Channel Model Considerations for P802.11af

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Abstract

- This presentation discusses the importance of correctly understanding the channel for OFDM system design.
- Existing channel models in VHF/UHF bands are discussed as references.
- It is noted that channel models that can be directly applied for 802.11af are not available.
- This fact shows the necessity for a set of new channel models for TG 802.11af .
- Based on current literature, how the expected channels would look like is discussed.
- It is concluded that new measurements could be necessary to get the whole picture.

Why Channel Model

- **OFDM system design depends on channel**
- **Channel at UHF/VHF are different than the channel at 5GHz**
- **Operations in TVWS bands include different use cases**
- **Realistic channel models are required for performance evaluation by simulations**
- **Hence, the necessity of new channel models for TVWS should be considered in TG 802.11af. Need to consider the possibility of**
  - use of existing data/models if any
  - new measurement
  - developing such channel models

802.11af Deployment Scenarios

- ***“Re-banding of the popular 802.11 systems”***
- **(FCC) EIRP: 4 W, 100 mW, 50 mW**
- **Possible deployment scenarios**
  - Indoor (< 100 m): Like present WLAN
  - Outdoor (< 5 Km): Range shorter than WiMax/802.22 and longer than 802.15.4g/4e. Comparable to the range of typical urban model.

What We Have Relevant

- **No appropriate indoor channel model for TVWS bands**
- **802.22, ITU-R, GSM, 802.16 and 802.15.4g/4e channel models are all for outdoor and each has shortcomings for short range TVWS applications**
  - 802.22 is for long range
  - ITU-R channels are for long range and 2 GHz
  - 802.16 channels are of medium range and 2 GHz
  - GSM typical urban model is for outdoor (up to few kms), however, anything below -10 dB as compared to the best path is neglected. (GSM has smaller packet size and relaxed error rate requirements)
  - 802.15.4g/4e is for outdoor (up to few 100 m) , however, anything below -10 dB as compared to the best path is neglected. (802.15.4g/4e has smaller packet size and relaxed error rate requirements)

Comparison of Channel/System Properties

	802.22 (WRAN)		802.16e (WMAN)	802.11af (WLAN)		UWB (WPAN)		
Coverage	**Typ.** 17 to 33 kms	**Max.** up to 100 kms	10 to 20 KMs	**Indoor:** up to few 100 m	**Outdoor:** up to few kms	**Indoor:** typ. up to 10 m	Max up to 30 m	**Outdoor:** up to 100 m
Ch. (Max Delay spread)	11 to 25 us	25 to 60 us	10 to 20 us	< 1us	1 to 10 us	100 ns	200 to 300 ns	400 to 500 ns
FFT Size	2048		128, 512, 1024, 2048	64 and (Also 128?)		128 in the proposal of MB-OFDM		
Total BW (MHz)	6, 7, 8		1.25 (for 128) 5 (for 512) 10 (for 1024) 20 (for 2048)	5, 20 ? Or/And, 6, 7, 8 ?		500 minimum		
T_FFT (us)	299 (6 MHz), 256 (7 MHz), 224 (8 MHz)		91.4 us	**12.8 for 64, 5 MHz** **3.4 for 64, 20 MHz** **(25.6 us for 128, 5MHz)**				
Guard interval	1/32, 1/16, 1/8, ¼		1/32, 1/16, 1/8, ¼	¼ (1/8 ?)				
Subcarrier spacing (KHz)	Around 3.34 (no mobility)		10.94 (supports delay spread up to 20 us, mobility up to 125 km/h)	**78 for 64 FFT, 5 MHz** **312 for 64 FFT, 20 MHz** **39 for 128, 5 MHz**		huge		

Review of Existing Channel Models (1/4)

- **Indoor**
  - UWB (< 30 m)): 4 models, huge number of paths each
  - 60 GHz (< 10 m): few models, huge number of paths each
- **Outdoor**
  - 802.22 (fixed) WRAN models (< 100 Km): 4 models, 6 paths each (at TVWS, around 50 to 800 MHz)
  - 802.16 (fixed) SUI models (< 10 Km): 6 models, 3 paths each (at 2 GHz, claimed to work well in 1 GHz too)
  - GSM Typical Urban (few KMs): 2 models, 12 path and 6 path. For 400, 900 MHz
  - 802.15.4g/4e (few 100 ms): 1 model, 2 path, for 900 MHz

