Study on the next generation ITS radio communication in Japan

Contents

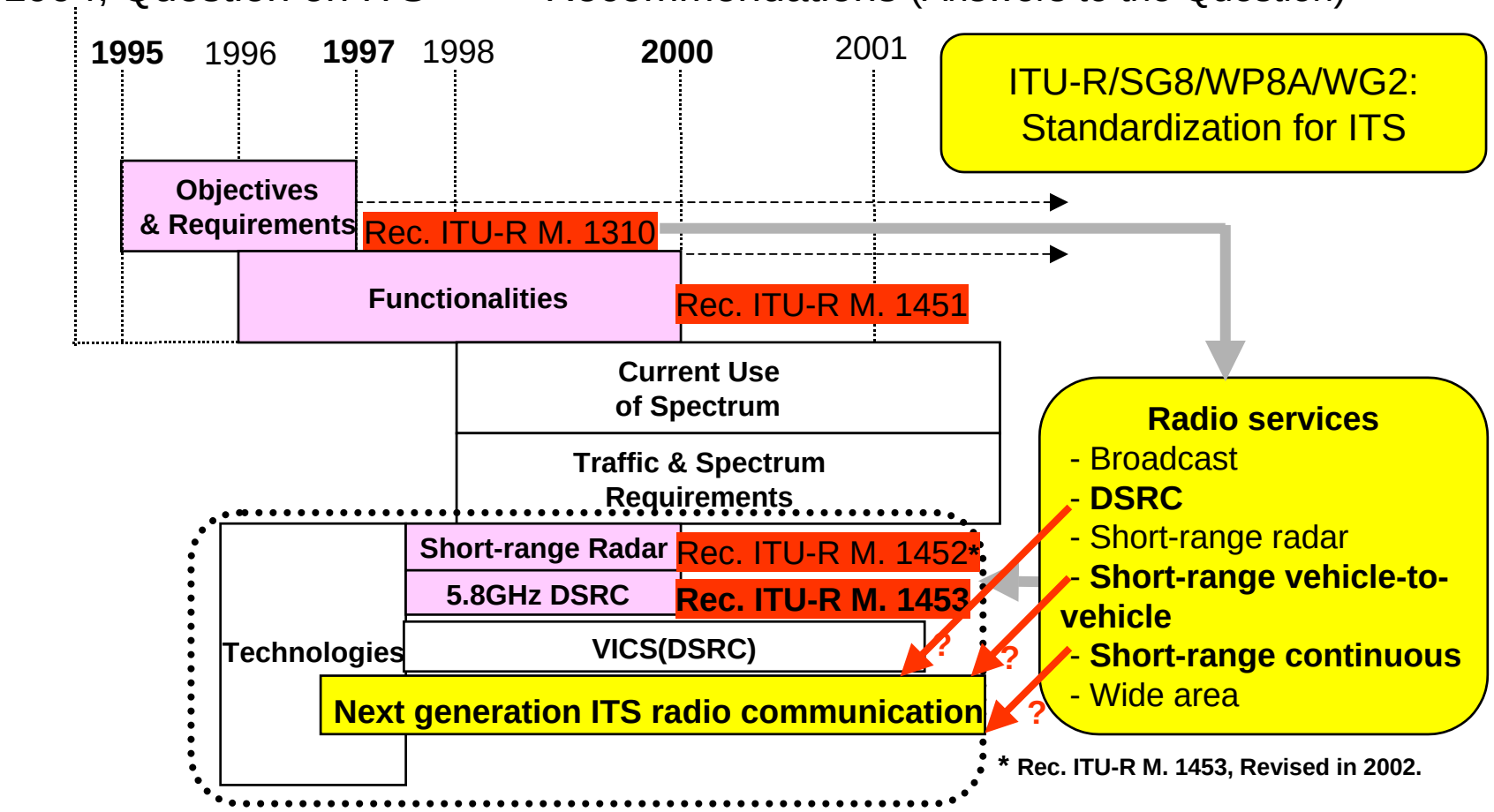
Sep.4 2003 ***DSRC International Task Force, Japan***

1.1 Regional standards of DSRC

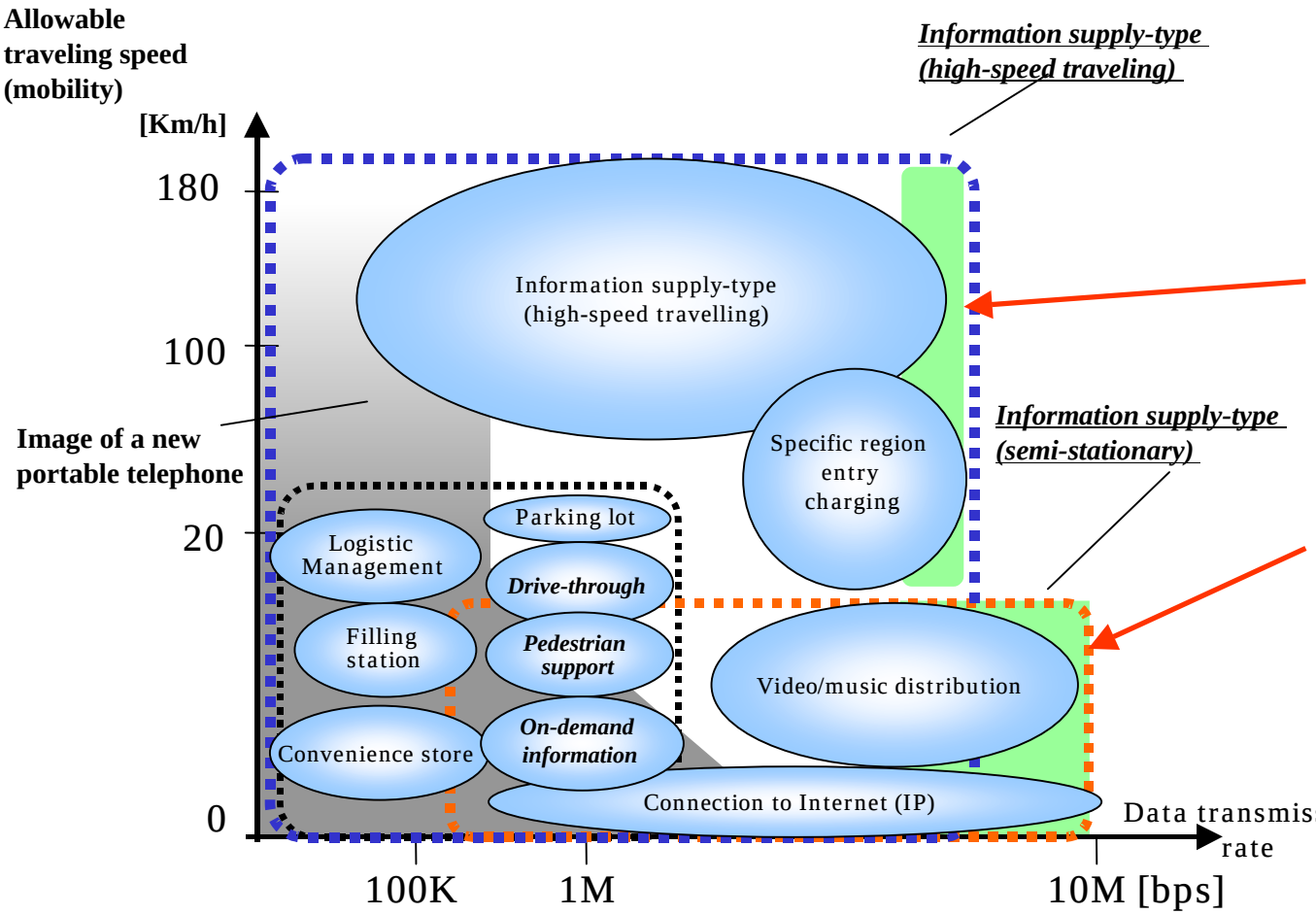
Item	Europe (CEN)	North America (ASTM)	Japan (ARIB STD-T75)
Radio frequency band	5.8GHz	5.8 - 5.9GHz	5.8GHz
Communication system	Passive	Active	Active
Data transmission rate	Downlink:500kbps Uplink :250kbps	Down/Uplink: 3 - 27Mbps	Down/Uplink: 1 or 4 Mbps
Duplex	Half-duplex	Half-duplex	Half-duplex(OBU) Full-duplex (RSU)

2.1 ITS Standardization in ITU-R
"What is the next generation ITS radio communication?"

1994, Question on ITS → Recommendations (Answers to the Question)



2.2 Data transmission rate requirement for the next generation ITS radio communication



ARIB STD-T75 generally satisfies the requirement except for the very small area shown below.

