Industrial Channels of Usecase 1d/2

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Abstract

In term of usecase-1d (Industrial Process Sensors) and use case-2 (Backhaul aggregation of sensors), the sigma of log-normal shadow fading should be larger then 11n CM, e.g. 5-7dB for LOS (Rice) and 7-10dB for NLOS. In addition, the movement of nodes and obstacles have to be identified.

An idea of channel model based on IEEE802.11n CM and Joint 3GPP/3GPP2 SCM is shown as well as the coverage distance and link budget;

(1) Shadowing and moving velocities of nodes and obstacles.

(2) Rough estimation of link budget.

(3) An idea of outdoor industrial channel model based on existing CMs.

Shadowing and moving velocities of nodes and obstacles

Shadow Fading in usecase 1d/2

- Even in the industrial plants (uc 1d) or the road side sensors (uc 2), the shadow fading is well fitted by ordinal log normal statistics (*), provided that the sigma is larger than 11n indoor model (4-6dB);
  7dB (even for Ricean LOS) to 10dB (NLOS, occultation by fixed large metallic obstacles like Tanks, Machine, etc.) are measured and reported, provided that shadowing is independent for each cluster.

→ Hence **<u>8dB</u>** for sigma of shadowing after BP is viable estimation.

* (1) T. S. Rappaport and C. D. McGillem, "UHF fading in factories," IEEE J. Select. Areas Commun., vol. 7, no. 1, pp. 40–48, Jan. 1989
* (2) S. Kjesbu and T. Brunsvik, "Radiowave propagation in industrial environments," in Proc. 26th Annual Conference of the IEEE Industrial Electronics Society, vol. 4, pp. 2425–2430, Oct. 2000.
* (3) Emmeric Tanghe, Wout Joseph, et al., "The Industrial Indoor Channel: Large-Scale and Temporal Fading at 900, 2400, and 5200 MHz " IEEE trans. on wireless communications vol. 7, no. 7, Jul. 2008

Velocity of nodes and obstacles in usecase 1d/2

- AP and STA are fixed still in usecase 1d/2 and the velocities are well below **0.1km/h**.
- While most obstacles in usecase 1d/2 are stationary, the vehicle and vessels have to be taken account ;
  (1) Parking vehicles obstruct the propagation path (shadowing)
  (2) Product or Vehicle which may be possibly passing by is a reflector as Doppler source, of which velocity can be up to **20km/h**.
  (3) Berthing vessels may alter the propagation channels drastically as a large stationary reflector, while the change happens infrequently.

→ Hence a tap with the wider Doppler spread within all other narrow spread taps is justifiable.

Path Loss model parameters in usecase 1d/2

Model Usecase	d_{BP} (m)	Slope before d_{BP}	Slope after d_{BP}	Shadow fading std. dev. (dB) before d_{BP} (LOS)	Shadow fading std. dev. (dB) after d_{BP} (NLOS)
Usecase 1d and Usecase 2a/b	30	2	3.5	3	8

Coverage distance and rough estimation of link budget

Link budget in Industrial high-rise complex

Parameter	unit	Backhaul Link	Sensor Leaf Link
Tx Power (STA)	dBm	23	13
TX Antenna Gain (STA)	dBi	3	3
Path Loss			
Frequency	MHz	920	920
Distance	m	750	250
AP Antenna Height	m	10	5
STA Antenna Height	m	5	1
Hata Small urban	dB		
A		3.17	7.76
B		38.35	40.32
Total Path Loss	dB	119.49	114.41
Path Loss + Shadowing	dB	127.49	122.41
Shadowing Sigma	dB	8.00	8.00
Received Power			
RX Antenna Gain (AP)	dBi	8	8
RSS(Signal Power)	dBm	-93.49	-98.41
Data Rate	kbps	2000	200
Eb	dBm	-156.50	-151.42
Eb/No	dB	4.50	4.58
NF+Implementation	dB	10	10
Multipath Fading Margin	dB	3.00	8.00
N_{total}	dBm	-164.00	-164.00
Noise Power			
BW	kHz	800	800
Total (N)	dBm	-105.0	-105.0
Required Diversity Gain (d)	dB	0.5	5.4
Assumed SNR (d*RSS/N)	dB	12.0	12.0

