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ITU-R IMT-Advanced 무선채널 모델 및 표준화 현황

IMT-Advanced Channel Model in ITU-R Standardization

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Presented to POSTECH

ETRI
Electronics and Telecommunications Research Institute

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  - As of 1st meeting of WP5D (2008. 1, Geneve)
- The ETRI Wideband MIMO Channel Sounder

Evolution of Mobile Communications

- 2G
  - Circuit switched voice service
  - Europe: GSM, USA: IS-95 (cdmaOne)
- 3G: IMT-2000 and its evolution
  - Circuit switched voice mode + packet switched data mode → Integrated service based on IP protocol
  - 3GPP: W-CDMA → HSDPA/HSUPA → LTE
  - 3GPP2: cdma2000 → EV-DO → UMB (EV-DO Rev. C)
  - Others: TD-SCDMA, etc.
  - Mobile WiMAX: IP-OFDMA (IEEE 802.16e OFDMA) approved as a new IMT-2000 technology
- 4G: IMT-Advanced
  - Integrated service based on IP protocol
    - All the existing and new services will be provided using IP protocol
  - Higher system & cell edge user throughput
  - Expected proposals: 802.16m, LTE-Plus, *UMB(-Advanced)?, others*

ITU-R SG5

- ITU-R Radiocommunications Assembly 2007 (Oct 15-19) addressed restructuring of the ITU-R Study Groups to better align mobile, fixed, terrestrial and satellite work
  - SG1 (SPECTRUM MANAGEMENT)
  - SG3 (RADIOWAVE PROPAGATION)
  - SG4 (SATELLITE SERVICES)
  - **SG5 (TERRESTRIAL SERVICES)**
    - SG 5 will undertake the terrestrial studies of the former Study Groups 8 and 9
  - SG6 (BROADCASTING SERVICE)
  - SG8 (SCIENCE SERVICES)

- Study Group 5 New Structure & Leadership
  (to be confirmed at Feb. 18-19, 2008 Study Group 5 meeting)

	Proposed Working Party	**Acting Chairman**
Land mobile other than IMT and amateur/amateur-satellite	WP 5A (former WP8A)	Mr. J. Costa
Maritime mobile, Aeronautical mobile, Radiodetermination	WP 5B (former WP8B)	Mr. T. Evers
Fixed wireless systems, HF systems in the FS and the land MS	WP 5C (former WP9B+9C+9D)	Mr. C. Glass
Land mobile (IMT)	**WP 5D (IMT) (former WP8F)**	**Mr. S. Blust**

IMT-Advanced: What's in a Name?

- ITU-R WP8F has determined the following nomenclature to describe the *IMT-2000 and Systems Beyond IMT-2000 universe*
  - **"IMT-2000"** encompasses also its enhancements and future devel opments
  - **"IMT-Advanced"** be applied to those systems, system component s, and related aspects that include new radio interface(s) that supp ort the new capabilities of systems beyond IMT-2000
  - **"IMT"** is the root name that encompasses both IMT-2000 and IMT-Advanced collectively
    - **IMT = IMT-2000 + IMT-Advanced**

IMT Bands (WRC-07)

IMT 후보대역	회의 진행 사항
410 ~430MHz	• NOC (지지국가 없음)
450 ~470MHz	• 유럽을 제외한 다수 제안서에서 IMT 분배 찬성 • 전세계 IMT 지정을 위한 신규 각주 도입 및 결의안 수정 완료 – 한국 : 가용 주파수 여유 없음
470~ 806/862MHz	• 지역별 IMT 대역을 따로 결정, IMT PRIMARY 분배 – Region 1 : 790~862MHz 대역 – Region 2 : 698~806 MHz 대역 – Region 3 : 790~806MHz 대역 * 한국 : 698~790MHz 대역 (footnote:5.YYY)
2 300 ~2 400MHz	• 전세계 공동대역으로 IMT 지정을 위한 각 주 도입 및 결의안 작업 완료
2 700 ~2 900MHz	• NOC (지지국가 없음)
3 400 ~4 200MHz	• 지역별 IMT 대역을 따로 결정, IMT 분배 (국가별 사용, 전파 제약 조건 포함) – Region 1 : 3 400 ~ 3 600MHz 대역 – Region 2 : 3 400 ~ 3 500MHz 대역 – Region 3 : 3 400 ~ 3 600MHz 대역
4 400 ~4 900MHz	• NOC (지지국가 없음, only 일본)

WRC-07 결과

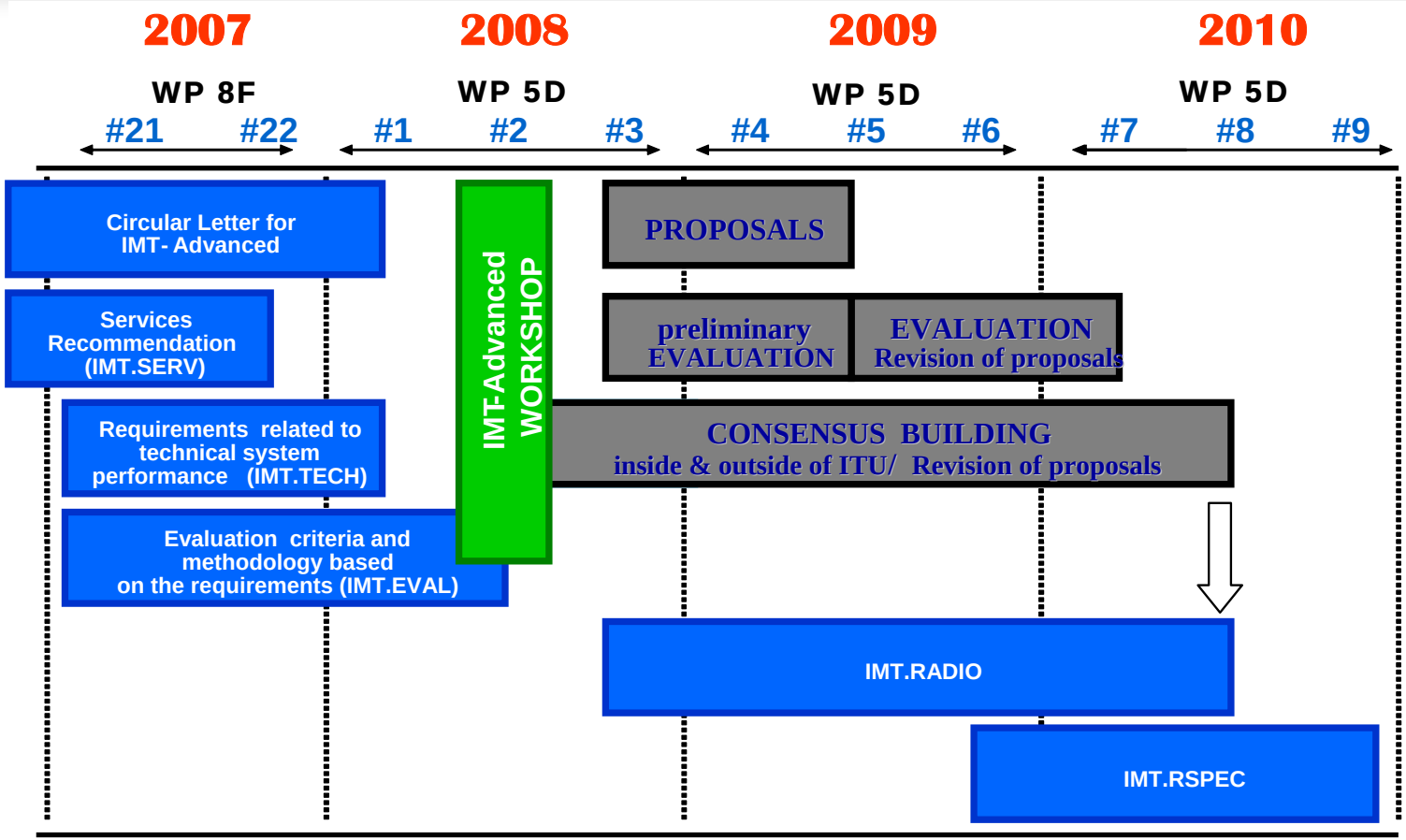
Global IMT 대역 확보

- 450 ~ 470 MHz
- 698 ~ 790 MHz
- 2 300 ~ 2 400 MHz
- 3 400 ~ 3 600 MHz

WARC-92
- 1,885 ~ 2,025 MHz, 2,110 ~ 2,200 MHz

WRC-2000
- 806 ~ 960 MHz(3지역), 1,710 ~ 1,885 MHz, 2,500 ~ 2,690 MHz
  (위성: 1,525~1,559/1,610~1660.5MHz,2,483.5~2,520/2,670~2,690MHz)

IMT-Advanced Work Plan



- Evaluation 및 consensus building 과정 중 제안한 기술의 revision 가능
- Proposal 제안 기간 중 preliminary evaluation 진행
- 무선규격 IMT.RADIO의 결정은 2010년 중순, 상세 Spec을 포함한 최종 규격 IMT.RSPC의 완료는 2010년 말

IMT-Advanced Work Plan

- Two key deliverables related to IMT-Advanced
  - **IMT.RADIO**
    - Document on framework and key characteristics of the radio interfaces of IMT−Advanced
    - The IMT.RADIO is the output of the work from the received proposal s on IMT-Advanced candidate radio interfaces, the evaluation activity , and the consensus building. This document would constitute the ov erall framework for IMT-Advanced and contain the key characteristics of the radio interfaces of IMT−Advanced
  - **IMT.RSPEC**
    - New PDNR on detailed specifications for IMT-Advanced
    - IMT.RSPEC would contain the detailed specifications of the IMT-Advanced technologies defined in IMT.RADIO

IMT-Advanced minimum requirements

Cell spectral efficiency

Test environment **	Downlink (b/s/Hz/cell)	Uplink (b/s/Hz/cell) [Case 1, see note 2]	Uplink (b/s/Hz/cell) [Case 2, see note 2]
Indoor	3	[2.5]	[1.5]
Microcellular	2.6	[2]	[1.3]
Base coverage urban	2.1	[1.5]	[1.2]
High speed	1	[0.7]	[0.6]

Peak Spectral Efficiency

- Downlink peak spectral efficiency is [7/10] b/s/Hz
- Uplink peak spectral efficiency is [2.5/5] b/s/Hz
- *assumptions on antenna configuration*
  - *downlink – 4x4, uplink – 2x4*

Bandwidth

- The RIT shall support a scalable bandwidth up to and including [20/40] MHz

IMT-Advanced minimum requirements

Normalized Cell edge user throughput

Test environment* *	Downlink (b/s/Hz)	Uplink (b/s/Hz)
Indoor	[0.1]	[0.08]
Microcellular	[0.075]	[0.05]
Base coverage urban	[0.06]	[0.03]
High speed	[0.05]	[0.02]

Latency

- Control plane latency : 100 ms
- User plane latency : 10 ms

VoIP Capacity

- A minimum of [40] active users/MHz/cell shall be supported

IMT-Advanced minimum requirements

Mobility

- Stationary: 0 km/h
- Pedestrian: 0 km/h to 10 km/h
- Vehicular: 10 to 120 km/h
- High speed vehicular: 120 to 350 km/h

	Test environments*			
	Indoor	**Microcellular**	**Base coverage urban**	**High speed**
Mobility classes supported	Stationary, pedestrian	Stationary, pedestrian	Stationary, pedestrian, vehicular	High speed vehicular, vehicular

Handover

Handover Type	**Max. Interruption Time (ms)**
Intra-Frequency	[25/30]
Inter-Frequency – within a spectrum band – between spectrum bands	[TBD]

Contents

- Intro : ITU-R WP5D Activities
- IMT-Advanced Channel Model
  - IMT-Adv Evaluation Process
  - MIMO Channel
  - Generic vs Reduced Variability Model
  - Channel coefficient generation procedure
- The ETRI Wideband MIMO Channel Sounder
  - BECS2006 Overview
  - Measurement Campaign
  - Spatial Channel Analysis
  - Parts of ETRI Channel Model for IMT-Advanced

IMT-Advanced Evaluation (IMT.EVAL)

- Simulations.
- Analytical (via a calculation).
- Inspection (by reviewing the functionality and parameterisation of the proposal).

Characteristic for Evaluation	Method
Cell spectral efficiency	Simulation
Peak spectral efficiency	Analytical
Bandwidth	Inspection
Normalized cell edge user throughput	Simulation
Control plane latency	Analytical
User plane latency	Analytical
Mobility	Simulation
Handover interruption time	Analytical
VoIP Capacity	Simulation
Deployment possible in at least one of the identified IMT bands	Inspection
Channel bandwidth scalability	Inspection
Support for a wide range of services	Inspection
Seamless connectivity	Inspection

- Test Environment / Deplomment Scenarios for evaluation
  - **Base coverage urban:**

    an urban macro-cellular environment targeting to continuous coverage for pedestrian up to fast vehicular users in built-up areas.
  - **Microcellular:**

    an urban micro-cellular environment with higher user density focusing on pedestrian and slow vehicular users
  - **Indoor:**

    an indoor environment targeting isolated cells at offices and/or in hotspot based on stationary and pedestrian users.
  - **High speed:**

    macro cells environment with high speed vehicular and trains.

Test environment	Base coverage urban	Microcellular	Indoor	High speed
Deployment scenario	Urban macro-cell scenario	Urban micro-cell scenario	Indoor hotspot scenario	Rural macro-cell scenario

Simulation Parameters for evaluation(1/2)

Deployment scenario	Urban macro-cell	Urban micro-cell	Indoor hotspot	Rural macro-cell	Suburban marco-cell
Layout	Cellular, Hexagonal grid	Cellular, hexagonal	Isolated site	Cellular, Hexagonal grid	[tbd.]
Evaluated Service Profiles	Full buffer best effort, VoIP	Full buffer best effort, VoIP	Full buffer best effort, VoIP	Full buffer best effort, VoIP	[tbd.]
Inter-site distance	[500m]	200 m	N/A	1732 m	[tbd.]
Carrier Frequency (CF)	2.5GHz	2.5 GHz	[3.4 GHz]	800 MHz	[tbd.]
Bandwidth (BW)	[tbd.]	[tbd.]	[tbd.]	[tbd.]	[tbd.]
Channel Model	C2	B1	A2	D1	[tbd.]
BS antenna height	25 m, above rooftop	10 m, below rooftop	[6 m, mounted on ceiling]	35 m, above rooftop	[tbd.]
Number of BS antenna elements	[tbd]	[tbd]	[tbd]	[tbd]	[tbd.]
Total BS TX power (total)	[49dBm for 20MHz]	37dBm for [?] MHz	21dBm for [?] MHz	[49dBm for 20MHz]	[tbd.]
UT power class	24dBm	24dBm	21dBm	24dBm	[tbd.]
UT antenna system	[tbd]	[tbd]	[tbd]	[tbd]	[tbd.]