- high data rate high-speed traveling;

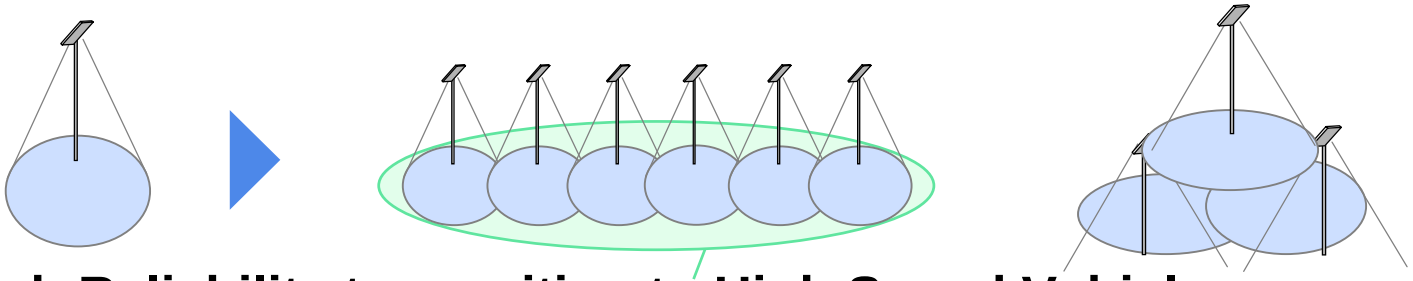
Continuous communication

- Very high data rate semi-stationary;

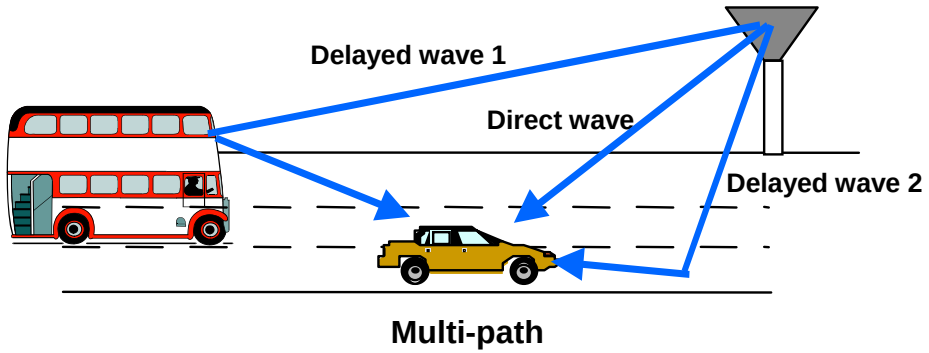
Broadband ITS Radiocommunication (Resolution RAST 10/7)

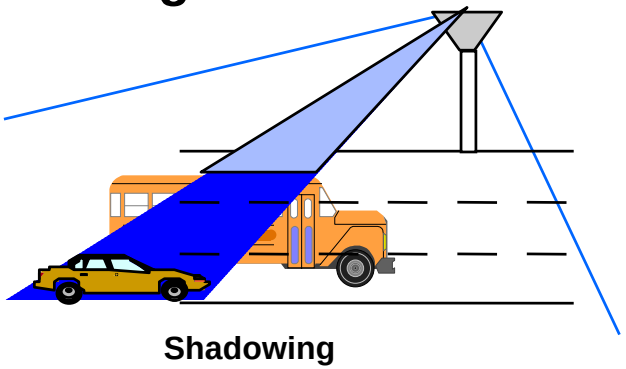
2.3 Technical Requirement for the next generation ITS Radio Communication

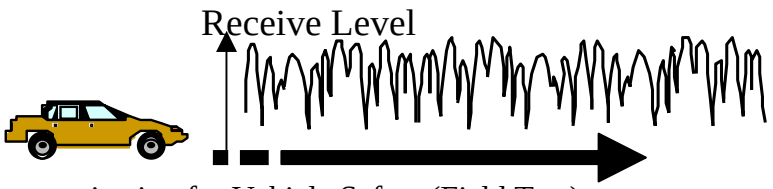
1. **Area Extension : Spot Area ⇒Continuous or Wide Area**



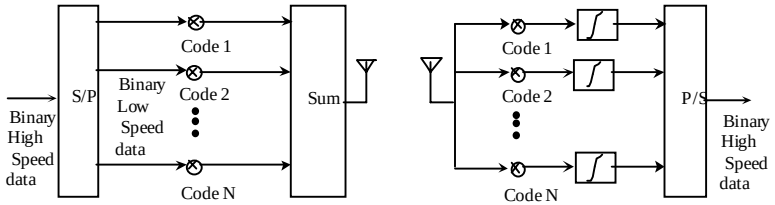
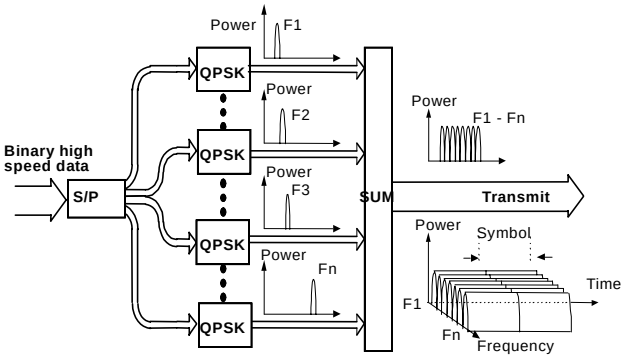
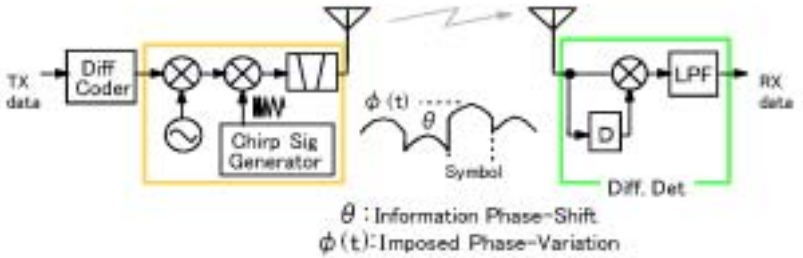
2. **High Reliability transmition to High Speed Vehicle in multi-path or/and Shadowing Situation**





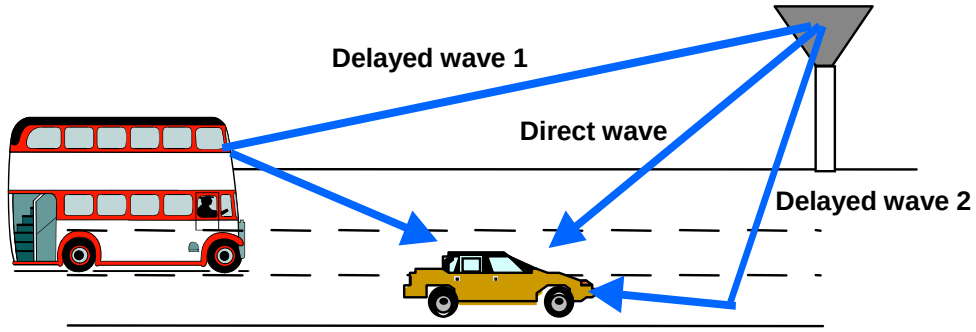


3.1 Development status in ARIB* for the next generation ITS radio communication

Technology		Status	Overview of the system
CDM (Code Division Multiplexing)		Under Study	
OFDM (Orthogonal Frequency Division Multiplexing)	802.11a	Under Study	
	Developped OFDM	Demonstration Finished	
PSK-VP (Phase Shift Keying with Varied Phase)		Demonstration Finished	

* The road-vehicle communications technology group in the study group for "Efficient Use of the Radio Spectrum for ITS"

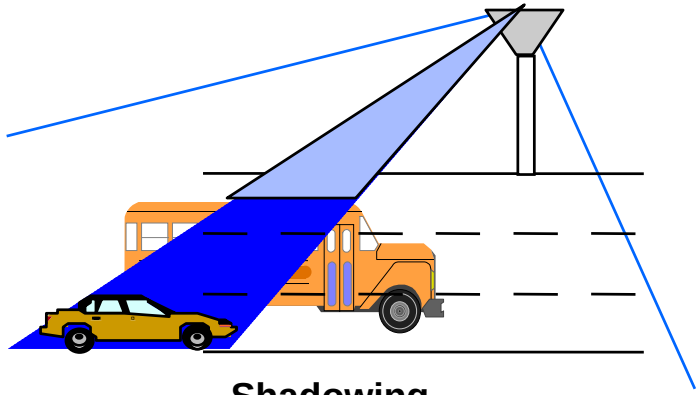
3.2 Countermeasures to Multi-path fading



Multi-path fading

Available Technology	Features
CDM	- RAKE / Path-Diversity - Low Inter-Symbol Interference (Low symbol rate)
OFDM	- Low Inter-symbol Interference (Low symbol rate) - Guard interval to reduce Inter Symbol and Inter Carrier Interference
PSK-VP	- Implicit RAKE / Path-Diversity

3.3 Countermeasures to Shadowing

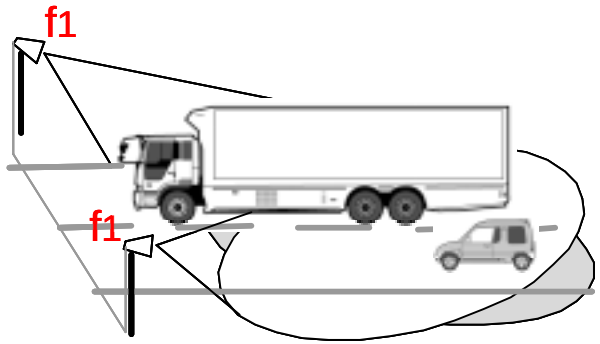


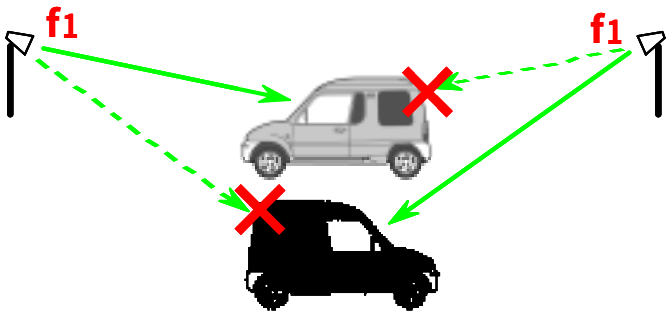
Shadowing

Technologies to realize reception from multiple antennas

Available Technology	Features
CDM	RAKE / Path-Diversity*
Developped OFDM	Guard interval to reduce Inter Symbol Interference / Path-Diversity*
PSK-VP	Implicit RAKE / Path-Diversity*