- Small urban Hata,

  Tx Power

  200mW (Backhaul link)

  20mW (Sensor leaf link)

  Ant Height (Backhaul link)

  H_{AP} = 10m

  H_{STA} = 5m

  Ant Height (Sensor leaf link)

  H_{AP} = 5m

  H_{STA} = 1m

  Shadowing Sigma 8dB

  Fading margin

  3dB (Backhaul link)

  8dB (Sensor leaf link)

Link budget in Industrial low-rise field

Parameter	unit	Backhaul Link	Sensor Leaf Link
Tx Power (STA)	dBm	23	13
Tx Antenna Gain (STA)	dBi	3	3
Path Loss			
Frequency	MHz	920	920
Distance	m	1000	400
AP Antenna Height	m	10	5
STA Antenna Height	m	5	1
Hata Suburban			
A		3.17	7.76
B		38.35	40.32
Total Path Loss	dB	114.29	112.64
Path Loss + Shadowing	dB	122.29	120.64
Shadowing Sigma	dB	8.00	8.00
Received Power			
RX Antenna Gain (AP)	dBi	3	3
RSS(Signal Power)	dBm	-93.29	-101.64
Data Rate	kbps	2000	200
Eb	dBm	-156.30	-154.65
Eb/No	dB	4.70	4.35
NF+Implementation	dB	10	10
Multipath Fading Margin	dB	3.00	5.00
N_{total}	dBm	-164.00	-164.00
Noise Power			
BW	kHz	800	800
Total (N)	dBm	-105.0	-105.0
Required Diversity Gain (d)	dB	0.3	8.7
Assumed SNR (d*RSS/N)	dB	12.0	12.0

- Suburban Hata
  - Tx Power
    - 200mW (Backhaul link)
    - 20mW (Sensor leaf link)
  - Ant Height (Backhaul link)
    - H_{AP} = 10m
    - H_{STA} = 5m
  - Ant Height (Sensor leaf link)
    - H_{AP} = 5m
    - H_{STA} = 1m
  - Shadowing Sigma 8dB
  - Fading margin
    - 3dB (Backhaul link)
    - 5dB (Sensor leaf link)

Link budget in Industrial low-rise field (Long Distance)

Parameter	unit	Backhaul Link	Sensor Leaf Link
Tx Power (STA)	dBm	23	13
Tx Antenna Gain (STA)	dBi	3	10
Path Loss			
Frequency	MHz	920	920
Distance	m	2000	1000
AP Antenna Height	m	20	10
STA Antenna Height	m	6	3
Hata Suburban			
A		4.01	5.52
B		36.38	38.35
Total Path Loss	dB	118.52	119.41
Path Loss + Shadowing	dB	122.52	123.41
Shadowing max	dB	4.00	4.00
Received Power			
RX Antenna Gain (AP)	dBi	3	7
RSS(Signal Power)	dBm	-93.52	-93.41
Data Rate	kbps	200	200
Eb	dBm	-146.53	-146.42
Eb/No	dB	14.47	14.58
NF+Implementation	dB	10	10
Multipath Fading Margin	dB	3.00	3.00
N_{total}	dBm	-164.00	-164.00
Noise Power			
BW	kHz	800	800
Total (N)	dBm	-105.0	-105.0
Required Diversity Gain (d)	dB	0.5	0.4
Assumed SNR (d*RSS/N)	dB	12.0	12.0

- Suburban Hata
  - Tx Power
    - 200mW (Backhaul link)
    - 20mW (Sensor leaf link)
  - Ant Height (Backhaul link)
    - H_{AP} = 20m
    - H_{STA} = 6m
  - Ant Height (Sensor leaf link)
    - H_{AP} = 10m
    - H_{STA} = 3m
  - Shadowing max 4dB
  - Fading margin 3dB

Wider coverage by Relay (Mesh)

- Typical industrial plant occupies 0.5km radius area,
  while larger industrial cluster sometimes spans up to 2km distance.

