE 802.11n use a generalized tapped delay line approach (where each tap has an angular spectrum, and no mention is made of "scatterer location"), while still others (3GPP-SCM) use a mixed geometric-tapped delay line approach.

4. Cluster-based double-directional channel models

We suggest that the channel model for IMT-Advanced is a Double-directional stochastic channel model as described in Sec. 3.1, though an implementation by means of a GSCM (as described in Sec. 3.3) should be permissible. In order to further describe the statistics of the MPC parameters, we propose an indirect characterization via a set of auxiliary parameters. In this section, we provide a list of such parameters.

It is important to understand that there can be dependencies between the different model parameters. For example, the famous Greenstein model established a correlation between the shadowing and the rms delay spread [6]. Thus, a complete channel model cannot simply take a pathloss/shadowing model and a delay spread model, and put them together into a single model. The list of the parameters that we are suggesting is adopted from the COST 273 model [11], which in turn is mostly based on the COST 259 model [7], [8].

Note that the parameters can be different in different environments, e.g., urban microcell, indoor office, etc. Establishing a list of suitable environments will be done in [32].

4.1 Parameter sets

4.1.1 External parameters

External parameters are parameters that remain fixed for a simulation run. They might change according to the system that is simulated, and according to geographical regions (for example the average rooftop height in city centers can be different in Northern Europe and in Japan).

The following parameters are to be used (though not all parameters are applicable to all environments):
f_c : Carrier frequency [Hz]:
h_{BS} : Base station height [m]:
h_{MS} : Mobile station height [m]:
$\vec{r}_{BS}$: Base station position [m]:
antenna scenarios (e.g., 4-element ULA) [no of antennas, antenna spacing, array shape]:
antenna orientation [pdf]:
Pathloss model [dB/m]:
h_B : Average rooftop height [m]:
w_r : Width of roads [m]:
wb : distance between buildings [m]:
ϕ_R : Road orientation with respect to direct path [degree]:
l_l , l_w : size of rooms [m×m]. .

N_{floor} : number of floors between BS and MS [integer]:
Whether there is a building on the opposite side of the building BS and MS are in [yes/no]:

4.1.2 Stochastic parameters

The stochastic parameters describe the variations according to the different locations and radio environments in which the MS might be. Their parameterization is influenced by the external parameters.

Following the concepts of [7], multipath components (MPCs) arrive in clusters. The total DDIR can thus be written as the sum of the cluster DDIRs, which in turn can be formulated as [8]

$$P(\tau,\theta_{\mathrm{BS}},\varphi_{\mathrm{BS}},\theta_{\mathrm{MS}},\varphi_{\mathrm{MS}}) = P_\tau(\tau) P_\theta^{\mathrm{BS}}(\theta_{\mathrm{BS}}) P_\varphi^{\mathrm{BS}}(\varphi_{\mathrm{BS}}) P_\theta^{\mathrm{MS}}(\theta_{\mathrm{MS}}) P_\varphi^{\mathrm{MS}}(\varphi_{\mathrm{MS}}). \quad (4)$$

Note that this model assumes that *within one cluster*, azimuth spread, elevation spread, and delay spread are independent at the BS and the MS. Note that this is *not* the common Kronecker model that assumes the angular statistics to be independent at BS and MS.

Visibility region: The concept of visibility regions is explained in [7]. Each cluster of IOs is associated with a visibility region. If the MS is in a visibility region, then a cluster is active and contributes to the impulse response; if the MS is outside the visibility region, the cluster does not contribute. The visibility region is characterized by
R_{C} : size of the visibility region [m].
L_{C} : size of the transition region [m].
A smooth transition from non-active to active cluster is achieved by scaling the path gain of the cluster by a transition function. Furthermore, the visibility region is characterized by the probability density function of its location which depends on the distance between the visibility region and the BS.

Line-of-sight occurrence: For some environments the occurrence of LOS is modeled stochastically. The modeling approach has a strong similarity to the visibility region for the clusters. The probability for LOS is described by a probability density function $p_{LOS}(d)$ as well as by the following parameters:
R_{L} [m]: radius of visibility region for LOS,
L_{L} [m]: size of transition region for LOS visibility region.
Depending on the existence of a LOS connection, the LOS power factor (power of the first component, compared to the power of all other components) varies, and thus is described as a random variable with a certain pdf.

Cluster generation: The distribution of the number of clusters N_{C} is modeled as a deterministic number $N_{\mathrm{C,min}}$ (corresponding to the cluster originating from interactions around the MS, plus possible the cluster around the BS) plus a random variable with parameter N_{P}, which can be, e.g., a Poisson-distributed variable. For the placement of clusters and visibility regions, the COST 259, COST 273, and 3GPP models propose a variety of methods, whose discussion is beyond the scope of the current document.