* ; Features to achieve continuous communication

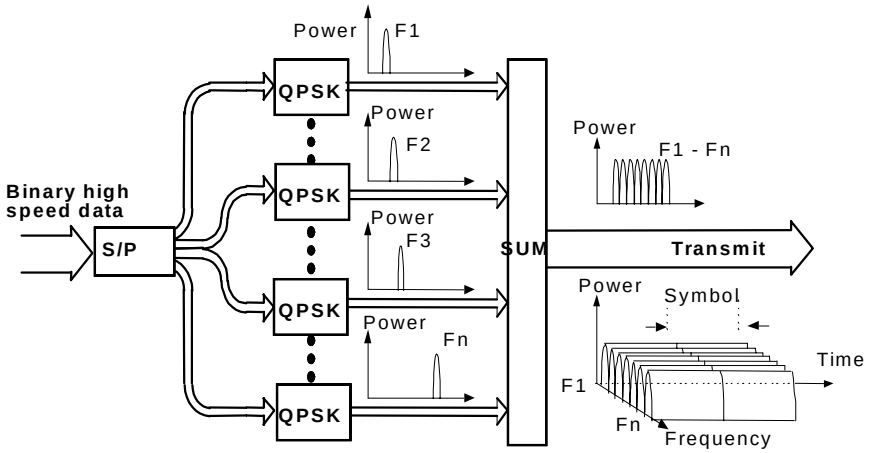




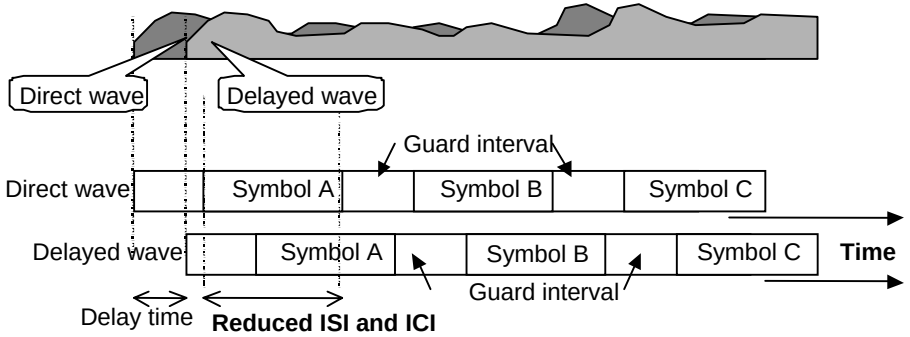
Avoidance of shadowing by reception from multiple Antennas

4. Modulation scheme and features of OFDM

- Concept of OFDM modulation scheme



- Anti-Multipath mechanism of OFDM



Features of OFDM

- Robustness against frequency selective fading (Narrow subcarrier)

- High spectrum efficiency (Minimum carrier frequency spacing)

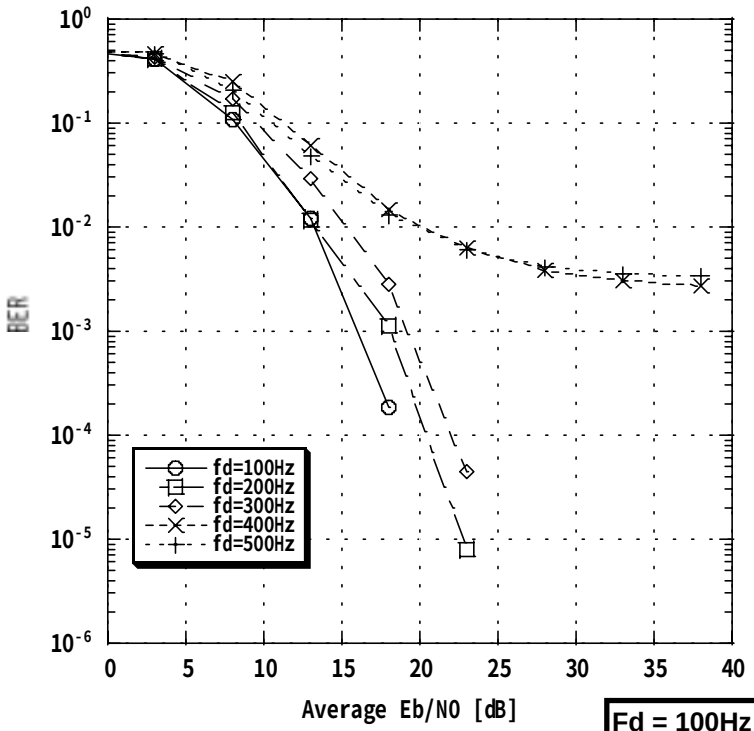
- Low Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI): (Provision of Guard Interval)

4.1 Specification of 802.11a based OFDM

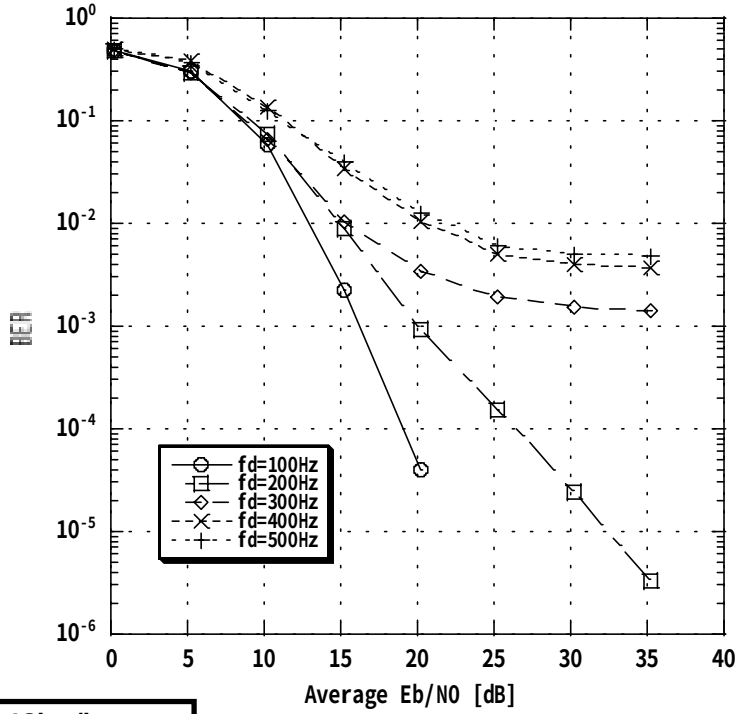
Item		802.11a	802.11a/RA
Std. Body		IEEE	ASTM
Freq. Band		5 GHz band 5.15–5.35 GHz 5.725–5.825 GHz	5.9 GHz band 5.850-5.925 GHz
Com. Range*		100m(typ) ex. 35m(54Mbps) 200m(6Mbps)	1,000m
Modulation		OFDM	OFDM
No of channels		12 ch	7 ch
Channel separation		20 MHz	10 MHz
Data rate		6 - 54 Mbps	3 - 27 Mbps
Vehicle speed		(Stationary)	200 km/h ?
Others	Spectrum mask	-	Severe than 11a
	TxPWR_level	1 - 8	1 - 64
	Adjacent ch Rej	-	Severe than 11a

* depends on environment condition and data rate.

4.1.1 BER Simulation Results for 802.11a (Line Of Site model ,16QAM)



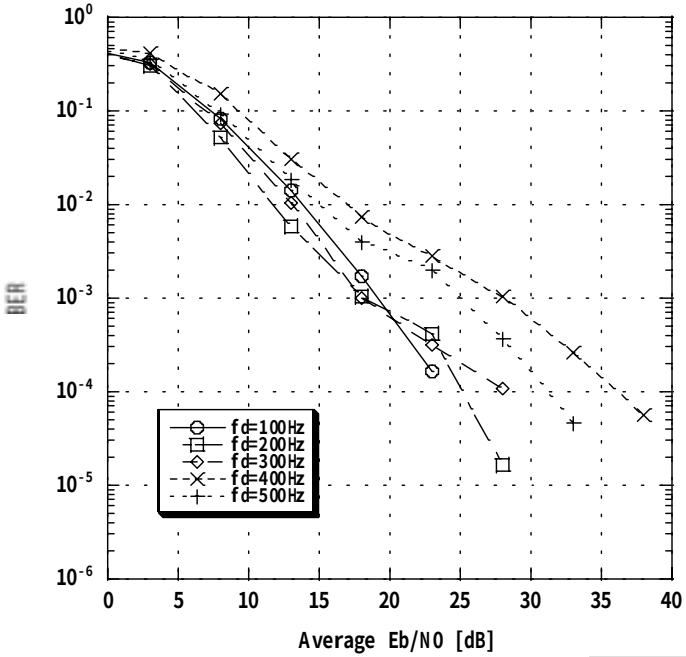
Rice K=5dB

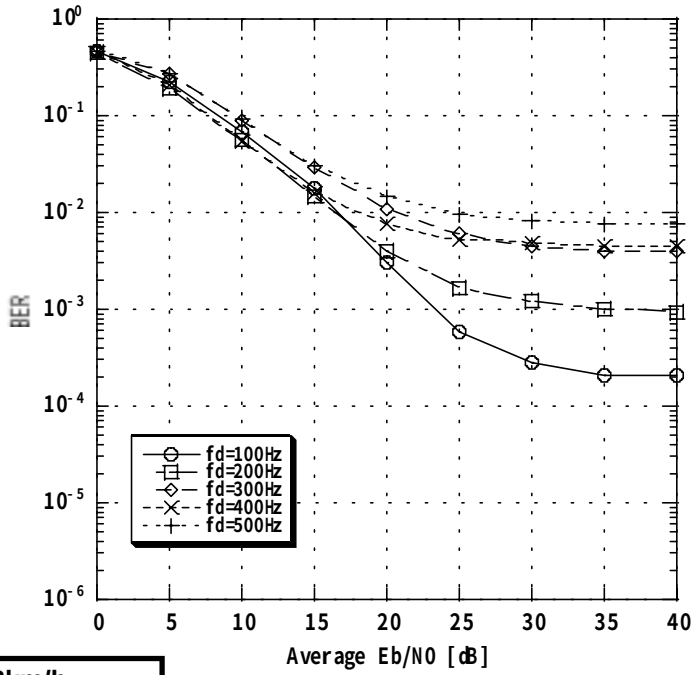


Delay Spread :10ns

Fd = 100Hz	**: 18km/h**
Fd = 200He	**:36km/h**
Fd = 300Hz	**:54km/h**
Fd = 400Hz	**:72km/h**
Fd = 500Hz	**:90km/h**