  → Hence, AP Relay is instrumental.

- Longer interference radius in sub-GHz bands has to be considered.

  → Throughput degradation due to interference from nodes within same MBSS should be well managed.

- Resilience by mesh path diversity is preferable.

  → 11s deserves.

An idea of outdoor industrial channel model based on existing 11n CM and Joint 3GPP/3GPP2 SCM

Correlated Statistical Fading Model and Ray Based SCM

- Ether IEEE802.11n CM or Joint 3GPP/3GPP2 SCM, or both should be useful if each parameters are properly selected, e.g. PAS, AS, PDP and so on.
- Cluster by cluster (path by path) independent shadowing may deserve for usecase-1d and usecase-2, because 11ah is expected to enhance the link robustness by utilizing the diversity gain.
- In case of Joint 3GPP/3GPP2 SCM, node B (Base station) PAS and AS should be scrutinized carefully for 11ah AP installation, but SCM has to be straight forward and simpler than the modification of 11n CM.

Channel of industrial usecase-1d/2

< No need to Doppler on every taps >

- Stationary nodes. Both AP and STA are fixed still. (<< 0.1km/h)

< Path delay time scaling comparable to reduction of sampling rate >

- Multipath-rich by large scale structures, similar to indoor Cluster-Ray.
  (e.g. Tank, Machine, Tower : 4 to 16 times larger than indoor office)
- Deep Shadow Fading by parked vehicle (e.g. Tank lorry)
- Infrequent drastic change of channel condition. (e.g. Ship berthing)

< Doppler only on a few taps >

- Fast moving reflectors occasionally passing by. (< 20km/h)
  (e.g. Vehicle, Moving product in plant (Rolled steel sheet), etc.)

11n CM-E/F and industrial usecase-1d/2b (1)

- 11n CM defines indoor and outdoor channels in term of stationary AP to STA link with relatively small coverage area.