802.22 Channel Models (2/4)

PROFILE A	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
Excess delay	0	3 μsec	8 μsec	11 μsec	13 μsec	21 μsec
Relative amplitude	0	-7 dB	-15 dB	-22 dB	-24 dB	-19 dB
Doppler frequency	0	0.10 Hz	2.5 Hz	0.13 Hz	0.17 Hz	0.37 Hz
PROFILE B	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
Excess delay	-3 μsec	0	2 μsec	4 μsec	7 μsec	11 μsec
Relative amplitude	-6 dB	0	-7 dB	-22 dB	-16 dB	-20 dB
Doppler frequency	0.1 Hz	0	0.13 Hz	2.5 Hz	0.17 Hz	0.37 Hz
PROFILE C	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
Excess delay	-2 μsec	0	5 μsec	16 μsec	24 μsec	33 μsec
Relative amplitude	-9 dB	0	-19 dB	-14 dB	-24 dB	-16 dB
Doppler frequency	0.13 Hz	0	0.17 Hz	2.5 Hz	0.23 Hz	0.10 Hz
PROFILE D	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
Excess delay	-2 μsec	0	5 μsec	16 μsec	22 μsec	0 to 60 μsec
Relative amplitude	-10 dB	0	-22 dB	-18 dB	-21 dB	-30 to +10 dB
Doppler frequency	0.23 Hz	0	0.1 Hz	2.5 Hz	0.17 Hz	0.13 Hz

802.16 Channel Models (3/4)

SUI – 1 Channel				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	0.4	0.9	µs
Power (omni ant.)	0	-15	-20	dB
Doppler	0.4	0.3	0.5	Hz

SUI – 4 Channel				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	1.5	4	µs
Power (omni ant.)	0	-4	-8	dB
Doppler	0.2	0.15	0.25	Hz

SUI – 5 Channel				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	4	10	µs
Power (omni ant.)	0	-5	-10	dB
Doppler	2	1.5	2.5	Hz

GSM Typical Urban and 802.15.4g/ 4e (4/4)

GSM Typical Urban Model

Profile 1	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
Delay (us)	0.0	0.2	0.5	1.6	2.3	5.0
Relative power (dB)	-3	0	-2	-6	-8	-10
Doppler spectrum	Equation given					

802.15.4g/4e Model

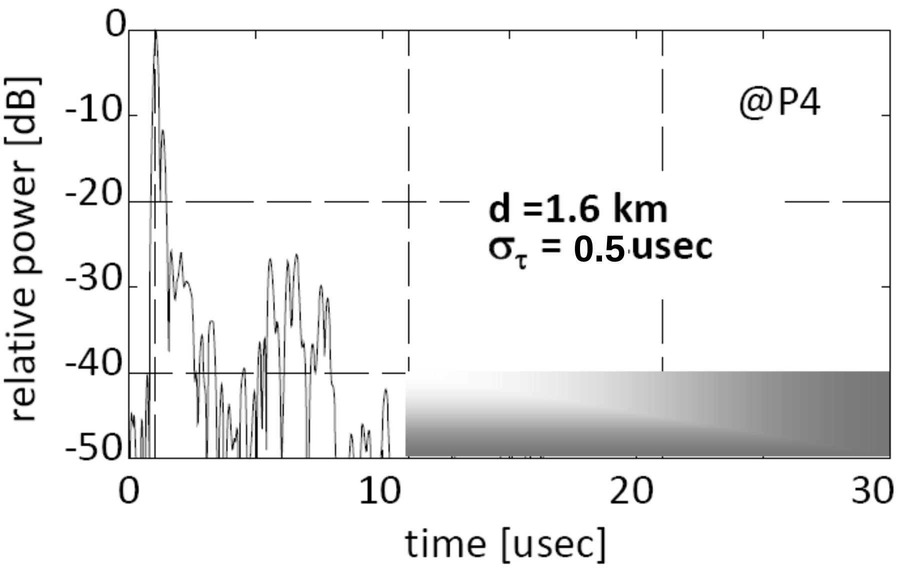
- 2 path (equal mean power) Rayleigh faded channel model proposed
- 2^{nd} path arrives at next sampling instant (1.6 us at 600 KHz sampling frequency)