4.1.2 BER Simulation Results for 802.11a (Line Of Site model ,QPSK)



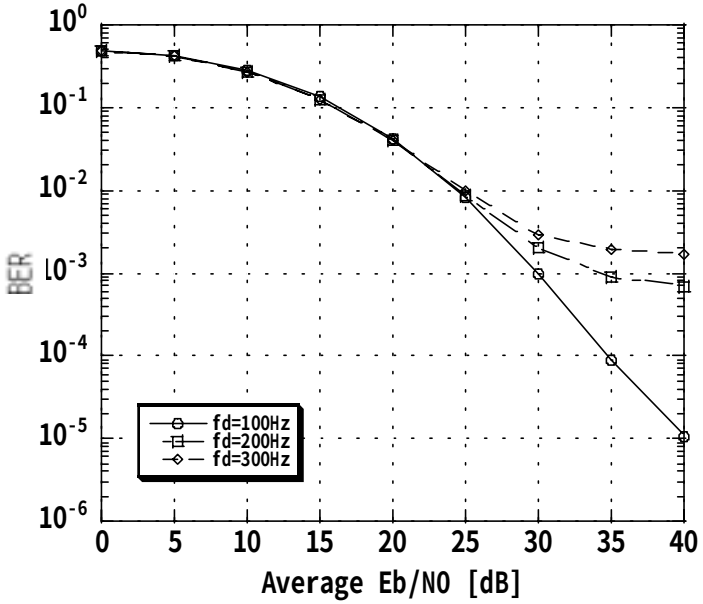


Rice K=5dB

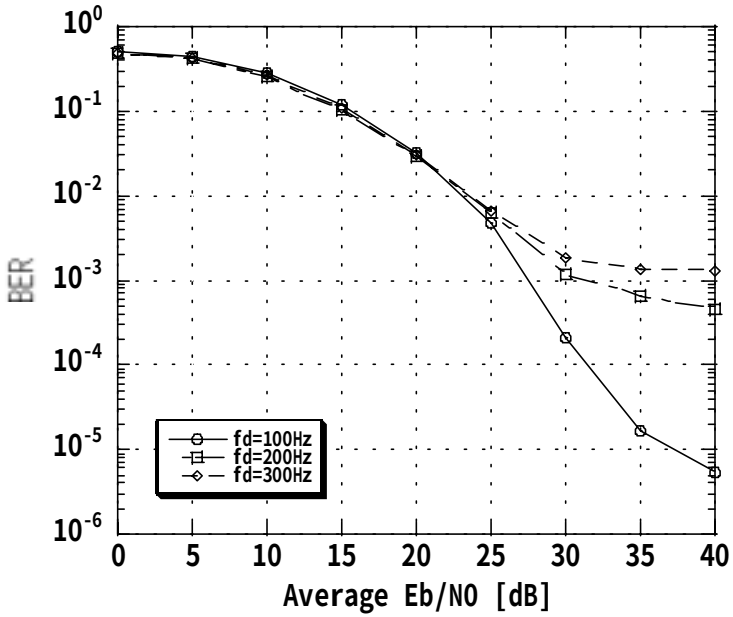
Fd = 100Hz	**: 18km/h**
Fd = 200He	**:36km/h**
Fd = 300Hz	**:54km/h**
Fd = 400Hz	**:72km/h**
Fd = 500Hz	**:90km/h**

Delay Spread :10ns

4.1.3 BER Simulation Results for 802.11a (Non-Line Of Site model ,16QAM)



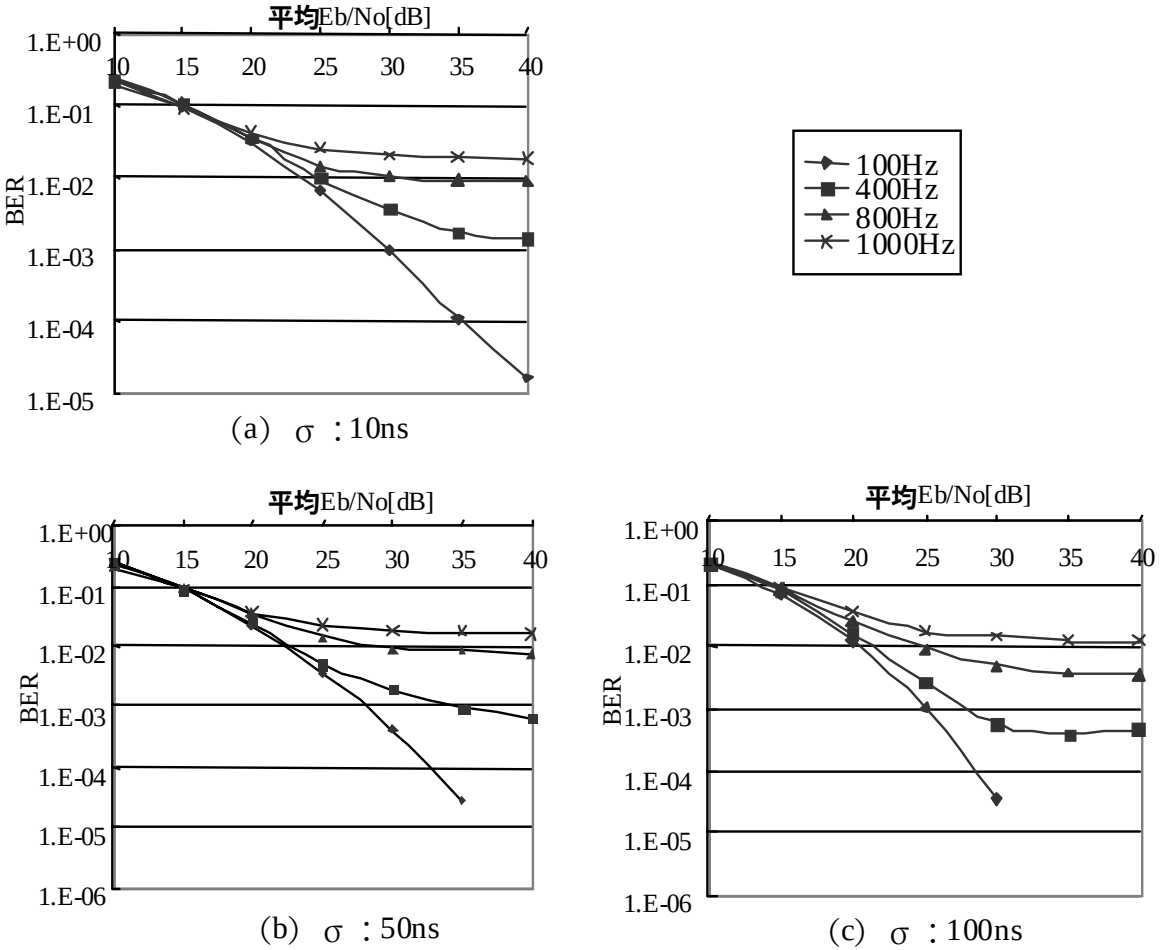
Delay Spread :50ns



Delay Spread :100ns

Fd = 100Hz	**: 18km/h**
Fd = 200He	**:36km/h**
Fd = 300Hz	**:54km/h**
Fd = 400Hz	**:72km/h**
Fd = 500Hz	**:90km/h**

4.1.4 BER Simulation Results for 802.11a (Non-Line Of Site model ,QPSK)



(a) σ ：10ns

(b) σ ：50ns

(c) σ ：100ns

4.2 Features of Developed OFDM systems

- Parameters of the system

Items	Model system A
Communication area	10mx300mxn
Radio zone size	10mx(30m-60m)
Handover distance	300m
Channel separation	5MHz
Radio transmission rate (Up / Down)	3.253Mbps
Modulation	OFDM-**DQPSK**
Error correction	RS(31,19)
RSE TX power	200mW
OBE TX power	10mW

- Comparison with IEEE 802.11a

Items	Model system A	IEEEE 802.11a
Access method	**TDMA／FDD**	CSMA/CA
Modulation	**DQPSK**	BPSK，QPSK，16QAM，64QAM
Symbol length	15.625μs	3.2μs
Guard interval	1/16	1/4
Guard time	0.98μs	0.8μs
Subcarrier spacing	64kHz	312.5 **k** Hz
Number of subcarrier	27	52（With 4 pilot carriers）
Bandwidth per channel	1728kHz	About 17MHz
Error collection	RS(31,19)	Convolutional coding (R=1/2，2/3，3/4)
Interleave	**Within slot**	Within symbol
Number of subcarrier division	**2**	