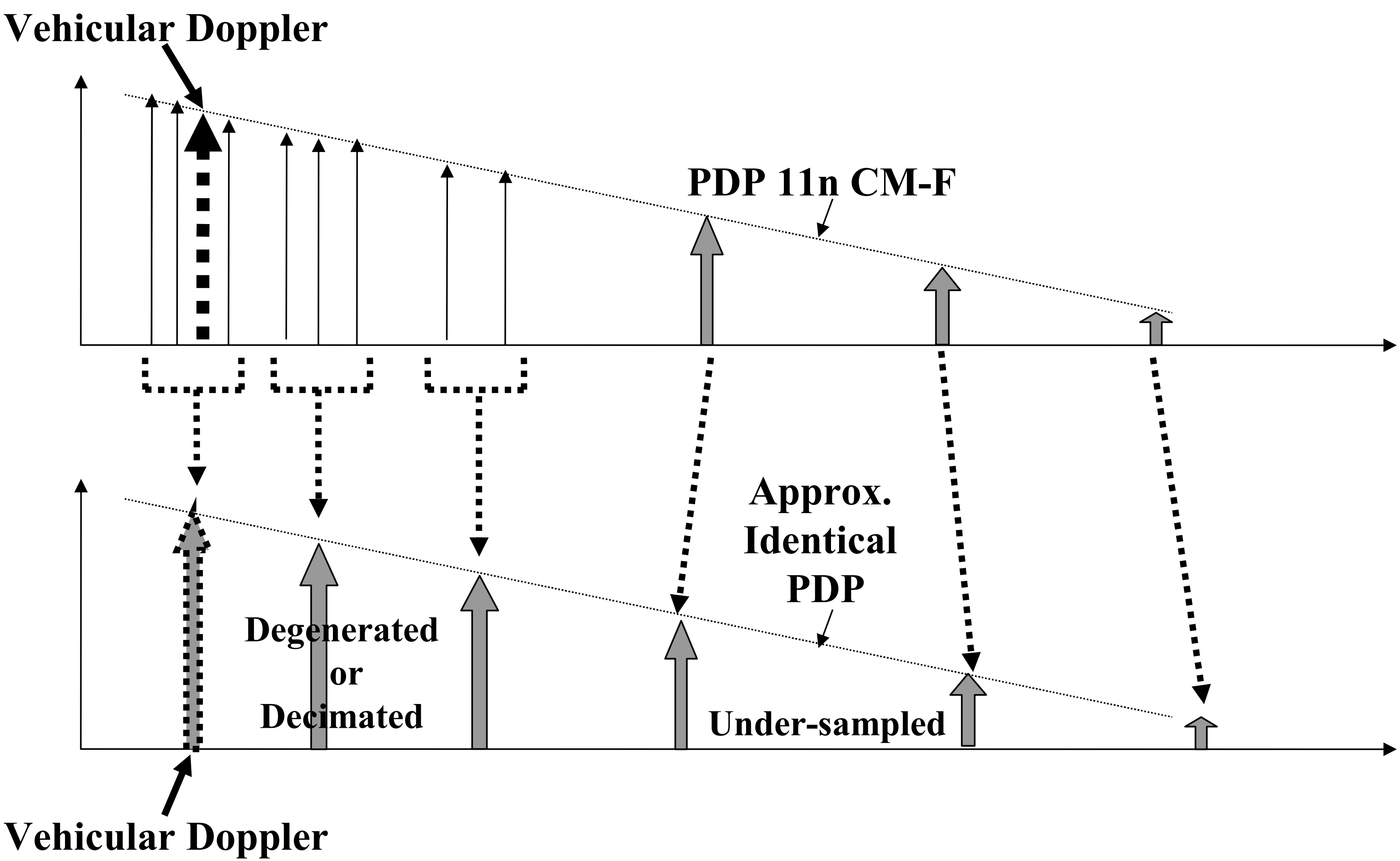
< 11n CM-F >

- Even if assumed RMS delay spread of 150ns in model F and corresponding max. delay of about 1 uS may be limited for outdoor usecases, 11n model F as is has to be useful, provided that the sampling rate is carefully managed, e.g. degeneration or decimation.

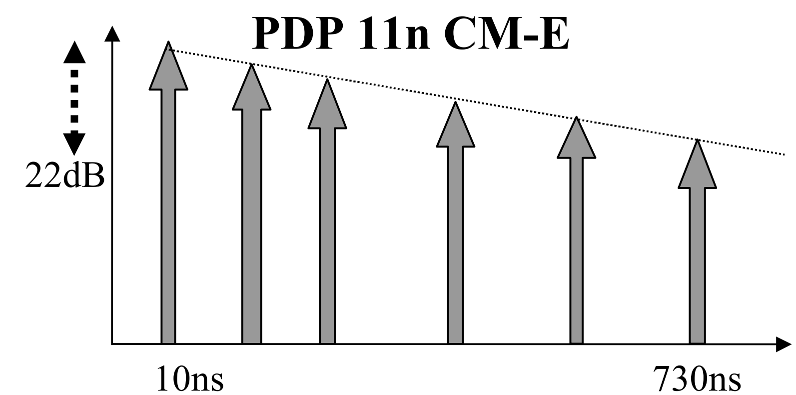
< 11n CM-B & E modified >

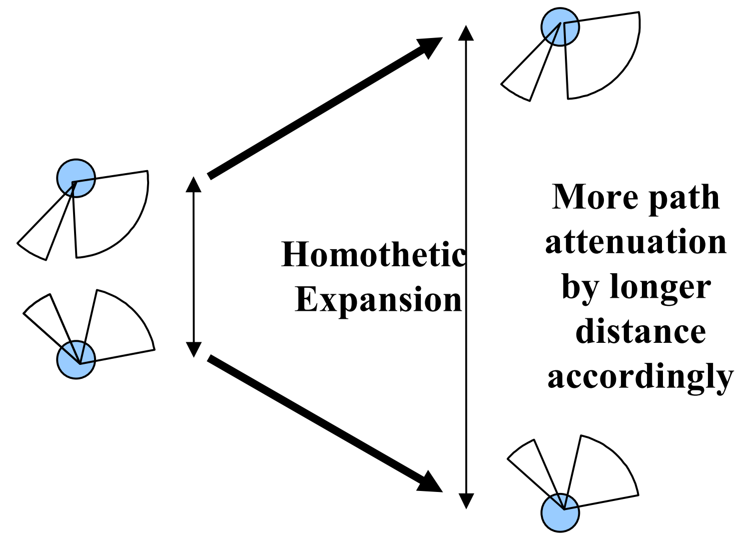
- Large structures in high-rise industrial complex are similar to CM-E of indoor office, if it is modified to scale 4 times wider ray separation and cluster span (delay times) corresponding to outdoor distance.
  In addition, CM-B as a simple 16 times area expansion model should be useful, i.e. using 16 times tap spacing of 160ns with 1.28us max delay.

