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| Source(s) | Glenn D. Golden  
135 Route 202/206 South  
Bedminster, NJ 07921  
Voice: 908-997-2000  
Fax: 908-947-7090  
Email: g.golden@flarion.com |
| Re: | IEEE 802.20 Session#1 Call for Contributions |
| Abstract | This presentation gives channel models and their implications for OFDM-based MBWA systems |
| Purpose | For informational purposes only |
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Channel Models and Performance Implications for OFDM-based MBWA

Glenn D. Golden

IEEE 802.20 MBWA WG
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Outline

• *Proposed channel model ensemble*: UTRA (UMTS Terrestrial Radio Access).
• Overview of UTRA test environments and channel models.
• Effects of channel characteristics on OFDM PHY layer parameters.
• Typical range of OFDM PHY parameters that arise from adopting UTRA models.
Model Choice: Overview

- UTRA Test Configurations [1].
- Subset of full ITU-R M.1034 channel set.
- Defines three basic test environments, with two delay profile variations (“A” and “B”) on each:
  - Indoor Office
  - Outdoor-to-Indoor and Pedestrian
  - Vehicular
- Also includes non-specific “mixed” environment, combinations of the basic 3 types.
Channel model provisions

• Mean loss model and parameters (deterministic):
  \[ L = F(R, f, ...) \]

• Shadow fading model and parameters (statistical):
  – Distr. model: log-normal  \[ \text{Parameter: } \sigma_{\text{lognorm}} \]
  – Pos’l corr. model: \[ R(\Delta x) = e^{\ln 2|\Delta x|/d_{\text{cor}}} \]  \[ \text{Parameter: } d_{\text{cor}} \]

• Delay spread model
  – Ray specifications (delay, loss)
  – Doppler spectrum model
  – No numerical values specified for mobility rates.
Indoor Office: General characteristics

- Base stations and users located indoors
- Small cells
- Low transmit power
- Doppler set by walking speeds
**Indoor Office: Path loss**

\[ L = 30 \log_{10} R + 18.3n^{\frac{(n+2)}{(n+1)-0.46}} + 37 \]

- **L**: Path loss (dB)
- **R**: Tx-Rx distance (m)
- **n**: Number of floors in path

- Shadowing: \( \sigma_{\text{lognorm}} = 12 \text{ dB} \)
Indoor Office: Delay profile
(Doppler spectrum: flat)
Pedestrian: General characteristics

- BSs with low antenna heights located outdoors; users located on streets or inside buildings/residences.
- Small cells
- Low transmit power
- Doppler set by walking speeds, with occasional higher rates due to vehicular reflections.
**Pedestrian: Path loss**

\[ L = 40 \log_{10} R + 30 \log_{10} f + 49 \]

- **L**: Path loss (dB)
- **R**: Tx-Rx distance (m)
- **f**: Carrier frequency (MHz)

- **Shadowing**:
  \[ \sigma_{\text{lognorm}} = 12 \text{ dB indoor} \]
  \[ \sigma_{\text{lognorm}} = 10 \text{ dB outdoor} \]

- **Building penetration loss**:
  \[ \mu = 12 \text{ dB}, \ \sigma = 8 \text{ dB} \]
Pedestrian: Delay profile
(Doppler spectrum: classic (Jakes))
Vehicular: General characteristics

• Base stations with roof antennas; users are in vehicles, walking, or stationary.
• “Larger” cells
• “Higher” transmit power
• Maximum Doppler rate set by vehicular speeds; lower values for walking and stationary users.
Vehicular: Path loss

\[ L = 40(1 - 4 \cdot 10^{-3} \Delta h_b) \log_{10} R - 18 \log_{10} (\Delta h_b) + 21 \log_{10} f + 80 \]

- **L**: Path loss (dB)
- **R**: Tx-Rx distance (km)
- **\( \Delta h_b \)**: BS ant. height (m above avg. rooftop level)

- Valid for \( 0 < \Delta h_b < 50 \) m
- Shadowing: \( \sigma_{\text{lognorm}} = 10 \) dB
Vehicular: Delay profile
(Doppler spectrum: classic (Jakes))
Proposed mobility rates

• Indoor: 3 km/h
• Pedestrian: 3, 30 km/h
• Vehicular: 0, 120, 250 km/h
Channel Characteristics → OFDM PHY Parameters

**Time-domain view**

- \( t \)  
  - OFDM symbol duration (μs)
- \( c \)  
  - Cyclic prefix (“CP”) length (μs)
- \( d \)  
  - IDFT duration
- \( N \)  
  - IDFT/DFT order
Channel Characteristics → OFDM PHY Parameters

**Frequency domain view (schematic)**

(Triangles represent main lobes of subcarrier freq-domain sinc functions)

\[ W = Nd^{-1} \]

\[ d^{-1} - t^{-1} = cd^{-1}t^{-1} \]
Channel Characteristics $\implies$ OFDM PHY Parameters

**Cyclic prefix constraint imposed by delay spread:**

$$c : \quad \int_{0}^{c} |h(t)|^2 \, dt > (1 - \theta_c) \int_{0}^{\infty} |h(t)|^2 \, dt$$

- $h(t)$: Channel impulse response
- $\theta_c$: ISI distortion threshold $0 < \theta_c < 1$

Typical range (SIR dependent): [2] $0.02 \leq \theta_c \leq 0.25$
Channel Characteristics $\rightarrow$ OFDM PHY Parameters

**IDFT duration constraint imposed by Doppler rate:**

$$d : \quad d < \theta_d \tau_{chan}$$

$\tau_{chan}$ Channel coherence time

$\theta_d$ Quasi-stationarity threshold $0 < \theta_d < 1$

Typical range (SIR dependent): [3] \hspace{1cm} \theta_d \leq 10\%
UTRA Channel $\Rightarrow$ OFDM PHY Parameters

Hypothetical MBWA system: Channel bandwidth $W = 1.25$ MHz, operating frequency 2 GHz, supporting mobility rate of 250 km/h. Desired per-subcarrier SINR $\approx 7 - 10$ dB.

- Set $\theta_c = 0.1$ [10 dB SIR]. To capture $(1 - \theta_c) = 90\%$ of impulse energy of worst-case delay spread UTRA channel (Vehicular B) requires $c \approx 10$ $\mu$s

- Set $\theta_d = 5\%$. Mobility rate of 250 kph at 2 GHz gives $D_{\text{max}} \approx 463$ Hz, $\tau_{\text{chan}} \approx 2160$ $\mu$s, $d = \theta_d \tau_{\text{chan}} \approx 108$ $\mu$s.
Channel-imposed constraints thus give

- **tone spacing:** \( d^{-1} \approx (108 \, \mu s)^{-1} \approx 9.2 \, \text{kHz} \)
- **number of tones:** \( N = Wd \approx 135 \)
References