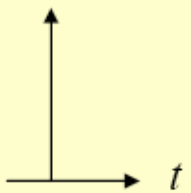
Simulation Parameters for evaluation(1/2)

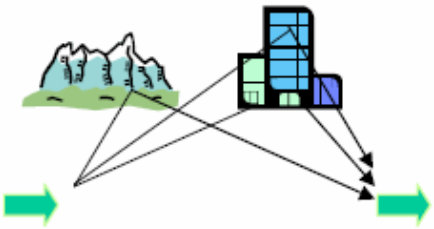
Deployment sc enario	Urban macro-cell	Urban micro-cell	Indoor hotspot	Rural macro-cell	Suburban marco-cell
User placement	[tbd]	[uniform, in the streets (outdoor UT simulations) or in the buildings (indoor UT simulations), 30% UT indoors]	[uniform, in the rooms, or in the hall, 90% UT in rooms]	uniformly in entire area, 100% UT outdoors in car	[tbd.]
User mobility model	Fixed and identical speed |v| of all UTs, direction uniformly distributed	Fixed and identical speed |v| of all UTs, UTs only move along the streets they are in. Direction is random and both directions are equally probable	Fixed and identical speed |v| of all UTs, random direction	Fixed and identical speed |v| of all UTs, direction uniformly distributed	[tbd.]
UT speeds of interest:	30km/h (assuming only outdoor users). This will not be used for evaluating mobility requirement	[3 km/h, 30km/h]. This will not be used for evaluating mobility requirement	3 km/h. This will not be used for evaluating mobility requirement	120 km/h. This will not be used for evaluating mobility requirement	[tbd.]
Penetration loss	5dB [Note: depends on carrier frequency]	[tbd]	[tbd]	5dB [Note: depends on carrier frequency]	[tbd.]
Minimum distance between UT and serving cell	>= 25 meters	>= 10 meters	>= 3 meters	>= 35 meters	[tbd.]

What's up in air ?

Time domain

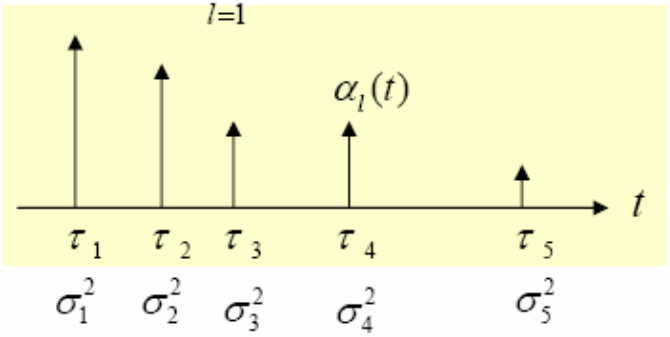
$\delta(t)$



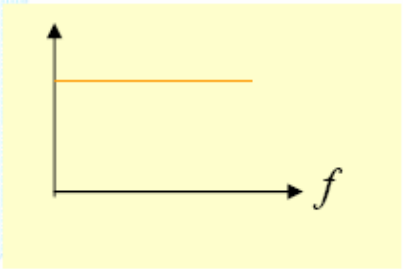


Wireless Channel

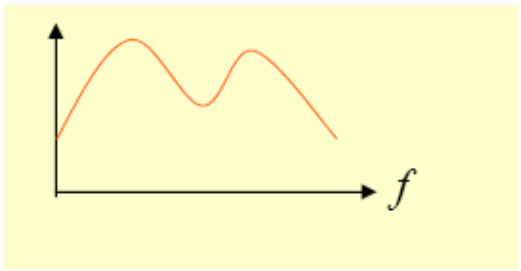
$$h(t) = \sum_{l=1}^{L} \alpha_l(t)\delta(t-\tau_l)$$



Frequency domain



Tx signal



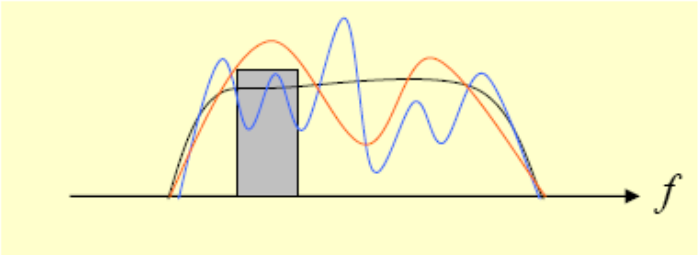
Rx signal

What's up in air ?

- Delay Spread
  - Frequency selectivity
  - Root mean square (RMS) delay spread

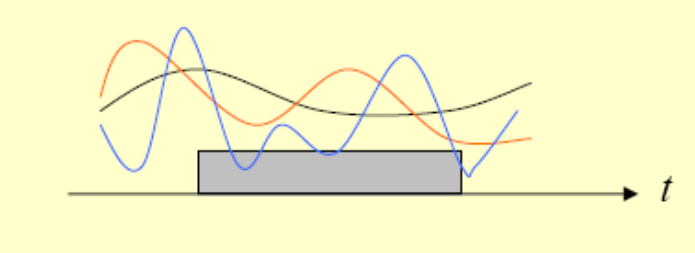
$$\tau_{rms} = \sqrt{\sum_{l=1}^{L} \tau_l^2 \sigma'^2_l - \left(\sum_{l=1}^{L} \tau_l \sigma'^2_l \right)^2}$$

$$\sigma'^2_l = \sigma_l^2 / \sum_{i=1}^{L} \sigma_i^2$$



- Doppler Spread
  - Time selectivity
  - Maximum Doppler spread

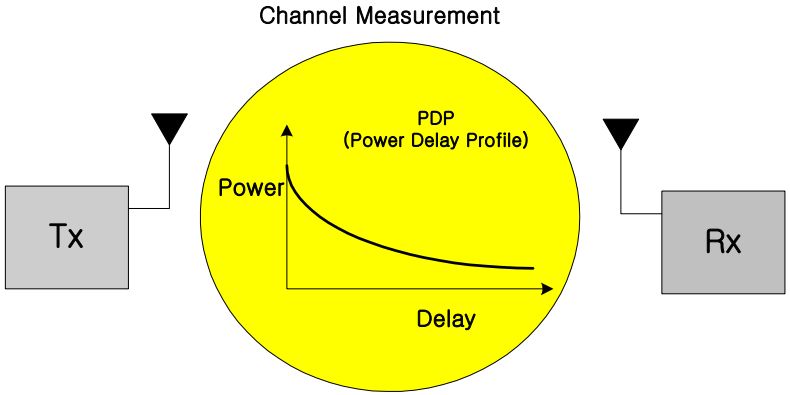
$$f_D = f_c \frac{v}{c}$$



- v : the velocity of the vehicle, f_c : the carrier frequency

Channel Parameters

- What is the wireless channel parameters to be focused on ?



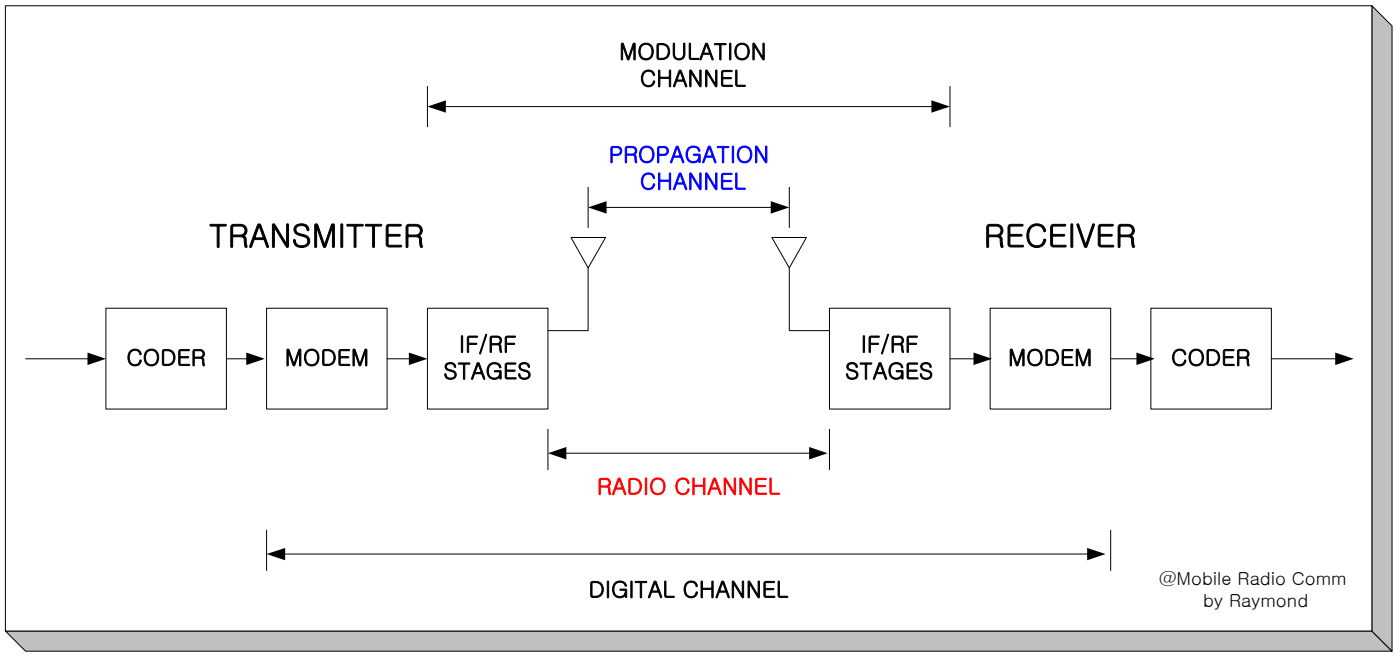
- Elements for Implementation (phenomena)
  - Path Loss : CW Rx power measurements
  - Rayleigh Fading : deterministic vs stochastic
  - Ricean Fading : K-factor (LOS)
  - Doppler Effect : U-shape, Flat, Rounded over [0, 2π]
  - Multipath : Tapped Delay Line
  - Shadowing : Lognormal Random Characteristics

- Channel Impulse Response (CIR) at n^{th} path, $\boldsymbol{h_n}$

$$h_n = \alpha(t)e^{j\gamma(t)}$$

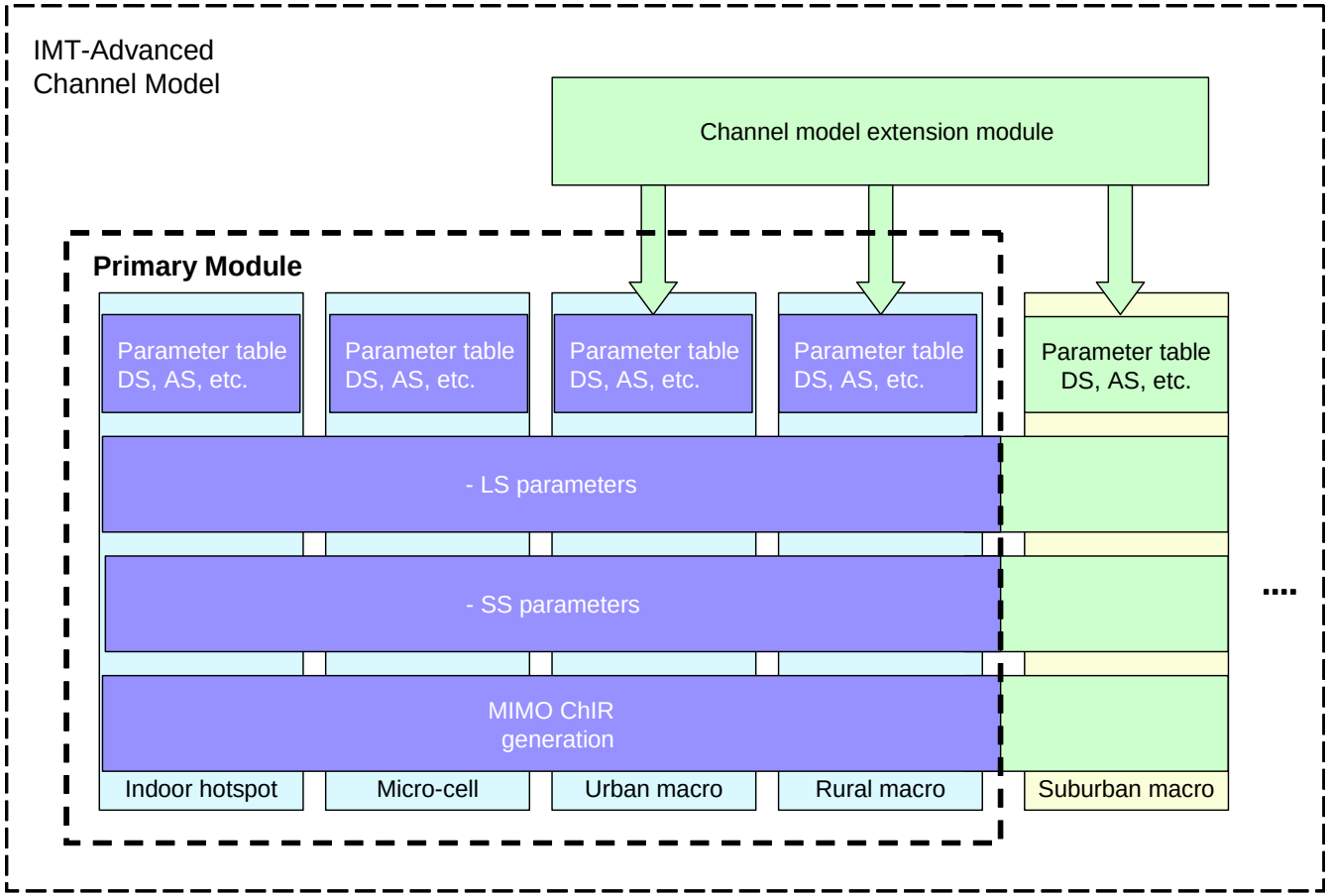
MIMO Channel Model Scope

- Moving Focus : from Propagation Channel to Radio Channel
  - Multiple Antennas
  - Spatial description of wireless channel parameters
  - Antenna pattern / Array spacing
  - Time-dependent trajectory of MS