Cluster power: The power contained in each cluster is a function of the delay (with respect to the LOS or quasi-LOS component). Typically, the longer the delay, the smaller is the power that it carries. However, there is limit to the cluster attenuation (if the attenuation becomes too high, the cluster does not have an impact on the impulse response, and is thus dropped from the considerations. In COST 259 and 273, the power of the $m-$th cluster is

$$P_m = P_0 \max\left\{\exp\left[-k_\tau(\tau_\mathrm{m}-\tau_0)\right], \exp\left[-k_\tau(\tau_\mathrm{B}-\tau_0)\right]\right\} \ . \tag{5}$$

The parameters describing this equation are

k_τ : attenuation coefficient given in units of [dB/ μ s],

τ_0 : delay of the LOS component given in units of [μ s],

τ_B : cut-off delay given in units of [μ s].

Cluster pairing: it is important to distinguish between the situations where the waves propagate from TX to RX via a single interaction (often called single-scattering in the literature), and those where multiple interactions occur. Single interaction leads to a strong correlation between the delays and the angles at transmitter and receiver; this relationship is mostly easily obtained by placing clusters geometrically, and computing the mean cluster delay, DOA, and DOD, from simple geometric relationships. For multiple-interaction clusters, the mean DOA, DOD, and minimum delay are computed as random realizations from the marginal distributions of those quantities, taken over a large measurement area. Since the variables are drawn from the marginal distributions, this means that delay and angles are independent. However, we stress again that this does not result in a Kronecker model, i.e., the angular delay power spectrum is not separable.

For macro cells, single interaction works quite well whereas for indoor scenarios the correlation between delays and angles does not exist. To cope with the wide range of scenarios, the model includes three kinds of clusters: local clusters around BS and/or MS, clusters incorporating single interaction, and multiple-interaction clusters. Not all kinds of clusters are mandatory for all scenarios. In macro cells the single interaction cluster is the dominant propagation mechanism whereas in indoor environments multiple interaction processes account for most of the energy of the arriving radiation. The model finally specifies a "selection parameter" K_{sel} that gives the ratio of single-interaction to multiple-interaction additional clusters.

Cluster dispersion: The DDDPS (i.e., the squared magnitude of the DDIR, averaged over the small-scale fading) can be characterized for each cluster by its dispersion in the following domains: delay, azimuth at the BS, elevation at the BS, azimuth at the MS, elevation at the MS. In the literature, the most common model for the power delay profile (behavior in the delay domain) is a single-exponential decay, while the power angular spectrum is Laplacian. Mathematically, this means

$$P_\tau\left(\tau\right) = \frac{1}{\sigma_\tau} e^{-(\tau-\tau_m)\sigma_\tau} . \tag{6}$$

The delay spread σ_τ is itself a log-normal random variable, with a mean $m_{\mathrm{S}\tau}$ (given in [ns]) and standard deviation $S_{\mathrm{S}\tau}$ (given in [dB]). Note that the mean increases with increasing distance between BS and MS [6], as

$$m_{\mathrm{S}\tau} = \overset{\square}{m}_{\mathrm{S}\tau} d^{-\varepsilon} . \tag{7}$$

For the angular spectrum

$$P_\varphi\left(\varphi\right) = \frac{1}{\sigma_\varphi \sqrt{2}} e^{-\sqrt{2}\left|\varphi-\varphi_m\right|\sigma_\varphi} , \tag{8}$$

where the azimuthal spread σ_φ is a log-normal random variable with mean $m_{\mathrm{S}\varphi}$ (given in [degree] and standard deviation $S_{\mathrm{S}\varphi}$ (given in [dB]). Similarly, the elevation power spectrum is given as

$$P_\theta\left(\theta\right) = \frac{1}{\sigma_\theta \sqrt{2}} e^{-\sqrt{2}\left|\theta-\theta_m\right|\sigma_\varphi} \tag{9}$$

where the elevation spread σ_θ is a log-normal random variable with mean $m_{\mathrm{S}\theta}$ and standard deviation $S_{\mathrm{S}\theta}$.

Similarly, the angular parameters are also defined for the MS. It is noteworthy that those parameters might depend on the delay of the cluster.

Shadow fading: Following a widely used approach, each cluster undergoes shadow fading, which is modeled log-normally distributed with standard deviation σ_{S} [dB]. The mean of the shadowing variance (see below) is correlated with the delay spread and angular spread.