11n CM-F and industrial usecase-1d/2b (2)

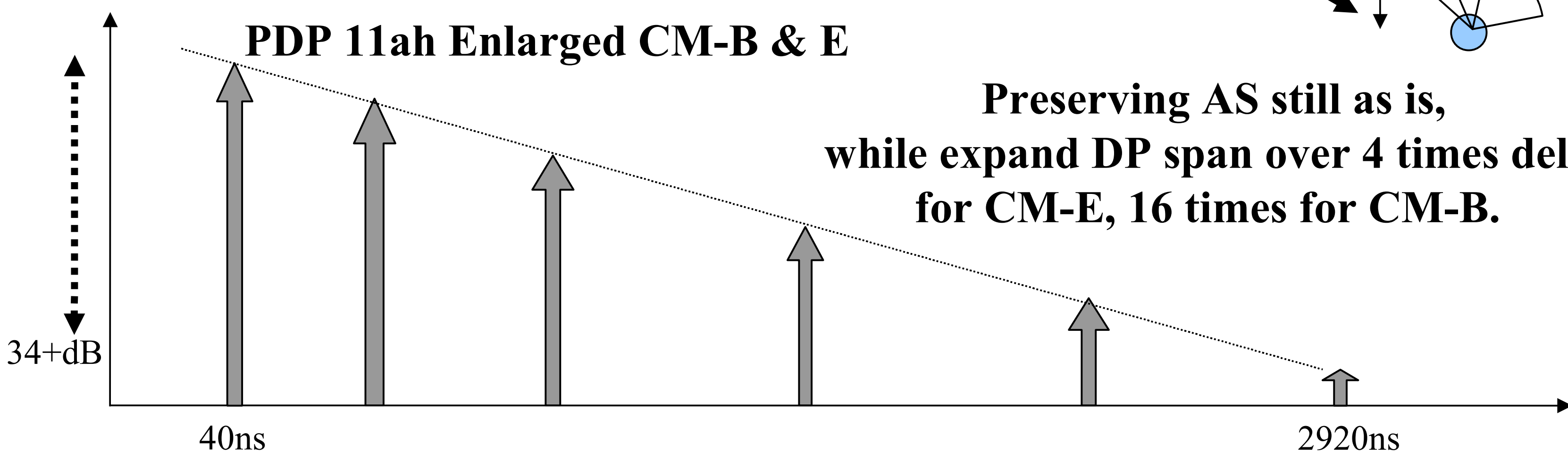


11n CM-Enlarged B & E for usecase-1d/2b (3)





**Preserving AS still as is,
while expand DP span over 4 times delay
for CM-E, 16 times for CM-B.**



Joint 3GPP/3GPP2 SCM and industrial usecase-1d/2b

SCM defines two pedestrian models A (Case I) and B (Case III), of which channels are links between a mobile user equipment and a base station.

The assumed base station of SCM was different from a traditional WLAN AP, and AS at the base station side is narrow in SCM. But in case of 11ah, AP installation may be rather similar with a cellular base station than a home use AP.

< Pedestrian B >

- If sufficient number of sub-rays are assumed with not too narrow AS, Pedestrian B of PDP up to 3.7us has to fit usefully for usecase-1d/2.
- It may be better to use for usecase-1d/2 than 11n CM model F.

< Pedestrian A >

- If both ends of link have same PAS and AS of a user equipment, Pedestrian B may fit better for relay link of usecase-1d/2.

End