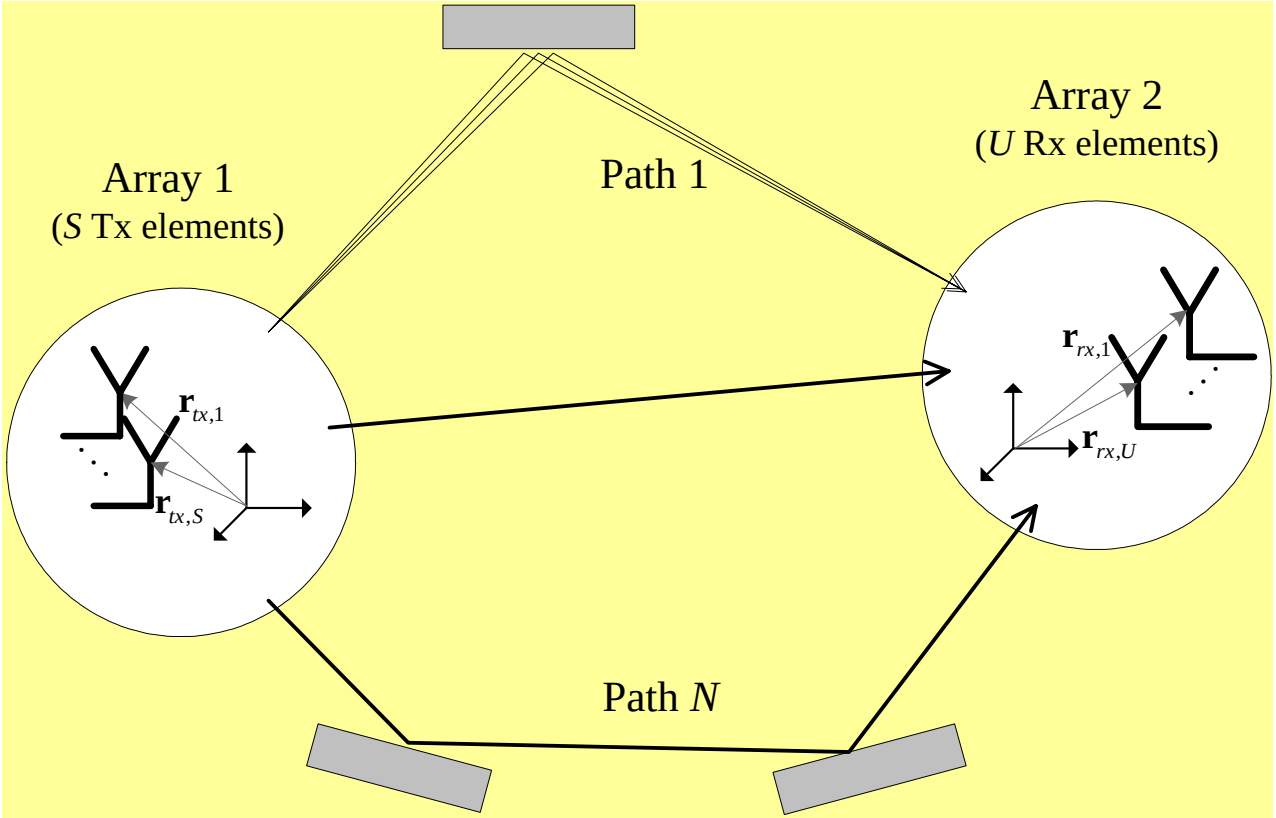
IMT-Advanced Channel Model

- **Primary** (WINNER II) vs **Extension** (JAPAN) Module
- Primary module = **Generic Model** (mandatory) + **Reduced Variability Model** (optional)



MIMO Channel

- S x U, N multipath (N Clusters)
- Geometry-based Stochastic Model



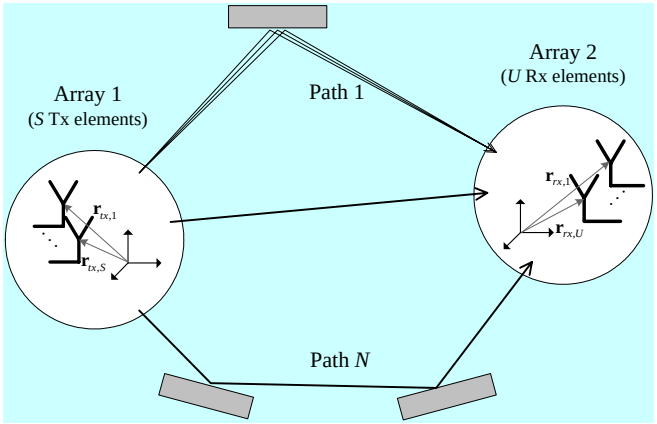
S x U, N multipath (N Clusters)

- Transfer matrix of the MIMO channel

$$\mathbf{H}(t;\tau) = \sum_{n=1}^{N} \mathbf{H}_n(t;\tau)$$

$$\mathbf{H}_n(t;\tau) = \iint \mathbf{F}_{rx}(\varphi)\mathbf{h}_n(t;\tau,\phi,\varphi)\mathbf{F}_{tx}^{T}(\phi)\,d\phi d\varphi$$

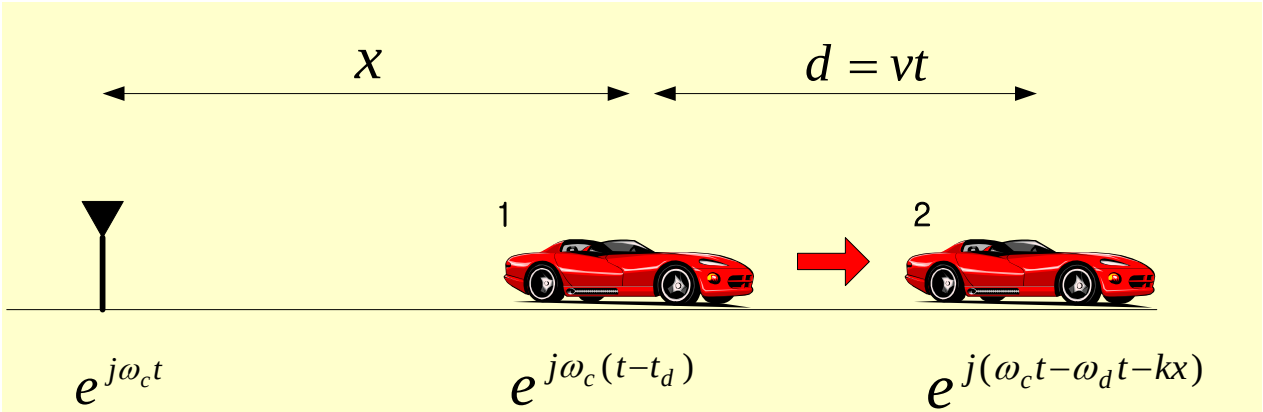
  - antenna array response matrices **F***tx* , **F***rx*
  - propagation channel response matrix **hn** for cluster n



- The channel from Tx antenna element s to Rx element u for cluster n

$$H_{u,s,n}(t;\tau) = \sum_{m=1}^{M} \begin{bmatrix} F_{rx,u,V}(\varphi_{n,m}) \\ F_{rx,u,H}(\varphi_{n,m}) \end{bmatrix}^{T} \begin{bmatrix} \alpha_{n,m,VV} & \alpha_{n,m,VH} \\ \alpha_{n,m,HV} & a_{n,m,HH} \end{bmatrix} \begin{bmatrix} F_{tx,s,V}(\phi_{n,m}) \\ F_{tx,s,H}(\phi_{n,m}) \end{bmatrix} \times \exp\left(j2\pi\lambda_0^{-1}(\bar{\varphi}_{n,m}\cdot\bar{r}_{rx,u})\right)\exp\left(j2\pi\lambda_0^{-1}(\bar{\phi}_{n,m}\cdot\bar{r}_{tx,s})\right) \times \exp(j2\pi\upsilon_{n,m}t)\delta(\tau-\tau_{n,m})$$

- Propagation with Doppler (Math. Description)



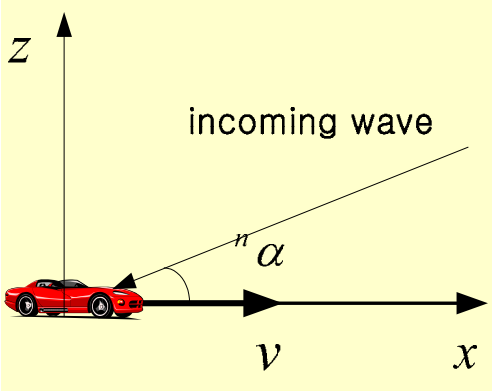
$$1\ e^{j\omega_c(t-t_d)} = e^{j\omega_c(t-\frac{x}{c})} = e^{j(\omega_c t-\frac{2\pi}{\lambda}x)} = e^{j(\omega_c t-kx)}$$

$$2\ e^{j(\omega_c t-k(x+d))} = e^{j(\omega_c t-kx-kvt)} = e^{j(\omega_c t-kx-\omega_d t)}$$

- Moving effect is equivalent to frequency shift by ω_d
- Frequency spreading from $|f - fc| < \omega_d$

Propagation with Doppler (Math. Description)

- Rayleigh Fading with Doppler Effect
  - Received signal at a moving vehicle in multipath environment



$$E_z = E_0 \sum_{n=1}^{N} C_n \cos(\omega_c t + \omega_{d,n} t + \varphi_n)$$

$$\omega_{d,n} = \omega_d \cos\alpha_n$$

$$\varphi_n \quad : \quad Uniform\ over\ [0, 2\pi]$$

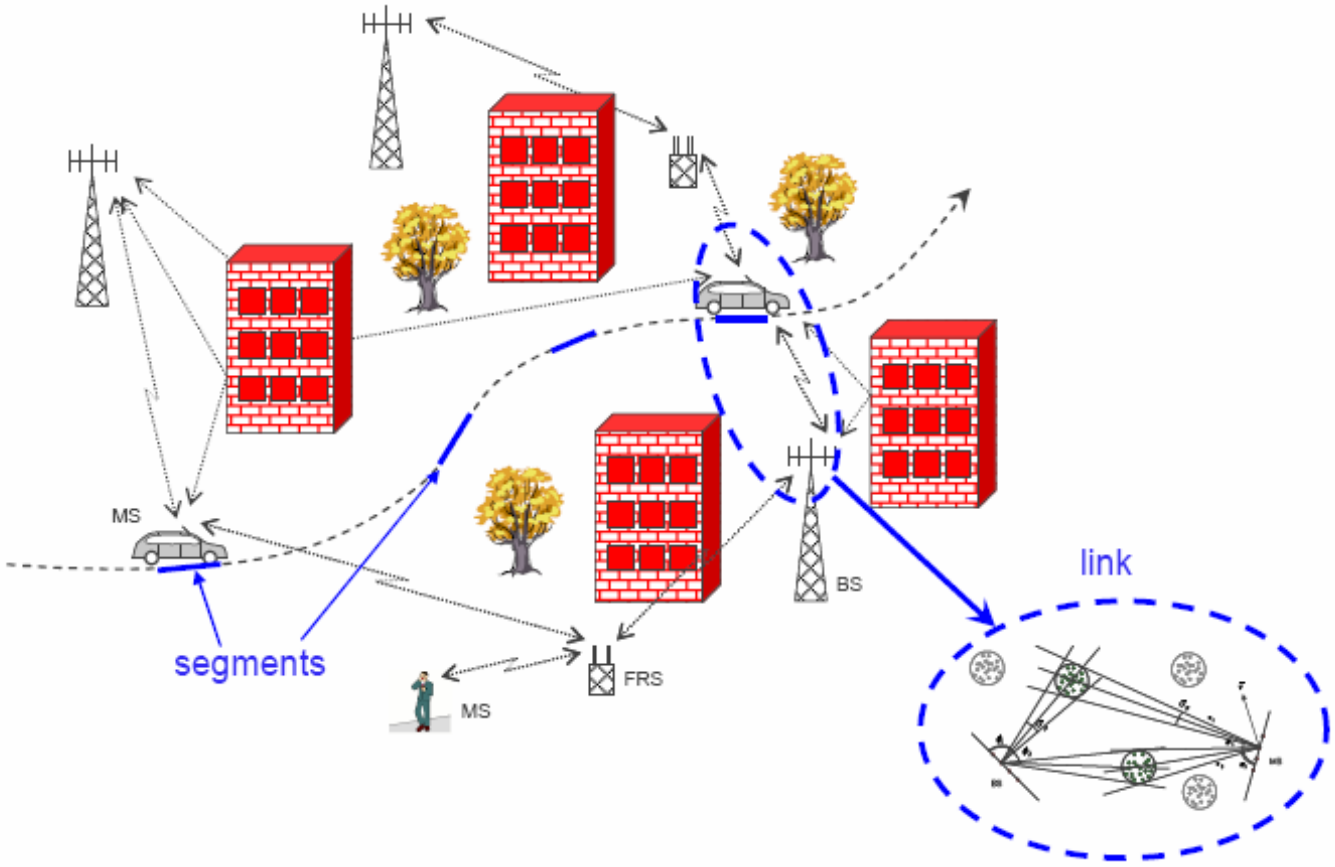
$$\left\langle \sum_{n=1}^{N} C_n^{\,2} = 1 \right\rangle$$

- A sum of horizontally traveling plane waves :
  - random amplitudes, angle of arrivals and phases

- Ez is a Gaussian Random Process
  - by Central Limit Thereom with N -> infinite
  - Colored Gaussian with Doppler Spread ω_d
  - Envelop of Ez follows Rayleigh distribution

“Drop” concept

- System level Approach : Several Drop
  - Drop or Snapshot definition
    - One simulation run over a certain time period
    - In a drop, random properties of the channel remain constant except the fast fading caused by changing phases of the rays, e.g. powers, delays, directions of rays