Features of the system

- Seamless hand-over on single radio frequency by dividing the sub-carrier

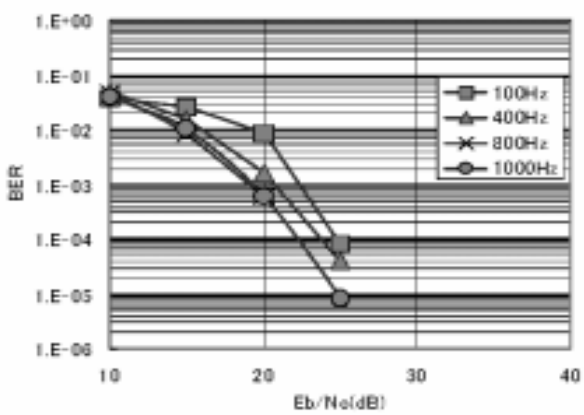
- Time interleave within the slot to compensate for time variation of the received signal

- High mobility through adoption of differential PSK without pilot carriers

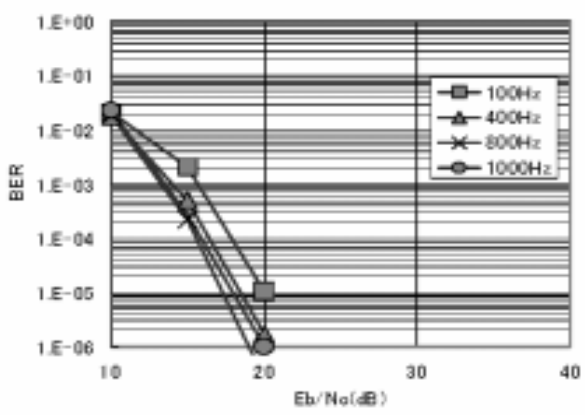
Note;
RLAN devices are generally not designed to be used at automotive or higher speeds.

4.2.1 System performance simulation (Developed OFDM systems)

- Error rate under Rice (k=6dB) type multipath interference, after error correction



Delay difference=122ns



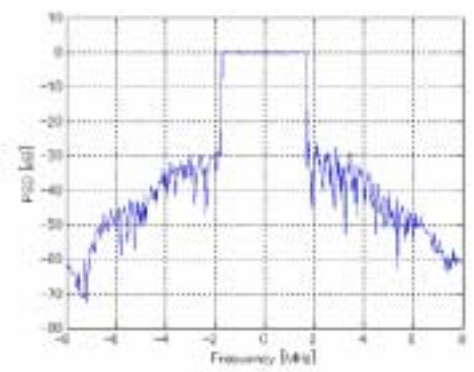
Delay difference=488ns

Maximum Doppler frequency=966Hz < < 64,000Hz (Subcarrier spacing) at vehicle speed of 180km/h

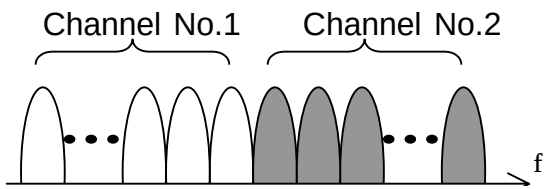
Parameters are as per listed on the slide No. 4.2

- Power spectrum

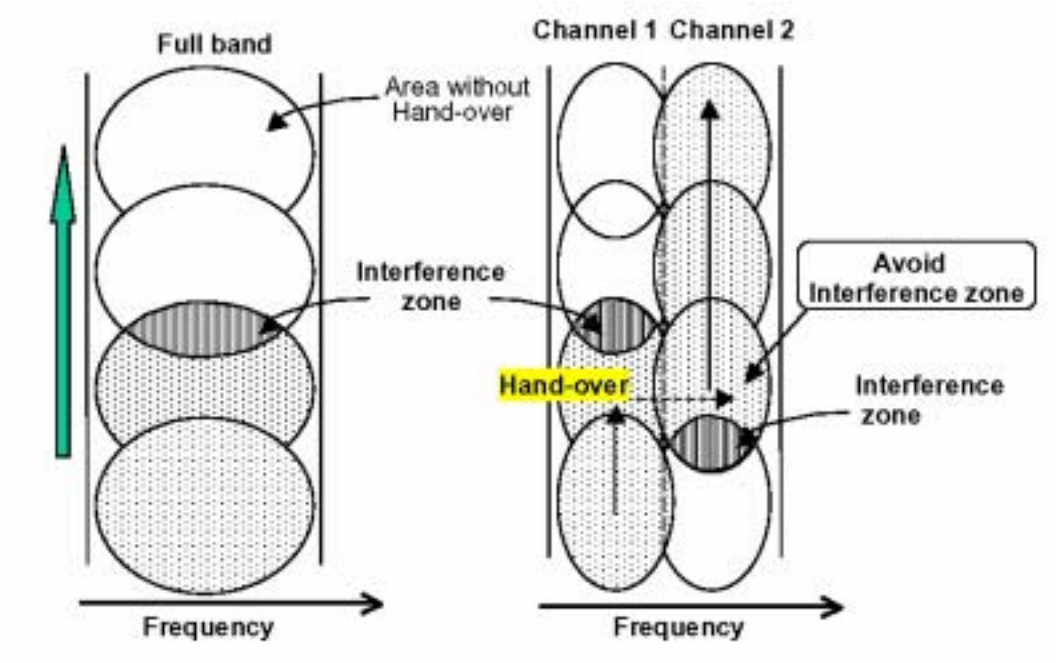
(6dB Back-off, Class AB)



4.2.2 Hand-over on Single radio frequency by dividing the subcarrier (Developed OFDM systems)



Divide subcarrier into two groups



Mechanism of high speed hand-over on single radio frequency

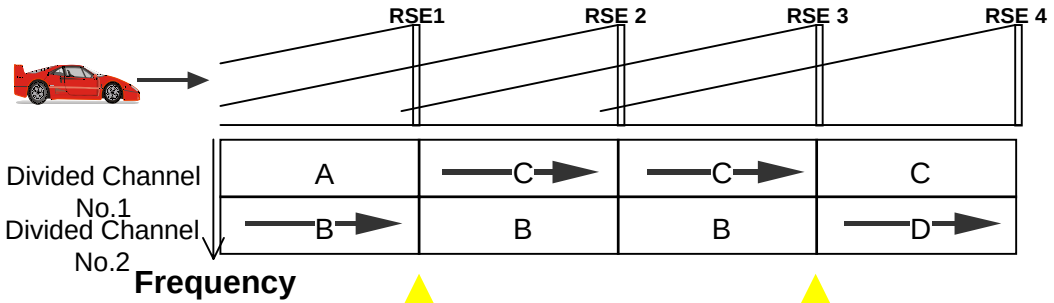
- The roadside transmitter transmits subcarrier groups arranged in frequency domain

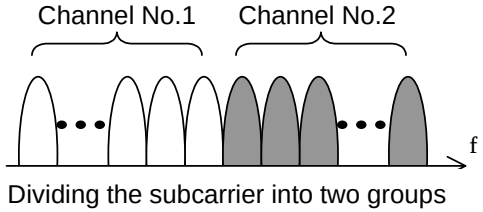
- The roadside transmitters in a data zone simulcast the identical data to reduce shadowing effects

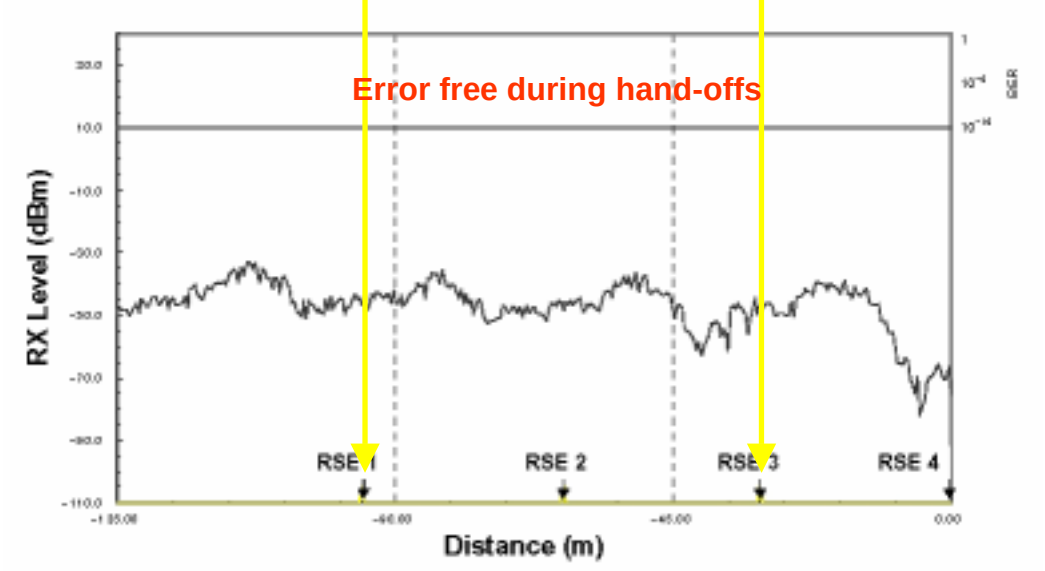
- All roadside transmitters are synchronized