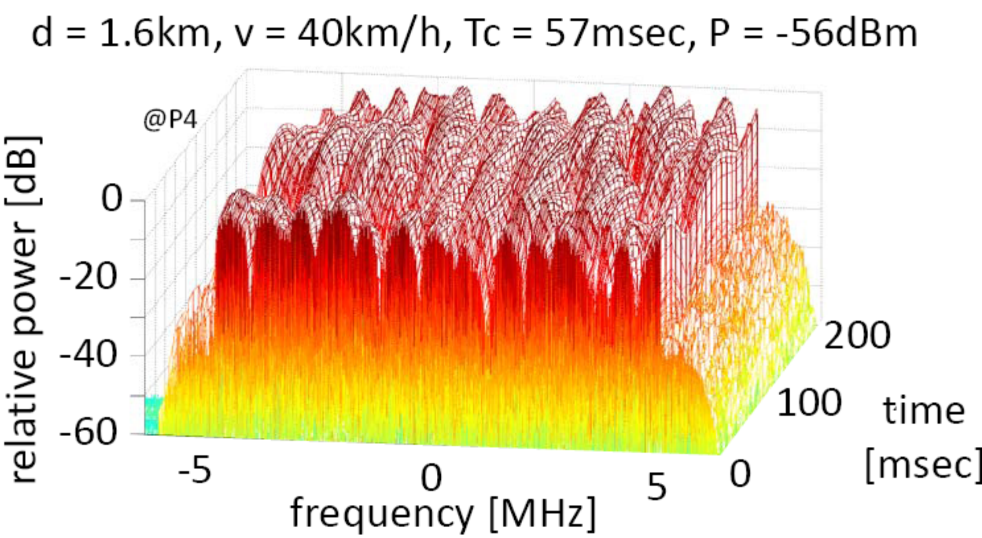
Measurement Data at 900 MHz (Short range)

- **Indoor Factory by Rappaport**
  - Range: up to 100 ms
  - RMS delay spread 30 ns to 130 ns, implying coherence BW (.5) of as wide as 6.67 MHz down to as narrow as 1.5 MHz
- **Outdoor from 802.15.4g/4e**
  - Range: up to few 100 ms
  - Delay spread of up to few us

Measurement Data at 190 MHz (Outdoor)

- **Performed by some colleagues at NICT in a small city of Japan**





Expected Channel Models for 802.11af

Indoor Models (IM)

	Range	LOS/ NLOS	Paths	Max delay (-30 dB)	RMS delay T_rms	Coh. BW (0.5)= 1/(5*T_rms)	Coh. BW (0.9)= 1/(50*T_rms)
IM 1	< 30 m	Yes	6 to 12	300 ns	50 ns	4 MHz	400 KHz
IM2	30 to 100m	Yes	12 to 20	1 us	100 ns	2 MHz	200 KHz

Outdoor Models (OM)

	Range	LOS/ NLOS	Paths	Max delay (-30 dB)	RMS delay T_rms	Coh. BW (0.5)= 1/(5*T_rms)	Coh. BW (0.9) = 1/(50*T_rms)
OM 1	< 500 m	-	2 to 4	2 us	0.4 us	500 KHz	50 KHz
OM 2	0.5 to 2 KM	-	3 to 6	6 us	1 us	200 KHz	20 KHz
OM 3	2 to 5 KM	-	3 to 6	10 us	3 us	67 KHz	6.7 KHz

Important Conclusion (1)

- **Channel parameters significantly affects system design**
  - The guard interval duration need to accommodate the channel response
  - Sub-carrier spacing should not be too-wide that it is more than the coherence BW of the channel, (especially, which could be a problem in NLOS in the range > 1KM)
- **Consideration of higher FFT size could be necessary especially for outdoor environment**
- **We will have more discussion on PHY design issues in the next presentation (802.11-10/155r0)**
- **Time selectivity (around 100 ms) may not be a big problem.**
- **More measurements could be necessary, especially in indoor**

Important Conclusion (2)

- **We can follow a step by step process**
- **Step 1**
  - To start with system design, we at least need to know some basic properties of the channel
    - Max. and RMS delay spreads, coherence BW, coherence time
- **Step 2**
  - To develop a channel model mainly for performance evaluation by simulations
- We expect to bring back more detailed results in 2 to 4 months

References

- **IEEE 802.22-05/55r7**
- **IEEE 802.16.3a-03/01**
- **3GPP 05.05 V08.20.0 Annex C**
- **ITU-R M. 1225**
- **IEEE 802.15.4g-09/279r1**
- **M. Oodo et al, "Radio propagation experiments for broadband wireless system in the VHF band," Proc. WPMC 2009.**
- **T. Rappaport, "Characterization of UHF multipath radio channels in Factory buildings,"** ***IEEE Trans. Ant. Prop.*****, vol. 37, pp. 1058-1069, no. 8, Aug., 1989.**
- **A. Saleh and R. Valenzuela, "Statistical model for indoor multipath propagation,"** ***IEEE JSAC*****, SAC-5, pp. 128-137, no.2, Seb. 1987.**