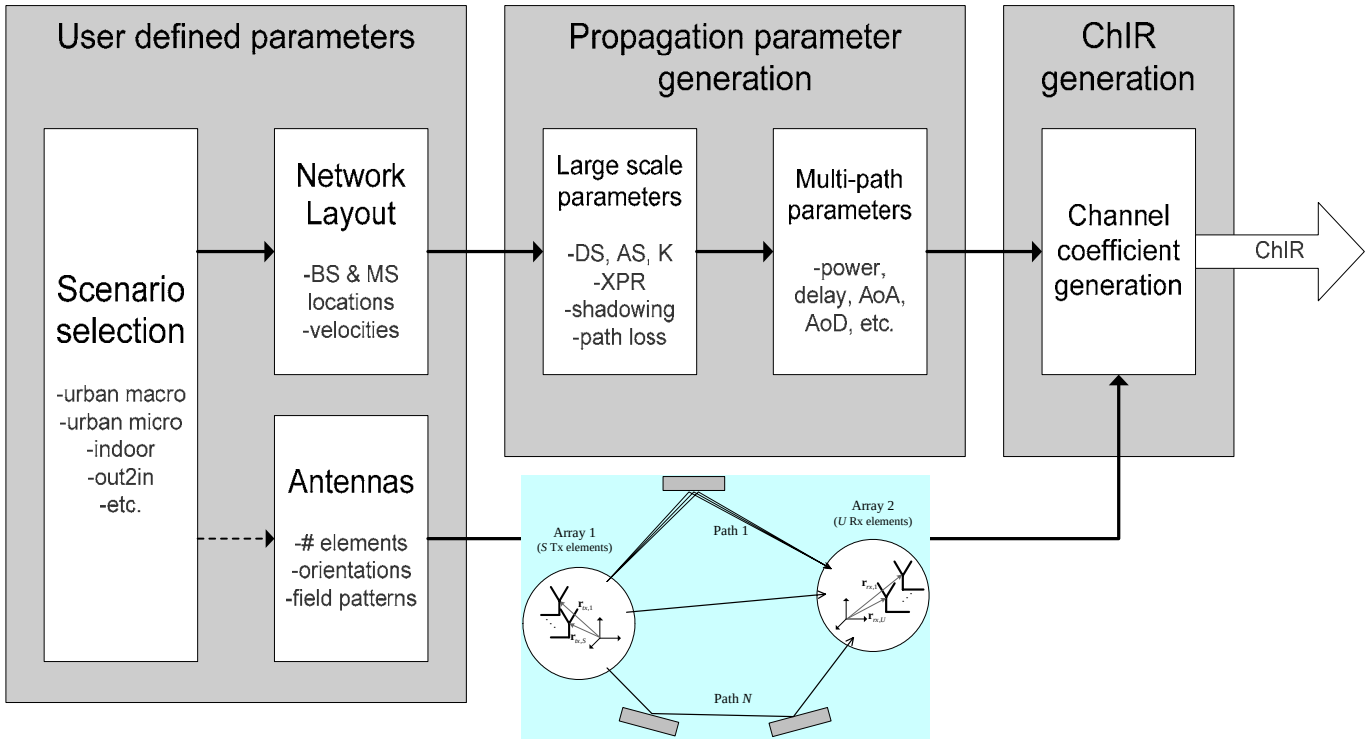


Generic Model

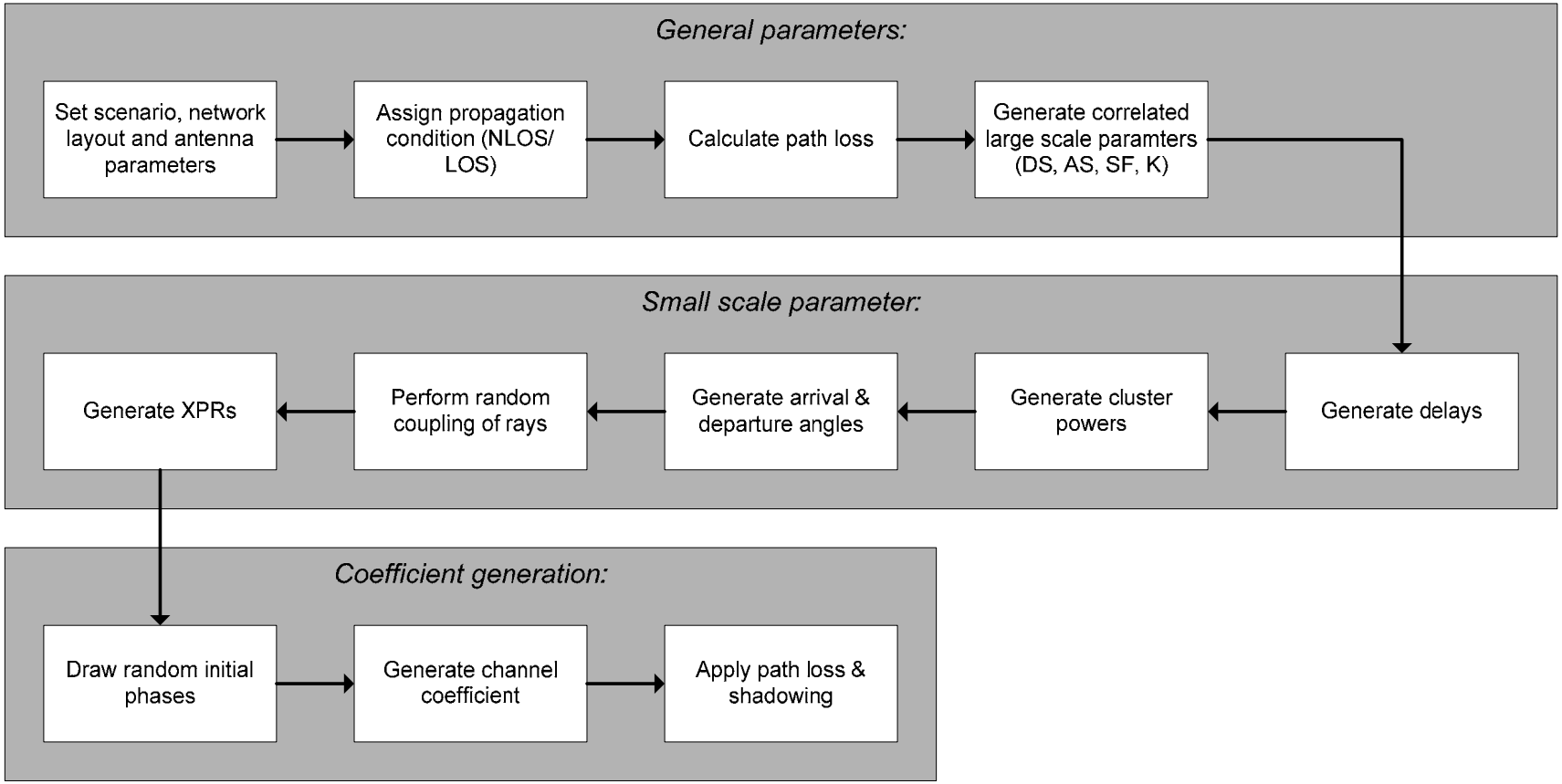
- System level Approach : Several Drops
  - Double-directional geometry-based stochastic model
  - System-level Model, which can describe unlimited number of propagation environment realizations for single or multiple radio links
  - All defined scenarios for arbitrary antenna configurations, with one mathematical framework by different parameter sets
  - A stochastic model with two (or three) levels of randomness
  - At first, large scale (LS) parameters
    - shadow fading, delay and angular spreads are drawn randomly from tabulated distribution functions
  - Secondly, the small scale parameters
    - delays, powers and directions of arrival and departure are drawn randomly according to tabulated distribution functions and random LS parameters (second moments).
  - Once geometric setup is fixed, only free variables are the random initial phases of the scatterers.
    - By picking (randomly) different initial phases, an infinite number of different realizations of the model can be generated.

Generic Model

- Channel model creation process
  - Propagation scenario, network layout and antenna configuration are defined
  - Large-scale and small-scale parameters are defined
  - Channel impulse responses (ChIRs) are calculated



Channel coefficient generation procedu



Channel coefficient generation procedu

General Parameters

- Step 1: Set environment, network layout and antenna array parameters
  - Choose one of the scenarios (A1, A2, B1,...)
  - Give number of BS and MS
  - Give locations of BS and MS, or equally distances of each BS and MS and relative directions φLOS and ϕLOS of each BS and MS
  - Give BS and MS antenna field patterns *Frx* and *Ftx* , and array geometries
  - Give BS and MS array orientations with respect to north (reference) direction
  - Give speed and direction of motion of MS
  - Give system centre frequency

Channel coefficient generation procedu

- Large Scale Parameters

  - Step 2: Assign propagation condition (LOS/NLOS).
  - Step 3: Calculate path loss with formulas of Table 1 for each BS-MS link to be modelled.
  - Step 4: Generate correlated large scale parameters,

    i.e. delay spread, angular spreads, Ricean K-factor and shadow fading term (Correlations between large scale parameters).

Channel coefficient generation procedu

Small Scale Parameters

- Step 5: Generate delays *t*.
  - *Delays are randomly drawn*
  - *Normalise the delays*

$$\tau_n' = -r_\tau \sigma_\tau \log(X_n)$$

$$\tau_n = \mathrm{sort}(\tau_n' - \min(\tau_n'))$$

- Step 6: Generate cluster powers *P*.
  - *assuming a single slope exponential power delay profile*
  - *With exponential delay distribution or uniform delay distribution*

$$P_n' = \exp\left(-\tau_n \frac{r_\tau - 1}{r_\tau \sigma_\tau}\right) \cdot 10^{\frac{-Z_n}{10}}$$

$$P_n' = \exp\left(\frac{-\tau_n}{\sigma_\tau}\right) \cdot 10^{\frac{-Z_n}{10}}$$

  - *Average the power*

$$P_n = \frac{P_n'}{\sum_{n=1}^{N} P_n'}$$

  - *Assign the power of each ray within a cluster as Pn / M*

Small Scale Parameters

Step 7: Generate arrival angles φ and departure angles ϕ.

- *the AoA are determined by applying inverse Gaussian function*
  - *with input parameters Pn and RMS angle spread sφ*

$$\varphi_n' = \frac{2\sigma_{\mathrm{AoA}}\sqrt{-\ln\left(P_n/\max\left(P_n\right)\right)}}{C} \qquad \sigma_{\mathrm{AoA}} = \sigma_\varphi/1.4$$

- *Assign positive or negative sign to the angles*
  - with a random variable *Xn* with uniform distribution to discrete set of {1,–1}
- *add component* $Y_n \sim \mathrm{N}(0, \sigma_{AoA}/5)$ *to introduce random variation*

$$\varphi_n = X_n\varphi_n' + Y_n + \varphi_{LOS}$$

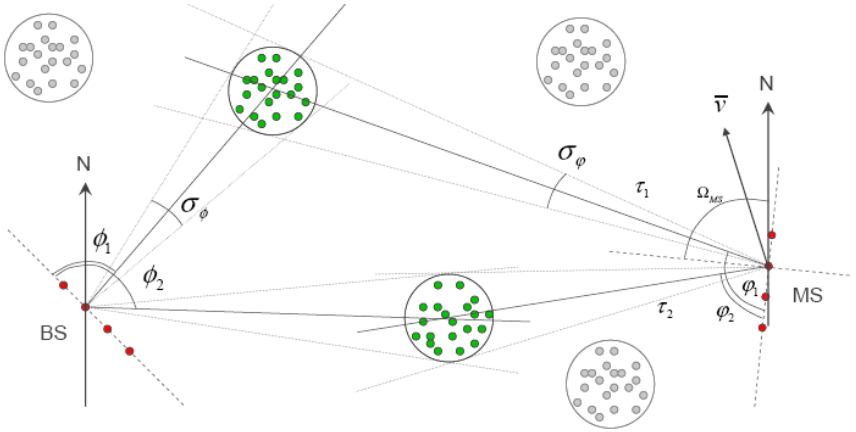
- *add offset angles* α_m *to cluster angles* $\varphi_{n,m} = \varphi_n + c_{AoA}\alpha_m$

Ray offset angles within a cluster, given for 1° rms angle spread.

Ray number *m*	offset angles a_m	Ray number *m*	offset angles a_m
1,2	± 0.0447	11,12	± 0.6797
3,4	± 0.1413	13,14	± 0.8844
5,6	± 0.2492	15,16	± 1.1481
7,8	± 0.3715	17,18	± 1.5195
9,10	± 0.5129	19,20	± 2.1551

Small Scale Parameters

- Step 8: Random coupling of rays within the clusters
  - *Couple randomly departure ray angles $\phi_{n,m}$ to arrival ray angles $\varphi_{n,m}$ within a cluster n*



- Step 9: Generate the cross polarisation power ratios (XPR) *k* for each ray *m* of each cluster *n*.
  - *XPR is log-Normal distributed*

$$\kappa_{m,n} = 10^{X/10}$$

Channel coefficient generation procedu

- Coefficient generation
  - Step 10: Draw random initial phase
    - *Distribution for initial phases is uniform, Uni(-π, π)*
  - Step 11: Generate channel coefficients for each cluster *n* and each receiver and transmitter element pair *u,s*.
    - *For the N – 2 weakest clusters, say n = 3,4,…,N*

$$\mathbf{H}_{u,s,n}(t) = \sqrt{P_n}\sum_{m=1}^{M}\begin{bmatrix} F_{tx,s,V}(\varphi_{n,m}) \\ F_{tx,s,H}(\varphi_{n,m}) \end{bmatrix}^T \begin{bmatrix} \exp(j\Phi_{n,m}^{vv}) & \sqrt{\kappa_{n,m}}\exp(j\Phi_{n,m}^{vh}) \\ \sqrt{\kappa_{n,m}}\exp(j\Phi_{n,m}^{hv}) & \exp(j\Phi_{n,m}^{hh}) \end{bmatrix} \begin{bmatrix} F_{rx,u,V}(\phi_{n,m}) \\ F_{rx,u,H}(\phi_{n,m}) \end{bmatrix} \cdot \exp\left(jd_s 2\pi\lambda_0^{-1}\sin(\phi_{n,m})\right)\exp\left(jd_u 2\pi\lambda_0^{-1}\sin(\varphi_{n,m})\right)\exp(j2\pi\upsilon_{n,m}t)$$

    - *For the two strongest clusters*, say *n* = 1 and 2
      - rays are spread in delay to three sub-clusters (per cluster), with fixed delay offset {0,5,10 ns}

Sub-cluster information for intra cluster delay spread clusters.

sub-cluster #	mapping to rays	power	delay offset
1	1,2,3,4,5,6,7,8,19,20	10/20	0 ns
2	9,10,11,12,17,18	6/20	5 ns
3	13,14,15,16	4/20	10 ns

Channel Model Parameters

Scenarios		A2		B1		C2		D1	
		LOS	NLOS	LOS	NLOS	LOS	NLOS	LOS	NLOS
Delay spread (*DS*) $\log_{10}([s])$	μ	-7.70	-7.41	-7.19	-6.89	-7.03	-6.44	-7.49	-7.43
	σ	0.18	0.14	0.40	0.54	0.66	0.39	0.55	0.48
AoD spread (*ASD*) $\log_{10}([°])$	μ	1.60	1.62	1.20	1.69	1.15	1.41	0.90	0.95
	σ	0.18	0.25	0.43	0.39	0.28	0.28	0.38	0.45
AoA spread (*ASA*) $\log_{10}([°])$	μ	1.62	1.77	1.75	1.88	1.81	1.95	1.52	1.92
	σ	0.22	0.16	0.19	0.20	0.23	0.24	0.24	0.27
Shadow fading (*SF*) [dB]	σ	3	4	3	4	4	6	4	8
K-factor (*K*) [dB]	μ	7	N/A	9	N/A	9	N/A	7	N/A
	σ	4	N/A	5	N/A	3.5	N/A	4	N/A
Cross-Correlations *	σ_{ASD} vs σ_{DS}	0.6	0.4	0.5	0.3	0.4	0.4	-0.1	-0.4
	σ_{ASA} vs σ_{DS}	0.8	0.3	0.8	0.4	0.8	0.6	0.2	0.1
	σ_{ASA} vs σ_{SF}	-0.5	-0.4	-0.4	-0.4	-0.5	-0.3	-0.2	0.1
	σ_{ASD} vs σ_{SF}	-0.4	-0.1	-0.5	-0.1	-0.5	-0.6	0.2	0.6
	σ_{DS} vs σ_{SF}	-0.8	-0.5	-0.4	-0.7	-0.4	-0.4	-0.5	-0.5
	σ_{ASD} vs σ_{ASA}	0.4	-0.1	0.4	0.1	0.3	0.4	-0.3	-0.2
	ASD vs *K*	-0.3	N/A	-0.3	N/A	0.1	N/A	0	N/A
	ASA vs *K*	-0.3	N/A	-0.3	N/A	-0.2	N/A	0.1	N/A
	DS vs *K*	-0.5	N/A	-0.7	N/A	-0.4	N/A	0	N/A
	SF vs *K*	0.5	N/A	0.5	N/A	0.3	N/A	0	N/A