Autocorrelation: The shadow fading, delay spreads and angular spreads are correlated random variables, and usually are modeled as lognormal:

$$S_{\mathrm{m}} = 10^{s_{\mathrm{S}} X_{\mathrm{m}} 10} \tag{10}$$

$$\sigma_{\tau,\mathrm{m}} = m_{\mathrm{s}\tau} \left(\frac{d}{1000} \right)^{\varepsilon} 10^{s_{\mathrm{s}\tau} Z_{\mathrm{m}} 10} \tag{11}$$

$$\sigma_{\varphi_{\mathrm{BS}},\mathrm{m}} = m_{\mathrm{s}\varphi_{\mathrm{BS}}} 10^{s_{\mathrm{s}\varphi_{\mathrm{BS}}} Y_{\mathrm{m}} 10} \tag{12}$$

where X_{m}, Y_{m}, and Z_{m} are correlated normal random variables with zero mean and unit variance. Similar expressions also hold for the elevation spread. Furthermore, the shadowing as well as the delay and angular spreads change as the MS moves over large distances and are therefore characterized by a spatial autocorrelation function:

$$ACF(x, x^{'}) = \exp(-| x - x^{'} | / L_x) \tag{13}$$

Polarization: The polarization is characterized by the polarization matrix

$$\begin{pmatrix} P_{VV} & P_{VH} \\ P_{HV} & P_{HH} \end{pmatrix} \tag{14}$$

where the entries characterize the powers, averaged over the small-scale fading. The entries of the correlation matrix are assumed to be lognormally distributed, and therefore are described by the mean and variance.

Temporal variations from moving scatterers: For fixed wireless systems, we need to define the temporal K-factor, which describes the ratio of the power in the time-invariant MPCs to that of the time-variant MPCs. The factor can depend on terrain, vegetation, and season, as well as the distance of the scatterer location to the BS and MS.

Moving scatterers can influence the impulse response in two ways: (i) moving scatterers that are physically small and a considerably distance away from the TX or RX (so that the angular extent of the scatterer as seen from the transceiver is less than, say, 2 degrees), result in a strong temporal variation of a single MPC. In a generalized tapped-delay line model (where taps are assigned a DOA and DOD as well as a delay), this implies that a single tap exhibits time variations. The resulting model is similar to the one suggested in [31]. (ii) moving scatterers that are seen under a large angle from the TX or RX. This situation typically occurs when a car or human being passes the transceiver in close proximity. In this case, the scatterer leads to *shadowing*, not to time-varying multipath-interference. A simple model for this approach is to attenuate the strength of the MPCs coming from a certain angular range; this range changes as the scatterer moves. A possible parameterization describes the strength of the attenuation, the width of the angular, range, and the angular velocity of the scatterer.

Diffuse scattering: Diffuse scattering is the part of the measured signal which can not be resolved in the angular domain. The diffuse radiation is described by the DDPS, which is typically assumed to be uniform in azimuth (both at the BS and the MS), and exponential in delay. A further important parameter is the percentage of the total energy of the impulse response contained in the diffuse radiation.

4.2. Implementation recommendation

In order to implement the model, we recommend the following procedure:

- Select the radio environment of interest and the external parameters.
- Select the number of clusters
- Create the cluster locations and visibility regions
- Create the LOS visibility regions
- Establish the initial position of mobile station
- Repeat for each considered time instant
    - Determine the position of the MS from the old position and the velocity vector.
    - Establish the number of currently active clusters, depending on whether the MS is in a visibility region of a cluster. Compute the delay and mean directions of those clusters, according to the geometry of the cluster location. Compute the mean cluster power according to the model for cluster power as function of delay.
    - Determine the delay spread, angular spreads (azimuth and elevation spreads at TX and RX) of each cluster from the correlated lognormal distributions. Note that the accumulated effect of the shadowing for each cluster determines the shadowing of the narrowband power. Note furthermore that the spreads and shadowing are correlated with previous positions of the MS, and also possibly with the spreads of shadowing of connections to other BSs. Appropriate spatial filtering, taking into account the correlation length of the shadowing, has to be used.
    - Determine the presence of LOS, depending on the LOS visibility region. Assign a K-factor according to the pdf of the K factor, conditioned on whether LOS exists or not.
    - Add the diffuse contribution to the DDPS
    - Discretize the DDPS, resulting in a generalized tapped-delay line model, or a GSCM. In the following, we will assume a generalized tapped-delay line model. A useful and generally established method of discretizing is the one suggested by 3GPP in [24], see also [33]. Important parameters in this discretization approach are the delay scaling factor (which determines the relationship between the power-weighted delay spread and the tap-delay spread), and the variation of the tap powers with respect to the average power.
    - For each discrete delay, establish the XPD according to the delay-dependent XPD distribution.
    - Compute the amplitude and (at random) phase of each tap. Determine the pairing between taps at TX and RX side.
    - For each angular tap, determine the amount of temporal variation due to moving scatterers. For type-1 scatterers (narrow angular range), choose the directional vector and speed of the scatterer from the appropriate pdf, and compute then deterministically the effect on the phase. For type-2 scatterers, compute deterministically the angular range that is attenuated by the scatterer, and then stochastically (following a certain pdf) the amount of attenuation of the taps in that angular range.

5. Summary and conclusions

We have presented a generic model for propagation channels that is suitable for simulations of IMT-Advanced. The model is based on a stochastic double-directional description of the channel and makes used of the clustered nature of the double-directional impulse response of typical wireless channels. We propose that the document, in particular Section 4, is adopted as for the evaluation methodology document of the 8F group of ITU, and that Secs. 2 and 3 are adopted as Appendices of the evaluation methodology document.

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