- When a vehicle passes a boundary between data zones, the receiver demodulates the signal of the two data zones, and extracts suitable data zones (Handover)

4.2.3 An example of seamless hand-over (Developed OFDM systems)

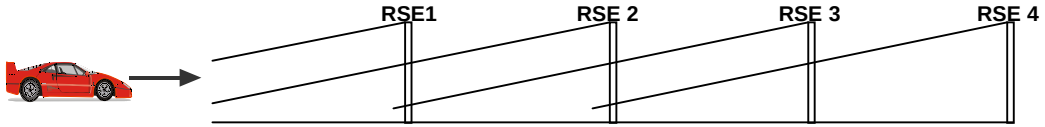




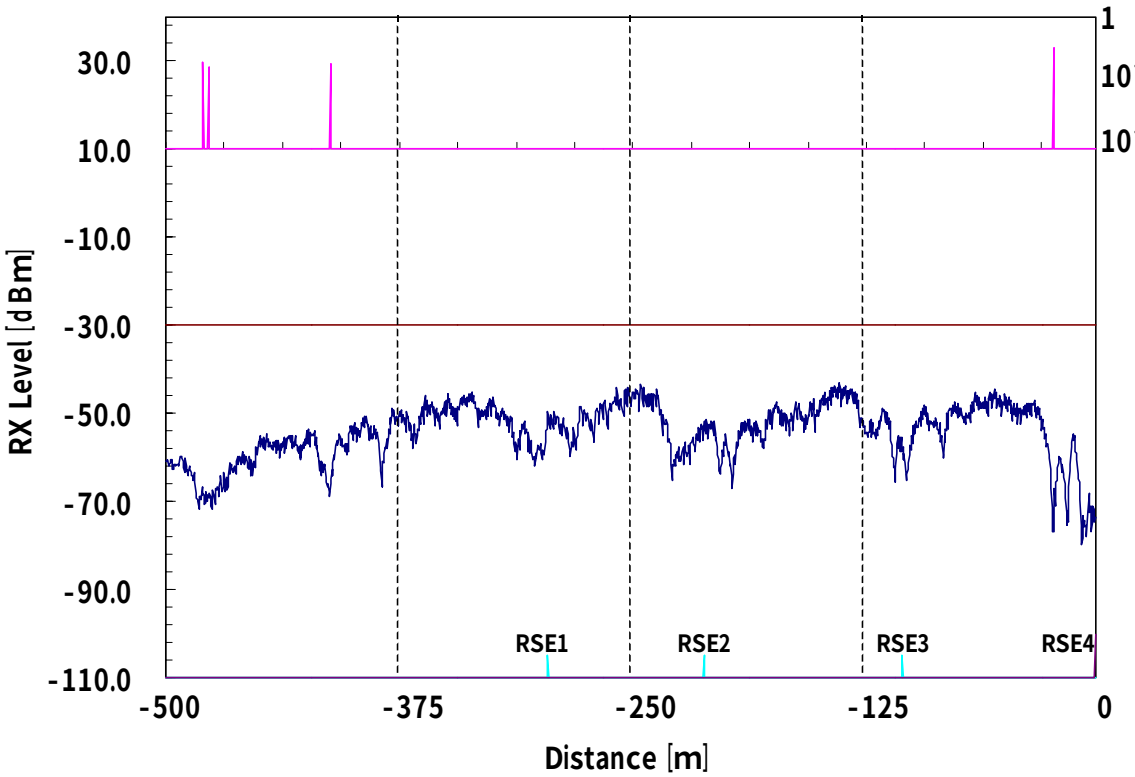


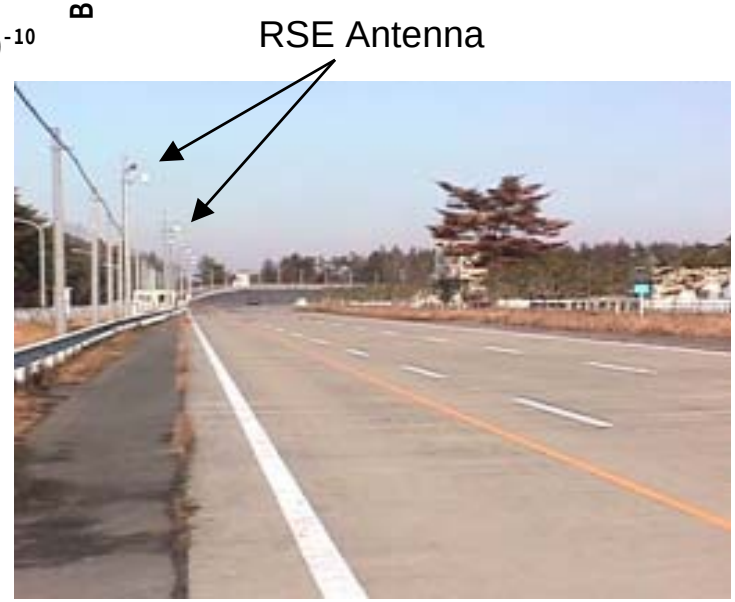
- RSE Communication range: 30m
- RSE Antenna height: 10m

4.2.4 An example of Continuous Communication (Developed OFDM systems)



Vehicle Speed: 120km/h

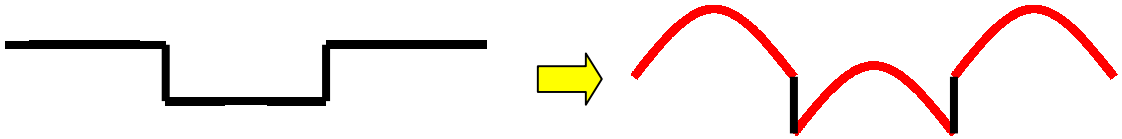




5.1 PSK-VP Modulation Scheme

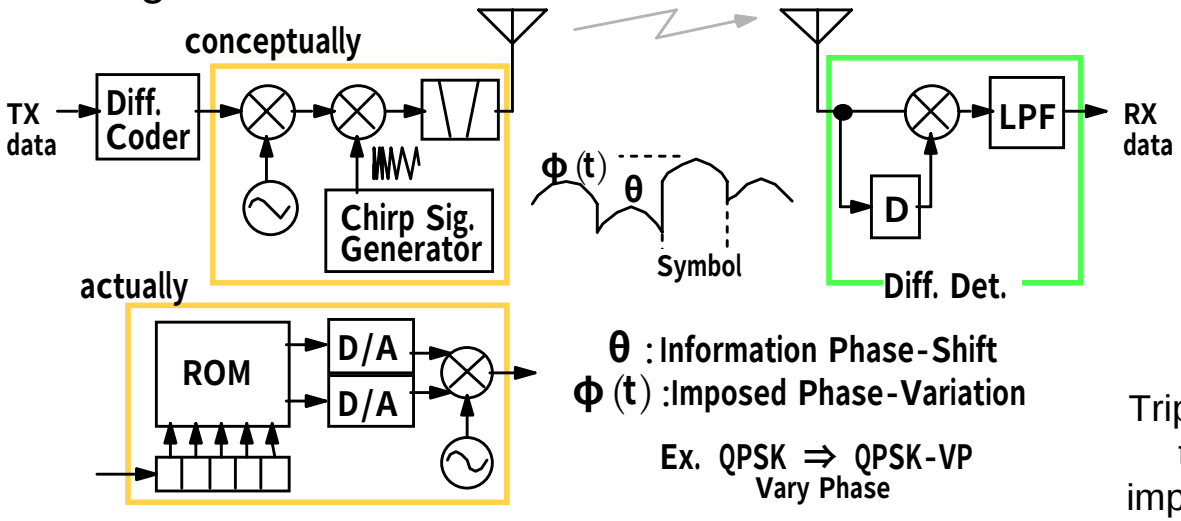
◆ Concept of PSK-VP (Phase Shift Keying with Varied Phase)

An anti-multipath scheme by imposing phase-variation on the symbol of PSK



cf. IEEE Trans. VT-42, No.4, pp. 625－640
IEEE Trans. VT-42, No.2, pp. 177－185
ITST2001 Proc., S3-3, pp. 625—639

◆ Configuration



Proto-Modem Example

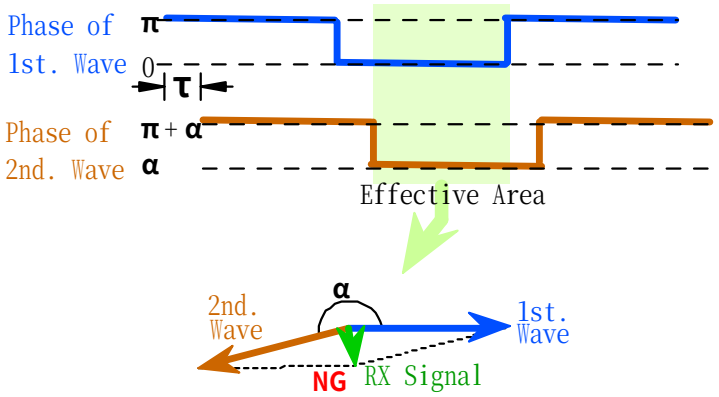
Triple mode (QPSK-VP/QPSK/ASK) transceiver baseband is easily implemented into single FPGA chip.