Channel Model Parameters

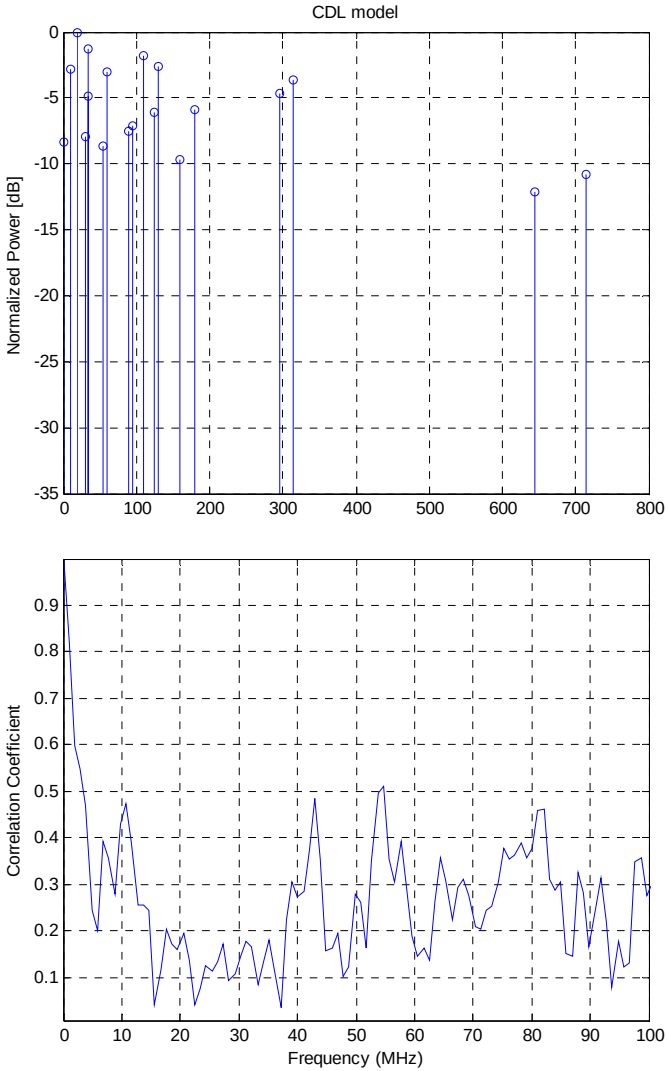
Scenarios		A2		B1		C2		D1	
		LOS	NLOS	LOS	NLOS	LOS	NLOS	LOS	NLOS
Delay distribution		Exp	Exp	Exp	Uniform ≤800ns	Exp	Exp	Exp	Exp
AoD and AoA distribution		Laplacian		Wrapped Gaussian		Wrapped Gaussian		Wrapped Gaussian	
Delay scaling parameter r_τ		3.6	3	3.2	—	2.5	2.3	3.8	1.7
XPR [dB]	μ	11	10	9	8.0	8	7	12	7
	σ	4	4	3	3	4	3	8	4
Number of clusters		15	19	12	19	12	20	11	10
Number of rays per cluster		20	20	20	20	20	20	20	20
Cluster *ASD*		5	5	3	10	5	2	2	2
Cluster *ASA*		8	11	17	22	11	15	3	3
Per cluster shadowing std z [dB]		6	3	3	3	3	3	3	3
Correlation distance [m]	*DS*	8	5	7	10	30	40	50	36
	ASD	7	3	8	10	18	50	25	30
	ASA	5	3	8	9	15	50	35	40
	SF	10	6	10	13	37	50	37	120
	K	4	N/A	15	N/A	12	N/A	40	N/A

Reduced Variability Models (Optional)

- channel model can be simplified (approximated) to reduce the simulation complexity.
  - ① by assuming no correlation between large scale parameters (angular spreads, delay spread, shadowing)
  - ② By fixing all the large scale parameters to median values.
  - ③ by fixing the delays, but keep angles as random
  - ④ by freezing all propagation parameters to obtain so called Clustered Delay Line (CDL) model

- CDL model
  - A spatial extension of tapped delay line (TDL) models
  - The CDL approach fixes all the parameters, except the phases of the rays.

Best Fit Selection



Cluster #	Delay [ns]	Power [dB]	AoD [°]	AoA [°]
1	0	-8.34	-100	119
2	10	-2.77	87	-54
3	20	0	-9	2
4	30	-7.93	75	-114
5	35	-4.83	72	84
6	35	-1.29	85	-42
7	55	-8.60	82	103
8	60	-3.00	71	-82
9	90	-7.49	-90	-126
10	95	-7.09	90	105
11	110	-1.79	156	-50
12	125	-6.12	64	113
13	130	-2.64	57	-56
14	160	-9.66	-99	116
15	180	-5.84	88	99
16	295	-4.70	76	96
17	315	-3.62	50	73
18	645	-12.10	-118	144
19	715	-10.80	-94	-153

Parameter	Statistics	CDL model
Delay Spread [nsec]	127	125
AoD Spread [deg]	62	63
AoA Spread [deg]	76	76

Contents

- Intro : ITU-R WP5D Activities
- IMT-Advanced Channel Model
  - As of 1st meeting of WP5D (2008. 1, Geneve)
- The ETRI Channel Model Research
  - BECS2006 Overview
  - Measurement Campaign
  - Spatial Channel Analysis
  - A part of ETRI Channel Model for IMT-Advanced

MIMO Channel Characterization

MIMO channel characteristics

- Multipath ⇨ Power delay profile
- Time variant ⇨ Doppler spectrum
- Directional ⇨ Angular power profile
- Polarizing ⇨ Polarization matrix

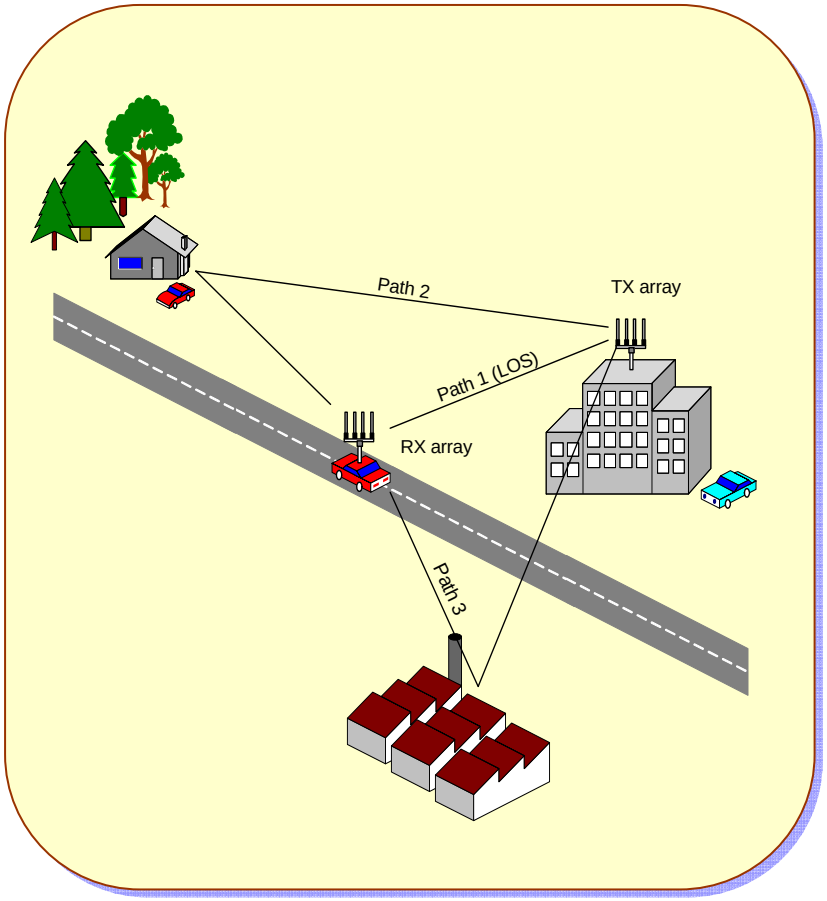
Assumptions

- Far field: plane waves received
- Specular reflections: no diffuse scattering

Each wave (path) can be described by

- Excess delay (with respect to line of sight)
- \+ Doppler shift
- \+ Arrival/Departure angle (azimuth/elevation)
- \+ Complex fading coefficient
- \+ Polarization state

How to obtain these parameters?

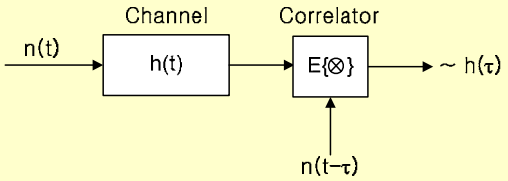


First, measure the channel:
Channel Sounding

PN Channel Sounding

- Channel impulse response (IR) can be obtained by feeding the channel with white noise $n(t)$ rather than an impulse $\delta(t)$

To see this, cross-correlate the channel output with n(t)



$$R_n(\tau) = E\left\{\left[n(t) * h(t)\right] n^*(t-\tau)\right\} = \underbrace{N_0}_{\text{Power spectral density of } n(t)} h(\tau)$$

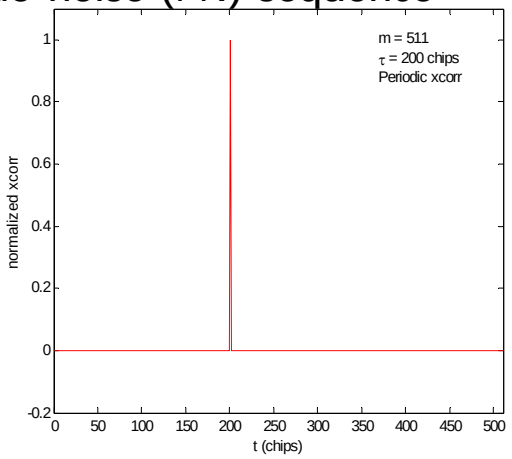
⇨ **Output of correlator is proportional to channel impulse response**

- In practice, white noise can be replaced by pseudo-noise (PN) sequence

Why?

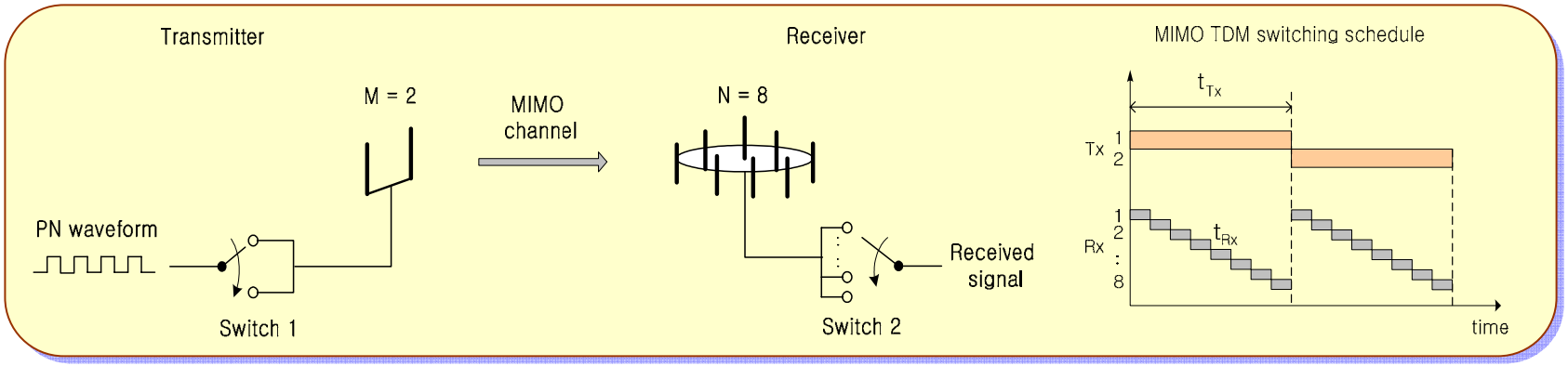
Because PN sequences have near-perfect autocorrelation properties

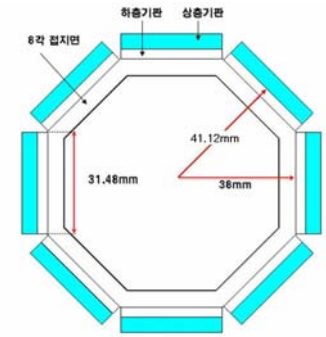
m = 511
delay = 200 chips



Time-Multiplexed MIMO Channel Sounding

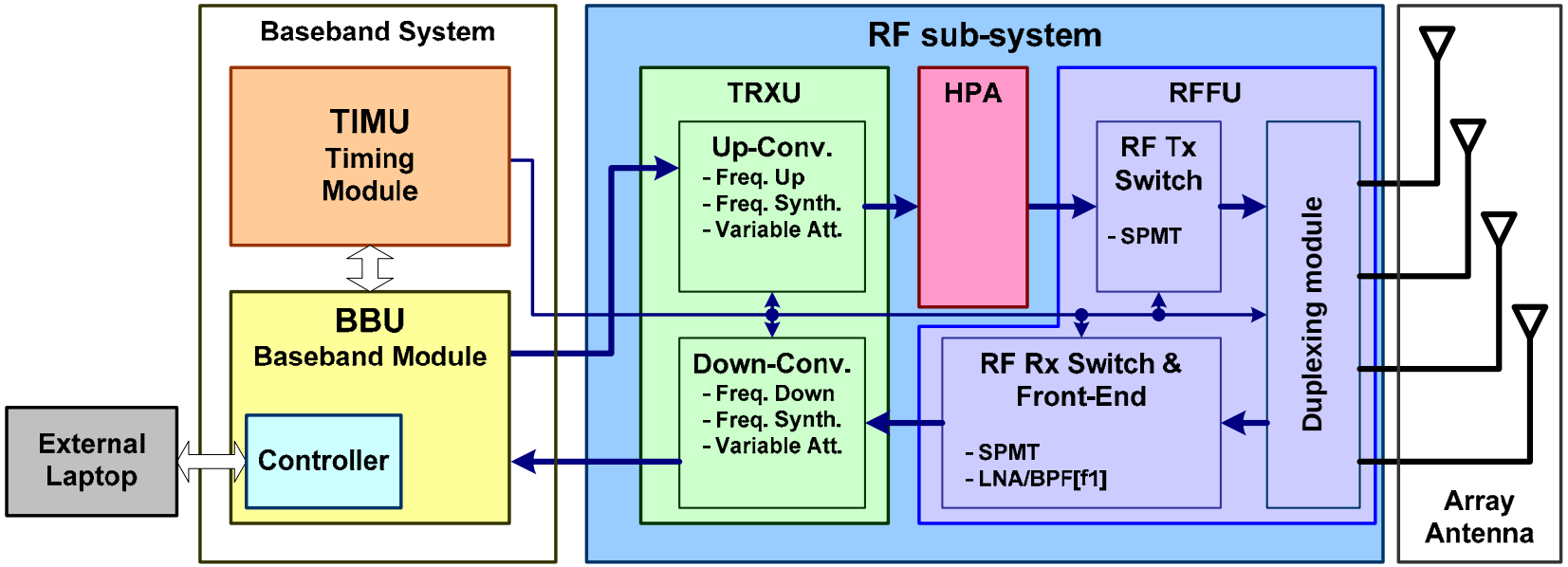
- MIMO Sounding : time-division multiplexed (TDM) fashion
  - Measure each TX-RX antenna pair of a MxN MIMO configuration in succession, e.g.





I-1. BECS2006 Overview

- BECS2006 System Block Diagram



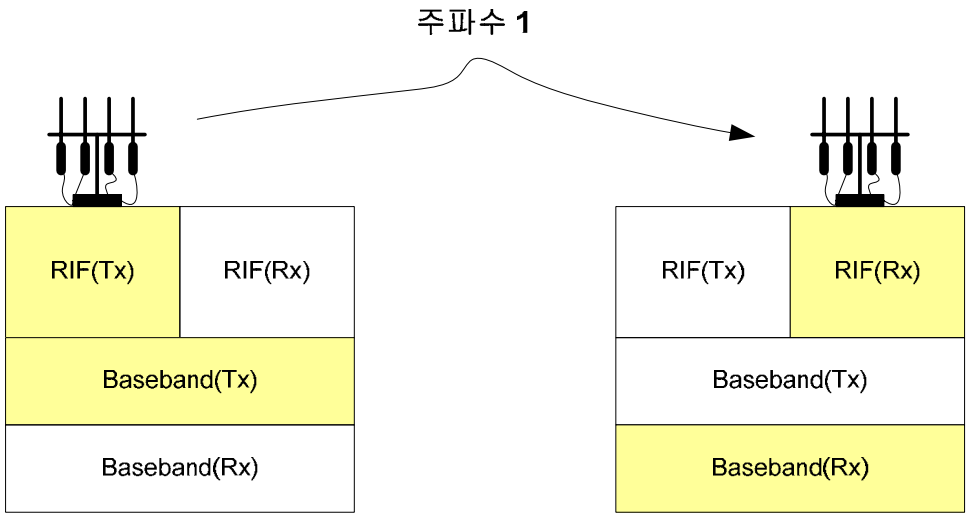
- Major Points
  - System Mode: Simplex mode(conversion for Tx/RX mode by using a system)
  - Bandwidth: Scalable Bandwidth(100/40/20/10/5 MHz)
  - MIMO Antenna: Tx Antenna(max. 8), Rx Antenna(max. 8)
  - Acquisition mode: Snap-shot mode, Burst mode

I-1. BECS2006 Overview

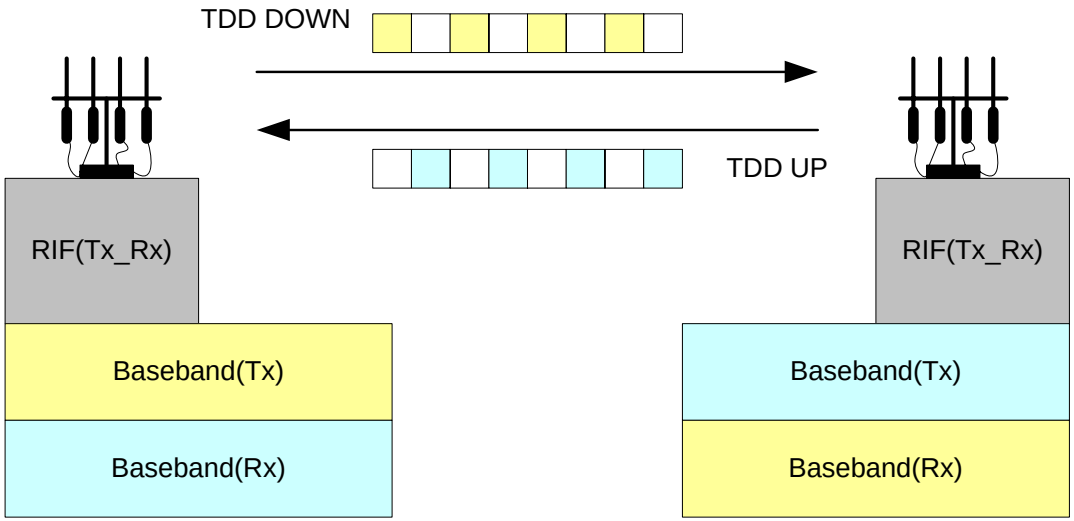
- Requirements for BECS2006

Item	Unit	Value	Remarks
Frequency	**GHz**	**5.15 ~ 5.35**	
Bandwidth	**MHz**	**100/40/20/10/5**	**Variable bandwidth**
Chip rate	**Mcps**	**100**	**Maximum chip-rate**
PN Length	**chips**	**31 ~ 4095**	**31, 63, 127, 511, 1023, 2048, 4095**
Number of Tx Antenna	**EA**	**8**	**Maximum**
Number of Rx Antenna	**EA**	**8**	**Maximum**
Rx ADC sampling	**MSa/s**	**400**	
Rx ADC resolution	**bits**	**12**	
Rx ADC memory	**Gsa**	**2**	**4GByte(2 Byte = 12 bit = 1 sample)**
Tx Output Power	**dBm**	**+35**	**3W**
Tx Attenuation range	**dB**	**30**	**0.5dB step**
Rx Attenuation range	**dB**	**60**	**0.5dB step**
Rx Max. input power	**dBm**	**-40**	
Receiver NF	**dB**	**7.5**	
Multi-path resolution	**nsec**	**10**	**Minimum resolution**

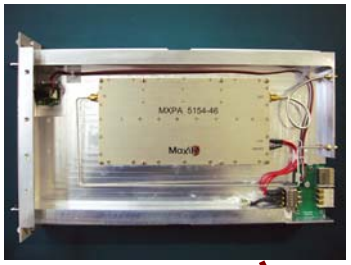
- Simplex Mode
  - One way transmission and one way receive structure
  - One way channel measurement
  - Possible conversion of Tx/Rx mode by a system
  - Portable Tx/Rx system
    - Transmission from BS to MS
    - Transmission from MS to MS



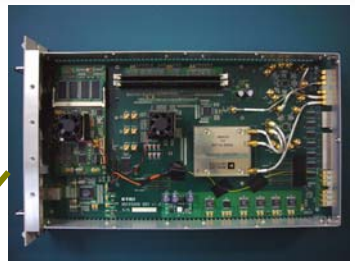
- TDD Mode
  - 이중 송신, 이중 수신 구조로서 동일 주파수 대역에서 양방향 채널 측정을 동시에 수행
  - Duplexer를 이용한 단일 RF 구조 설계
  - 양방향 채널 측정을 위한 기지국/이동국간 TDD 동기 획득
    - TDD timing parameter 설정을 통한 송/수신 time 조정 가능



I-1. BECS2006 Overview

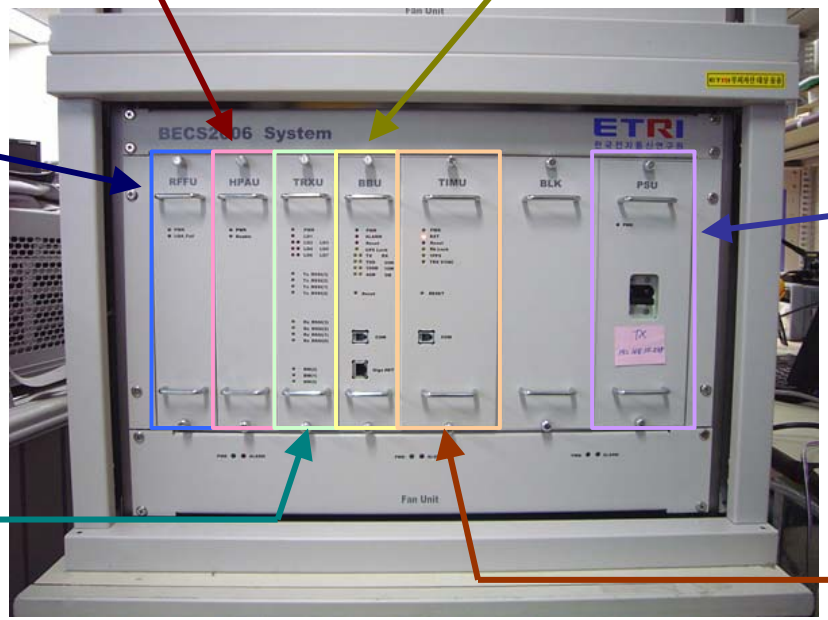


HPAU : High power amplification

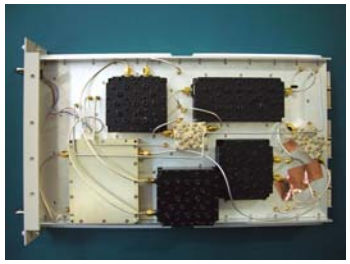


BBU : High-speed D/A & A/D, baseband signal processing

RFFU : Support for two way communication, multiple antennas

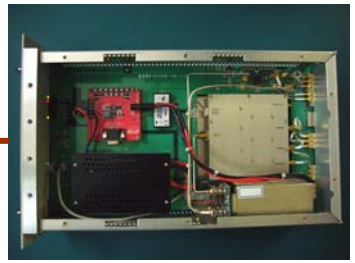


PSU : Power supply for modules



TRXU : Support for frequency conversion, variable gain function

BECS2006 System Hardware



TIMU : Tx/Rx timing

II-1. Measurement Scenario

Measurement Environment

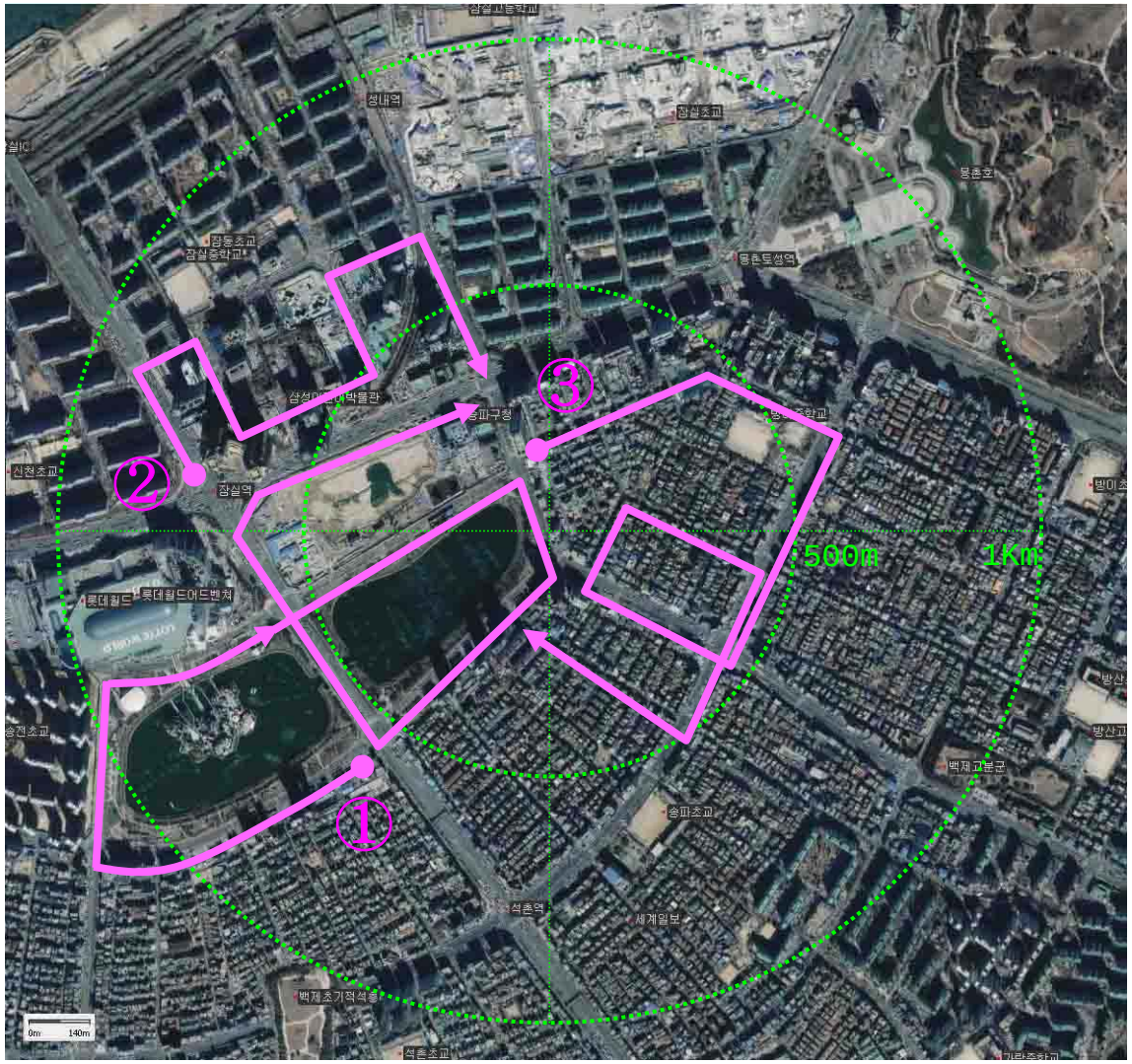
- Measurement using BECS2005 / BECS2006
- Garak, Daechi, Bangi, Gaepo, Munjung and Geoyeo-dong in Seoul city
- Urban Macrocell Scenario
  - The height of BS is higher than average height of building
  - BS selection standing for Korea metropolis

Measurement Cases

측정 시나리오	수신안테나 형태	수신안테나 간격	1 DAQ 당 Frame 수	송수신 방식	수신차량 운행속도
Case 1	Linear	0.5 λ	1	SIMO	~ 30 Km/h
Case 2	Linear	2 λ	1	SIMO	~ 30 Km/h
Case 3	Linear	0.5 λ	1	MIMO	~ 10 Km/h
Case 4	Linear	2 λ	1	MIMO	~ 10 Km/h
Case 5	Circular	-	1	SIMO	~ 30 Km/h
Case 6	Circular	-	10	SIMO	~ 30 Km/h
Case 7	Circular	-	20	SIMO	~ 30 Km/h

II-1. Measurement Scenario

Bangi Base Station



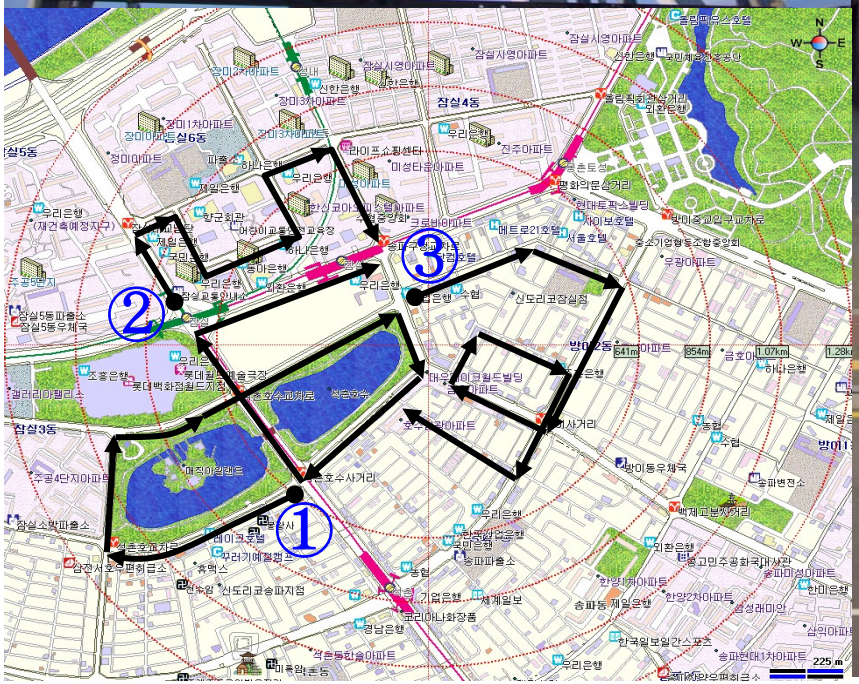
BS name	Bangi
BS height	72.22 (m)
Average height	39.24 (m)

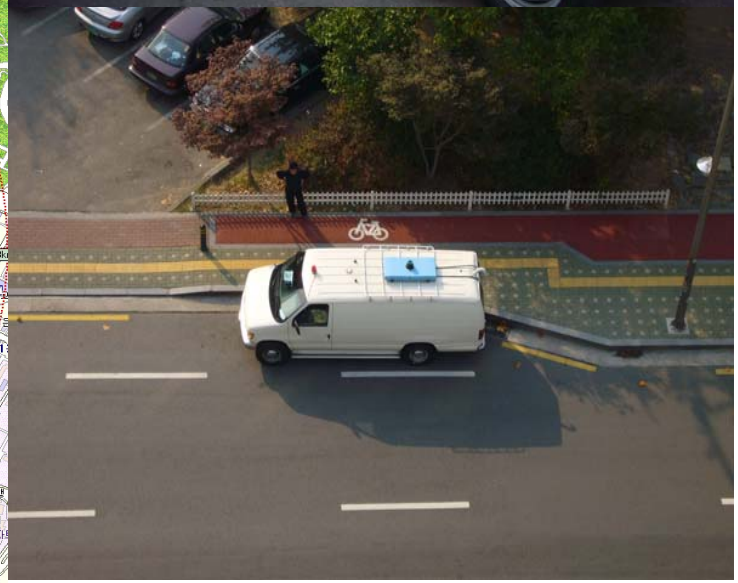
<Building heights within radius 1km>

Height(m)	Count	Per (m)
10	-	-
20	257	6.45 %
30	2789	70.01 %
40	786	19.72 %
50	86	2.17 %
60	25	0.65 %
70	9	0.24 %
80	14	0.36 %
90	3	0.09 %
100	15	0.41%
합 계	3984	100 %