Multimode by swapping waveform tables
/ A common detector applies to PSK and PSK-VP

5.2 Anti-Multipath Mechanism of PSK-VP

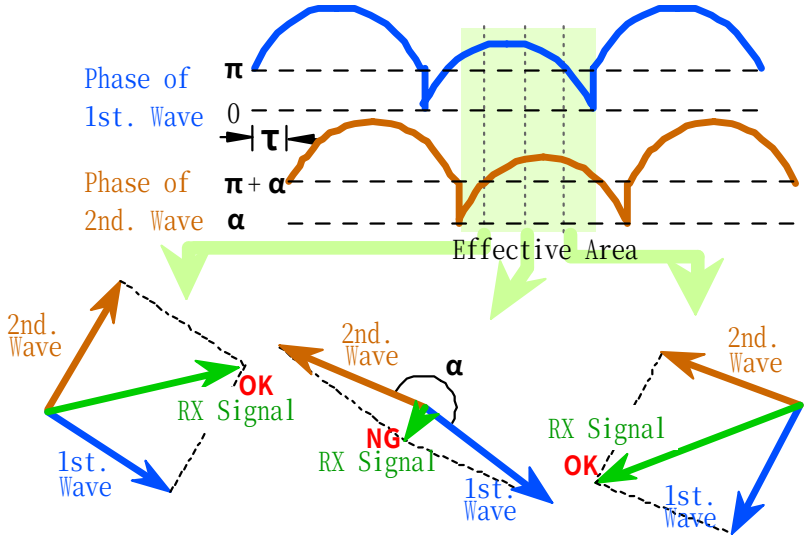
No complete cancel in multipath by imposed phase-variation,
i.e., survivor somewhere exists. ⇒ *Implicit RAKE / Path-Diversity*

i) Vector Diagram for Conventional PSK

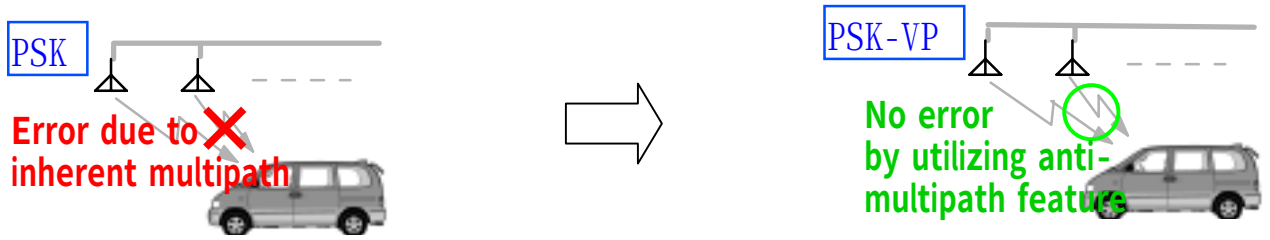


Total cancel over the effective area occurs when phase difference **α** *approaches* **π**.

ii) Vector Diagram for PSK-VP

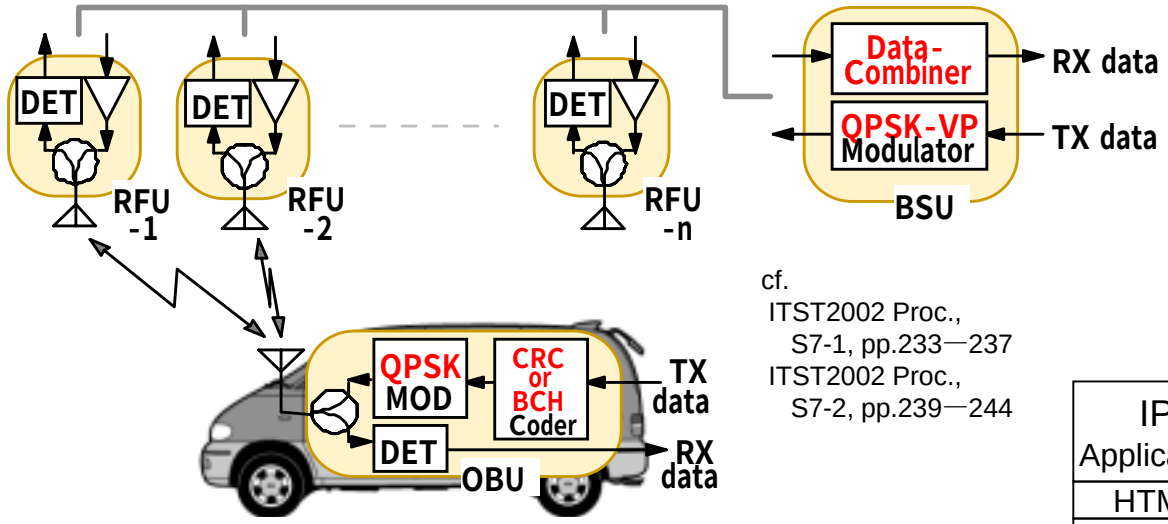


No complete cancel over the effective area



5.4 Structure and Specification for DSRC

◆ Basic Structure and Specification



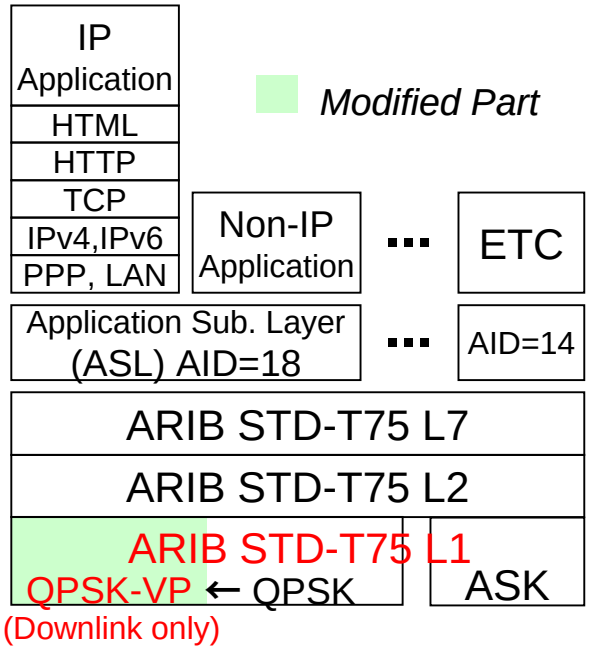
cf.
ITST2002 Proc., S7-1, pp.233—237
ITST2002 Proc., S7-2, pp.239—244

◇ Downlink (Road to Vehicle)
Simultaneous transmission using path-diversity effect of PSK-VP

◇ Uplink (Vehicle to Road)
Site-diversity using bit-error based data-combining scheme

Main Specification

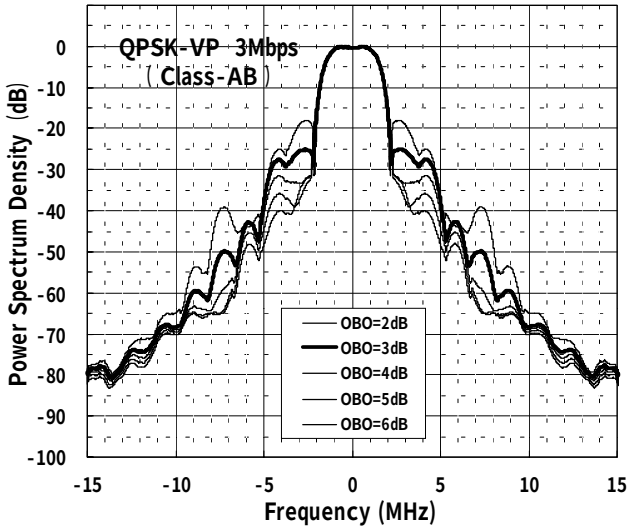
Radio Area Size	typ. 30～50m×n
Channel Spacing	5MHz
Downlink	π/4-QPSK-VP (3.072Mbps) + ARIB STD-T75 Higher Layer
Uplink	π/4-QPSK (4.096Mbps)+BCH(63,51) in conformity to ARIB STD-T75



Modified Part

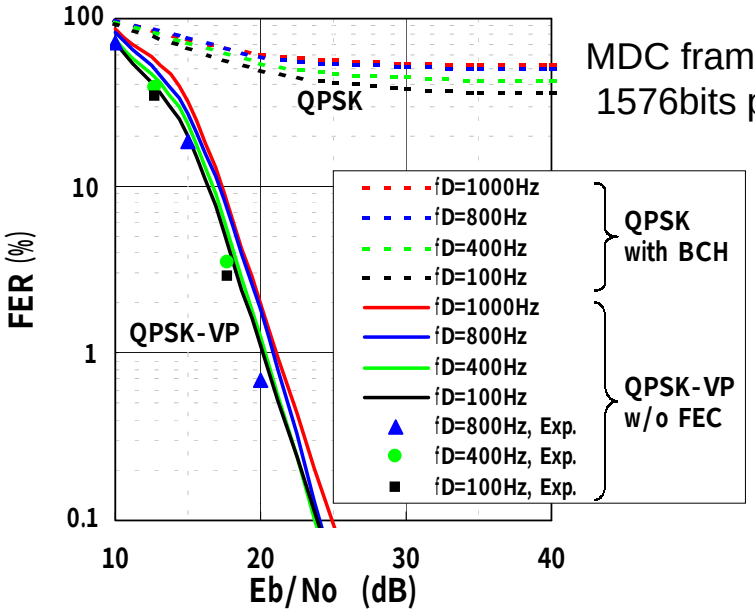
5.5 System Performance Simulation (PSK-VP)