II-2. Measurement Data Base

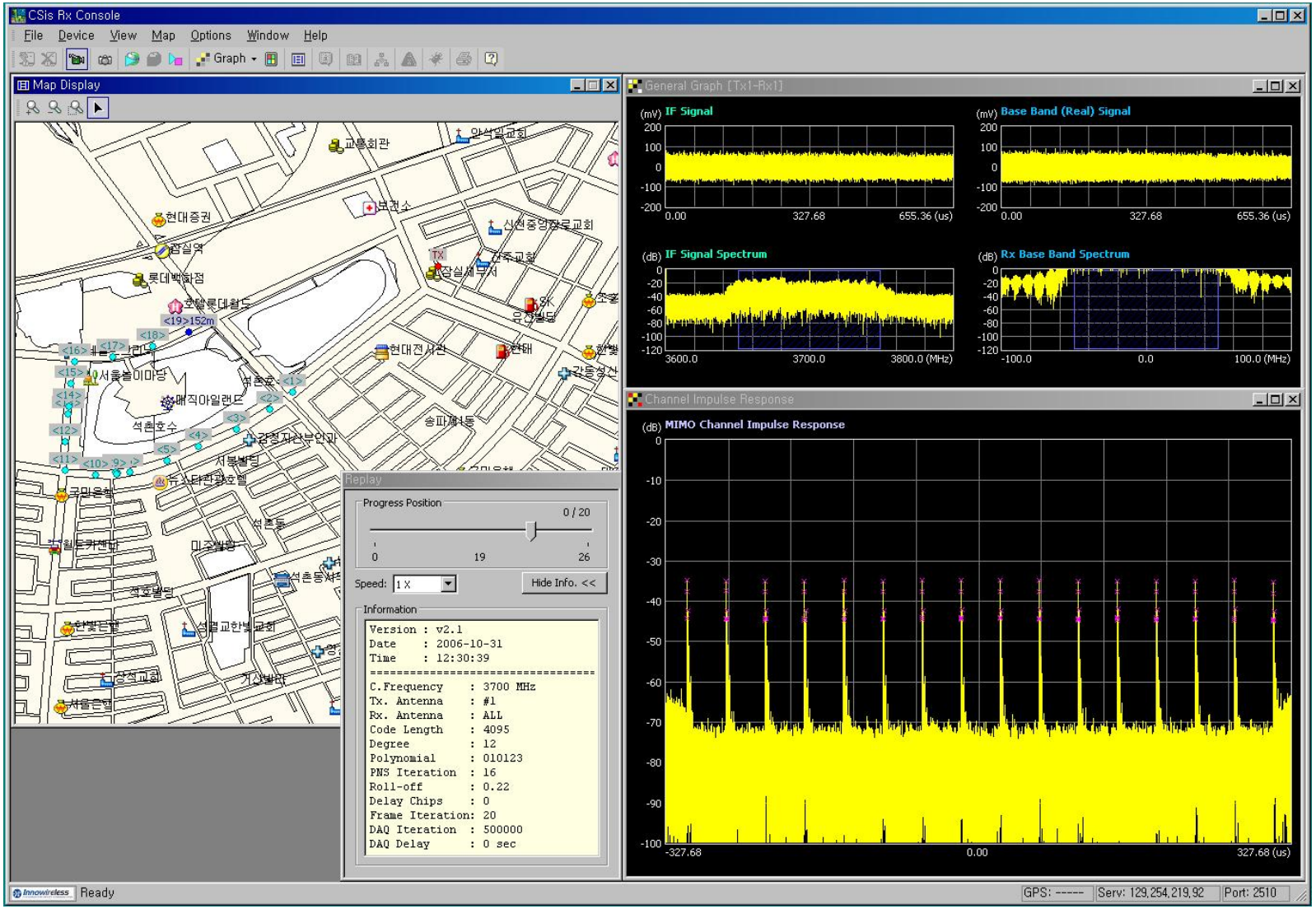
Measurement Campaign





II-2. Measurement Data Base

- Replay and GIS Mapping



II-2. Measurement Data Base

Measurement Campaign (3.7 GHz)

- Movie of measurement

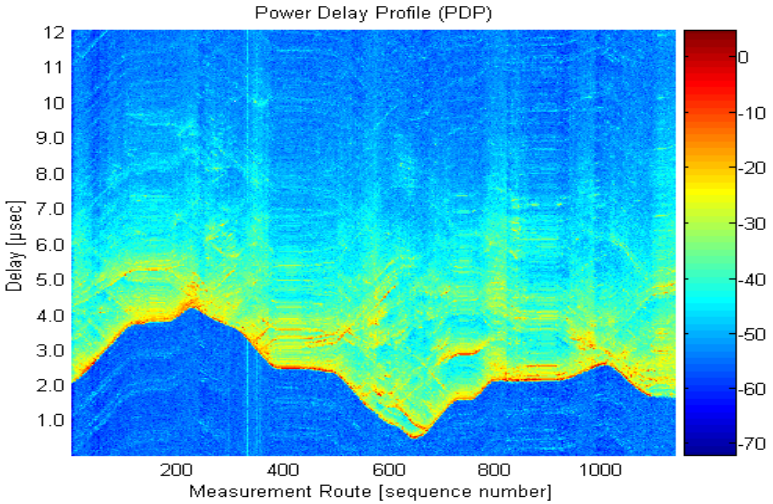
- Measurement Environment
  - Frequency : 3.7 GHz
  - Bandwidth :100 MHz
  - Scenario : Urban Macrocell
  - Area : Daechi (dense building area)
  - Route : LOS
  - Antenna type : SIMO, Circular antenna

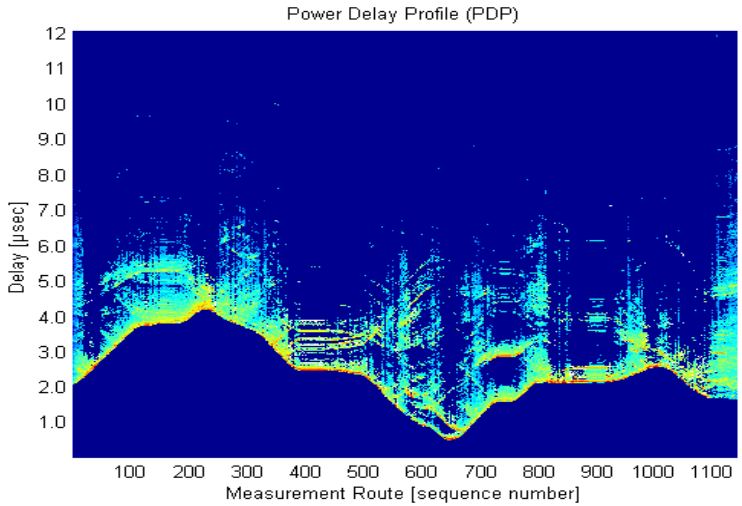
II-2. Post-Processing S/W 개발

- 공간채널 파라미터 정의
  - 기존 채널모델의 채널 파라미터
    - **시간 영역**: Path Loss, Delay Spread, Power Delay Profile(PDP), multipath **수**, Fading **등**
    - **공간 영역**: DoA, DoD, Power Azimuth Spectrum(PAS)
    - **주파수 영역**: Doppler spread
    - MIMO **적용**: **송/수신안테나간 상관계수**
    - Link-level **및** System-level **파라미터로 구분** (SCM, WINNER)
  - **상용시스템의 채널 파라미터** (Electrobit社 PROPSound)
    - **시간, 공간영역의 채널 파라미터 위주**
  - **연구 결과**
    - **기존 채널모델의 채널 파라미터를 사용**
    - MIMO **성능 검증을 위한 파라미터 추가**: **수신안테나간 상관계수**, MIMO Capacity

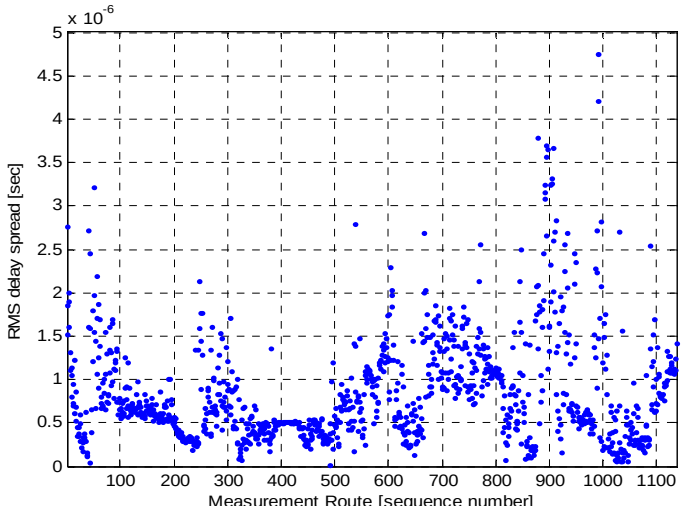
III-1. Bangi Measurement Analysis

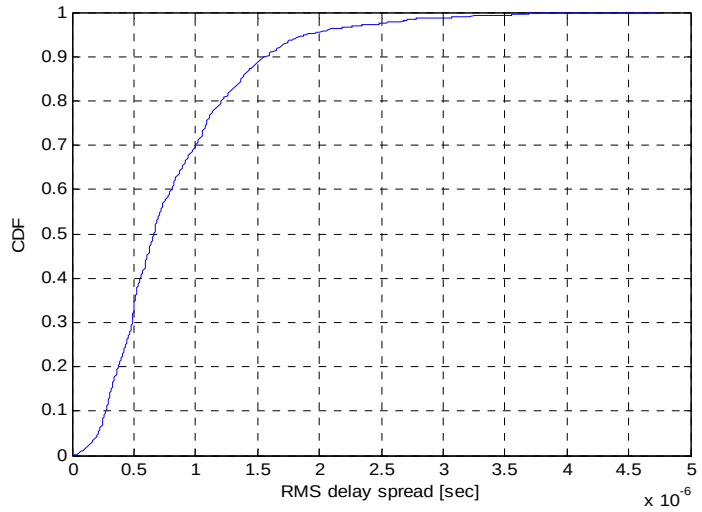
- Uniform Circular Array, Route 1 of 1x8 system
  - Power Delay Profile





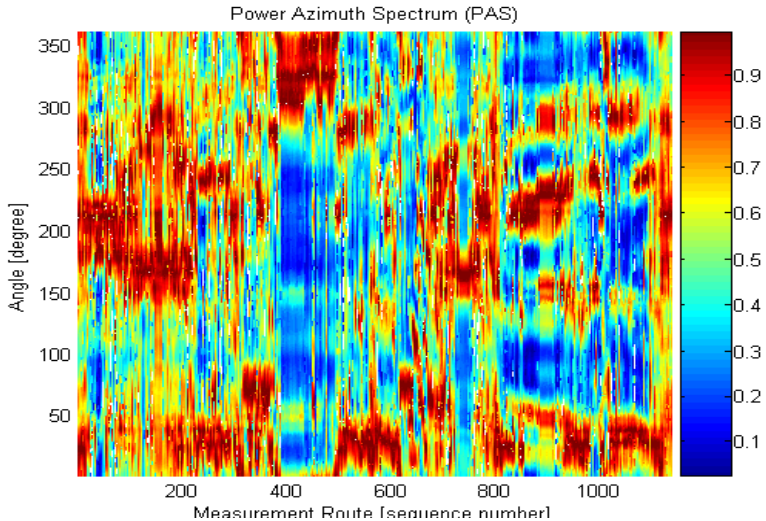
  - RMS delay spread

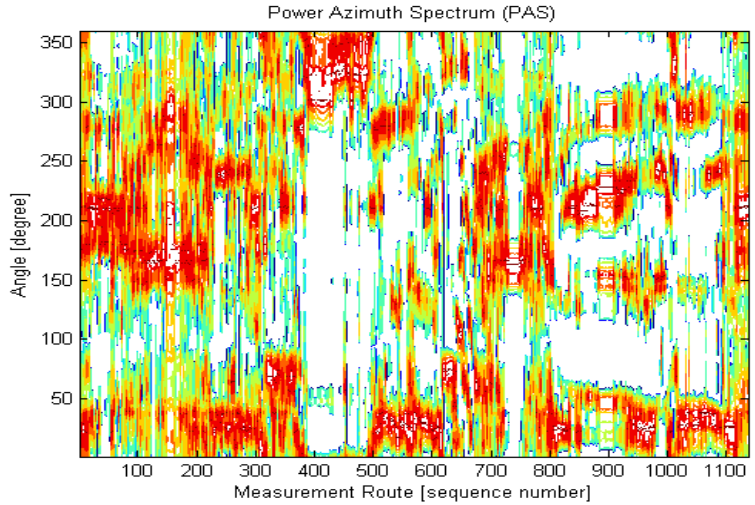




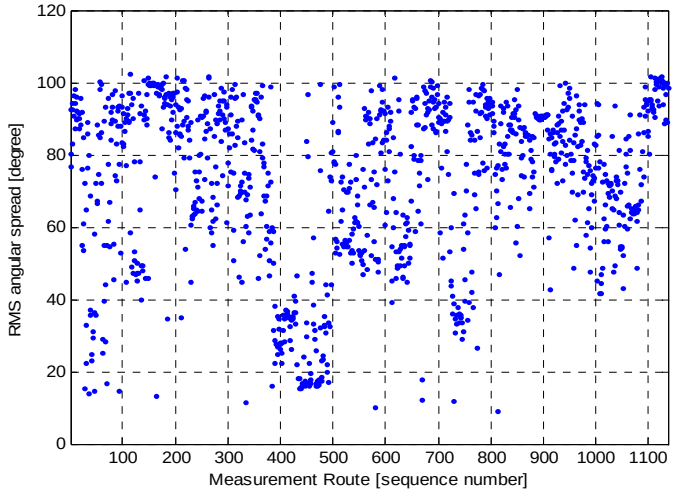
III-1. Bangi Measurement Analysis

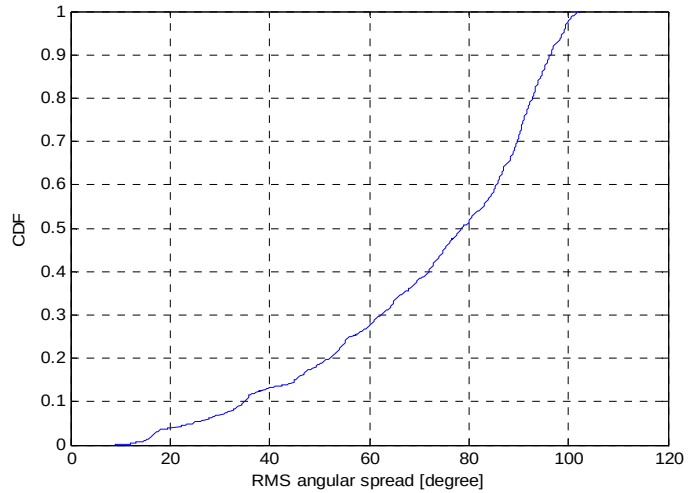
- Uniform Circular Array, Route 1 of 1x8 system
  - Power Azimuth Spectrum





  - RMS angular spread

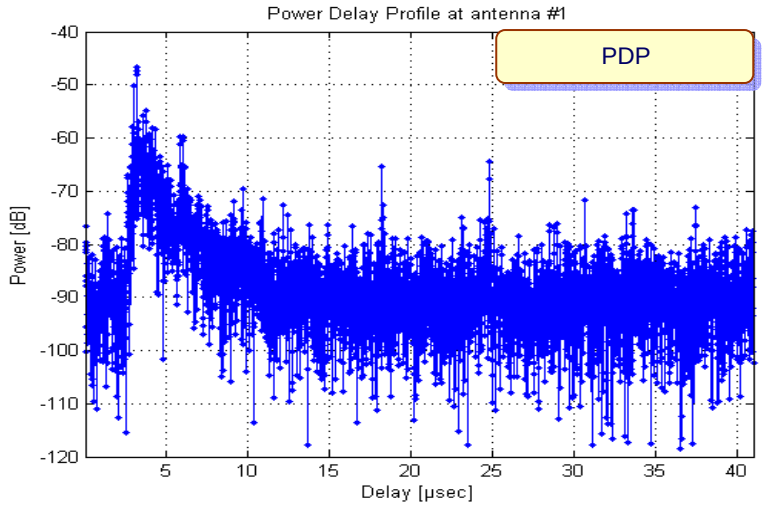




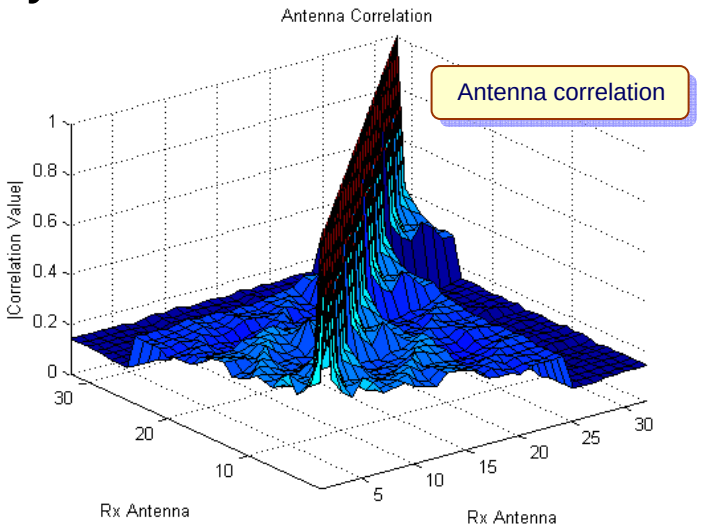
III-1. Bangi Measurement Analysis

- Uniform Linear Array, Route 1 of 4x8 system

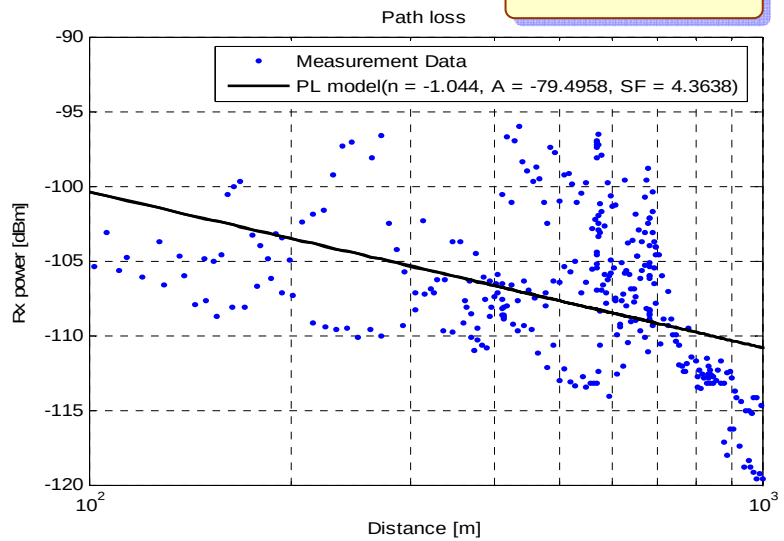
PDP



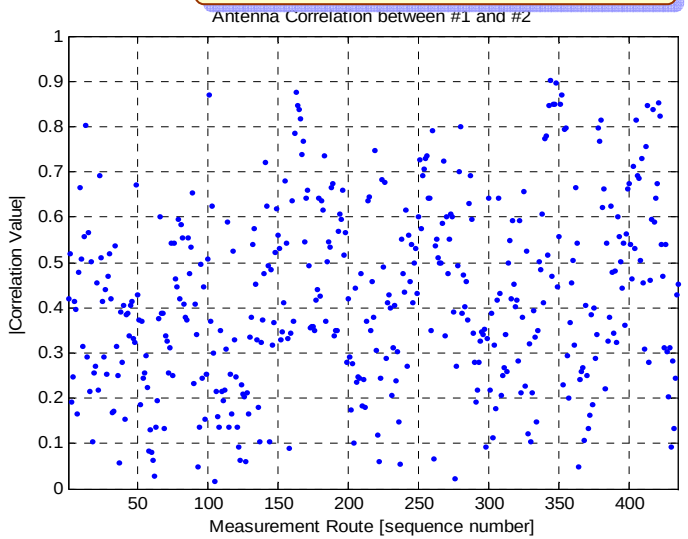
Antenna correlation



Path loss

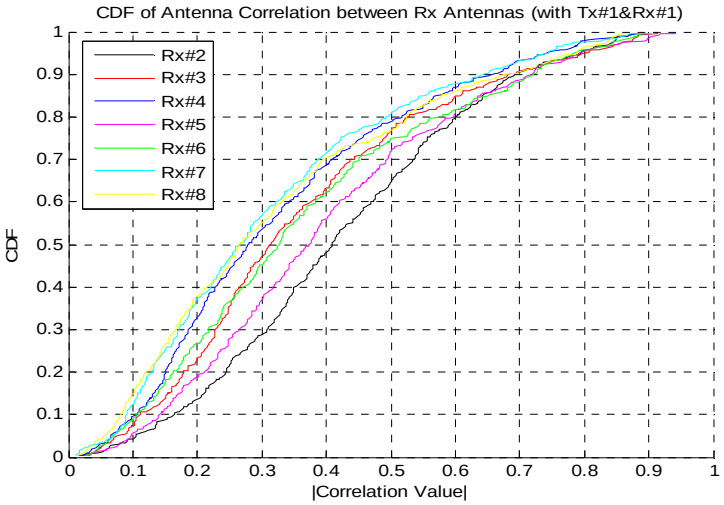


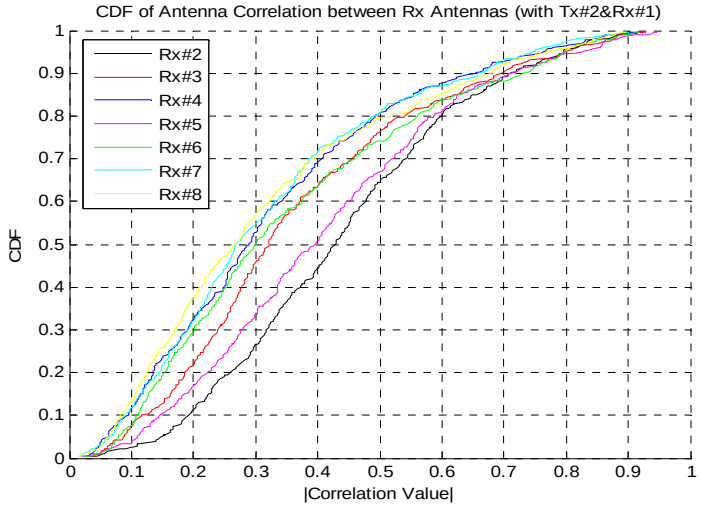
Antenna correlation between Rx 1 and 2

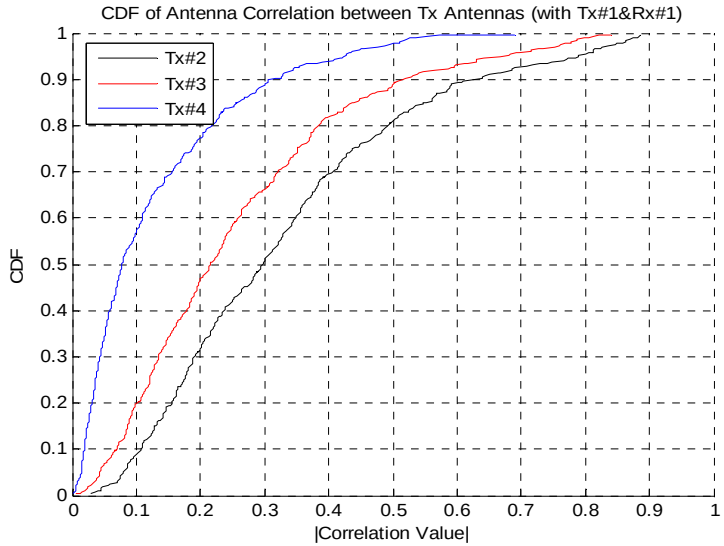


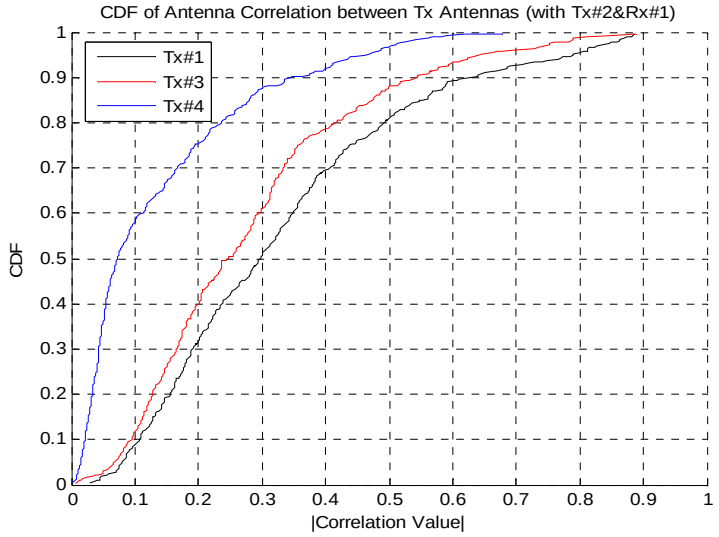
III-1. Bangi Measurement Analysis

- Uniform Linear Array, Route 1 of 4x8 system
  - Antenna correlations









Measurement Site Information

- 3.7 GHz, 100 MHz BW
- B1 (Urban Micro) scenario

	Site Name	BS Height [m]	Avg. Building Height [m] (500m)	Δh [m] (h_{BS}- h_{build})	Building Density [%] (500m)
B1	Yeoksam	15.4	13.16	2.24	39.47
	Kildong	16.2	10.96	5.24	37.51
	Chunho	10.1	10.54	-0.44	44.51

- C2 (Urban Macro) scenario

	Site Name	BS Height [m]	Avg. Building Height [m] (1Km)	Δh [m] (h_{BS}- h_{build})	Building Density [%] (1Km)
C2	Garak	24.4	13.23	11.17	26.37
	Munjeong	30	12.89	17.11	24.12
	Samsun	27.7	7.12	8.2	36.17
	Pungnab	28.9	10.96	20	29.4
	Shinchon	30.8	8.4	18.92	35.86

Comparison of parameters

B1 (Urban Micro) scenario

Parameter	WINNER II Final	ETRI
B1 LOS Delay spread[nsec]	36	115
B1 LOS Delay Scaling parameter ($r\tau$)	3.2	2.0
B1 NLOS Delay spread[nsec]	76	215
B1 NLOS Delay Scaling parameter ($r\tau$)	-	1.47
B1 LOS AoD spread [deg]	3	76
B1 NLOS AoD spread [deg]	15	63
B1 LOS AoA spread [deg]	25	69
B1 NLOS AoA spread [deg]	35	75

C2 (Urban Macro) scenario

Parameter	WINNER II Final	ETRI
C2 LOS Delay spread [nsec]	41	194
C2 LOS Delay Scaling parameter ($r\tau$)	2.5	2.05
C2 NLOS Delay spread [nsec]	234	300
C2 NLOS Delay Scaling parameter ($r\tau$)	2.3	1.42
C2 LOS AoD spread [deg]	10	49
C2 NLOS AoD spread [deg]	8	53
C2 LOS AoA spread [deg]	50	73
C2 NLOS AoA spread [deg]	53	82

Concluding Remarks

- ITU-R WP5D
  - IMT-Advanced RIT Report / recommendation under progress
- IMT-Advanced Channel Model
  - WINNER II-based “geometry based stochastic model”
  - Single Framework with different profile depending on scenarios
  - Simplification issues remained
- ETRI Research Activities
  - Identifying propagation characteristics showing differences between Eastern vs. Western
    - Suggest separate profile for B1 & C2 scenario to ITU
    - Provide measurement-based parameters for baseband research

[Reference]

- [1] ITU-R Document 5D/TEMP/46-E, WORKING DOCUMENT TOWARDS PROPOSED DRAFT NEW [REPORT/RECOMMENDATION] [GUIDELINES FOR EVALUATION OF RADIO INTERFACE TECHNOLOGIES FOR IMT-ADVANCED]
- [2] ITU-R Document 5D/TEMP/28-E, DRAFT [REPORT ON] REQUIREMENTS RELATED TO TECHNIC AL SYSTEM PERFORMANCE FOR IMT-ADVANCED RADIO INTERFACE(S) [IMT.TECH]
- [3] IST-WINNER II Deliverable D1.1.2 v1.0, “WINNER II Channel Models”, September, 2007.
- [4] 3GPP, “TR 25.996, spatial channel model for Multiple Input Multiple Output (MIMO) simulations”, Tech. Rep., 2003.
- [5] ITU-R Document 5D/40-E, PROPOSAL ON CHANNEL MODEL PARAMETER SETS FOR URBAN MICRO & MACRO SCENARIO BASED ON MEASUREMENT CAMPAIGNS (Rep. of Korea)
- [6] WWRF research forum, WG4 & WG5 Paper, chap 4.3 “INTERIM MEASUREMENT RESULTS AT 3.7 GHz IN URBAN MACROCELL IN KOREA”.
- [7] Jae Joon Park, Won Sop Kim, Myung Don Kim, Hyun Kyu Chung , “Measurement Results at 3.7 GHz in Urban Macrocell Environment”, IEEE VTC(Vehicular Technology Conference) 2007 Fall, Baltimore.
- [8] Won Sop Kim, Jae Joon Park, Myung Don Kim, Hyun Kyu Chung , “Time-Division Multiplexing based MIMO Channel Sounder using Loosely Synchronous Codes”, IEEE VTC(Vehicular Technology Conference) 2007 Fall, Baltimore.

www.etri.re.kr