◆ Power Spectrum Calculation Result



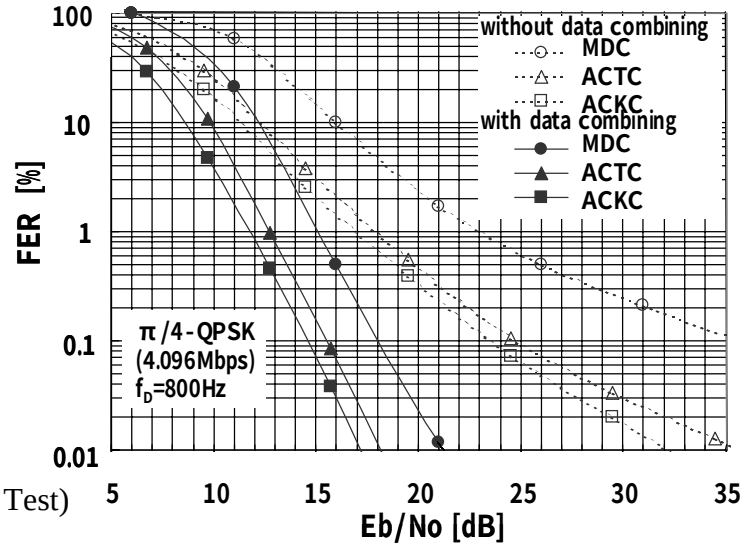
◆ FER (Frame Error Rate)
Performance Simulation Results

i) Downlink



MDC frame:
1576bits payload

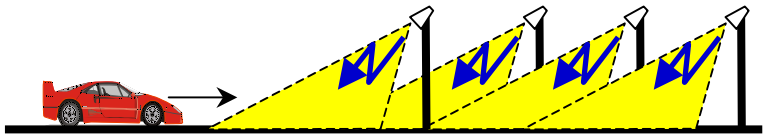
ii) Uplink

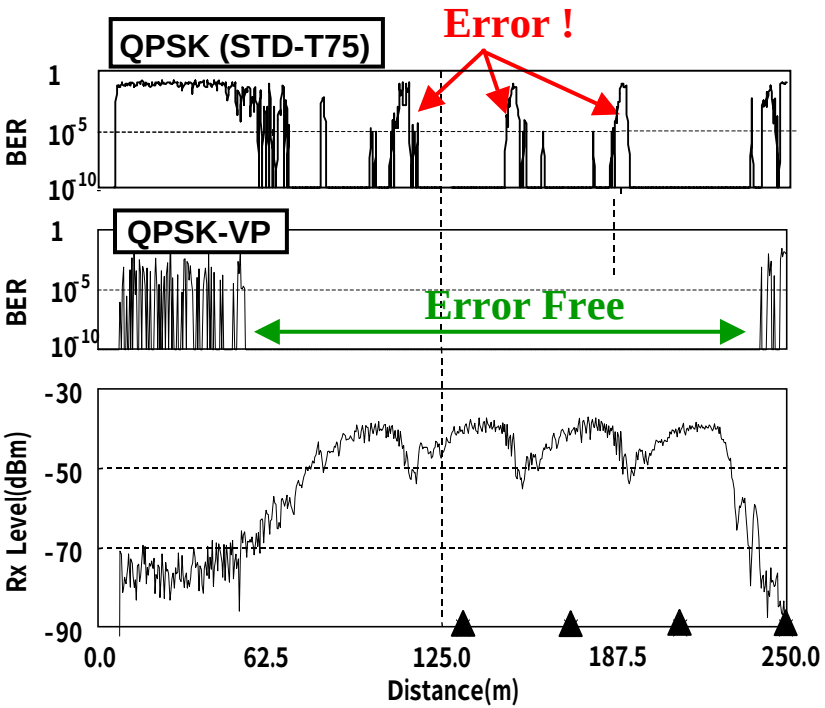


(τ=200ns, fD=1000Hz corresponds to 180km/h)

5.6 Field Verification for Continuous Communication without Hand-Off

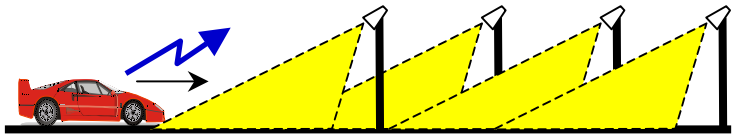
◇ Downlink (Road to Vehicle)

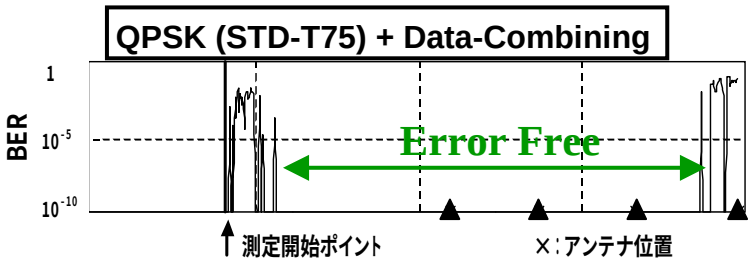




▲: Position of Roadside Antenna

◇ Uplink (Vehicle to Road)

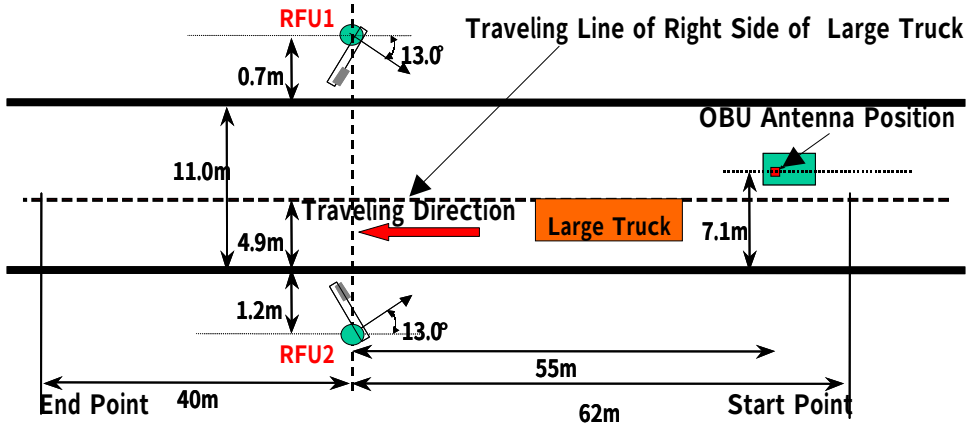


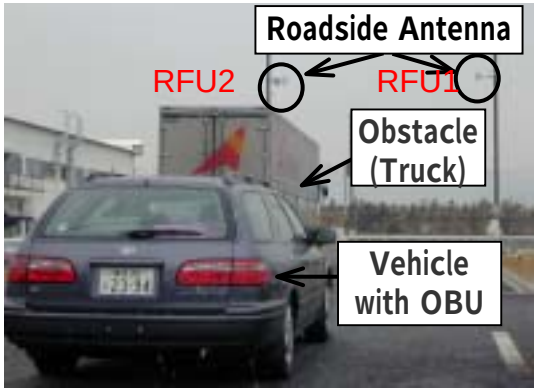


Starting Point

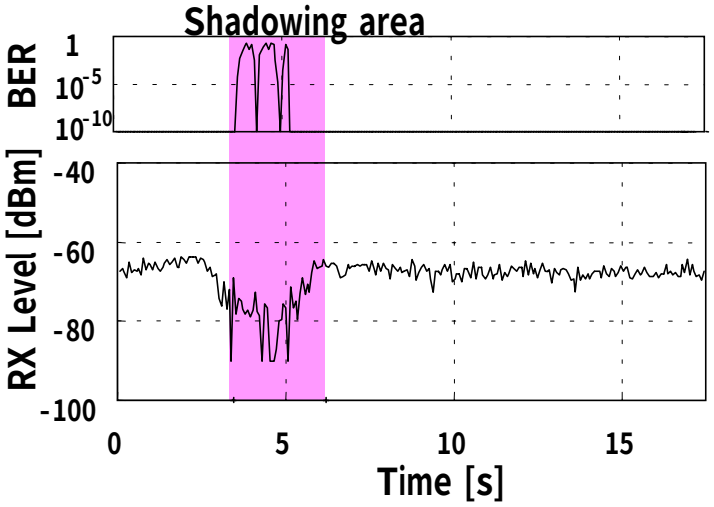
▲: Position of Roadside Antenna

5.7 Field Verification for Anti-Shadowing Effect

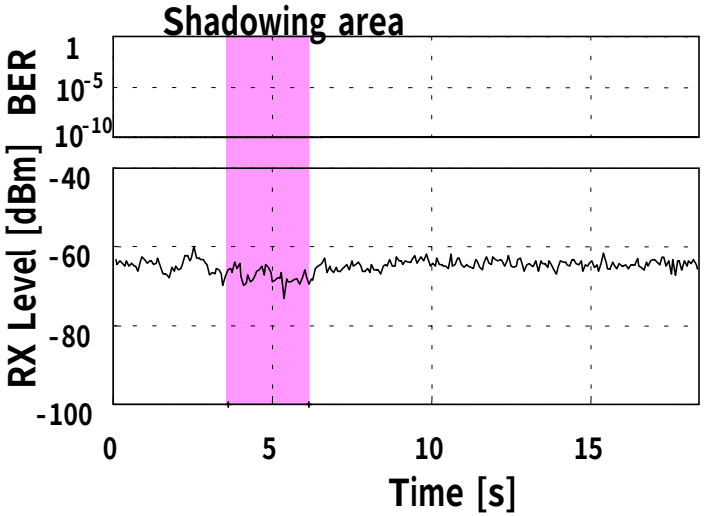




◇ Single Transmission from RFU2



◇ Simultaneous Transmission from RFU1&2



5.7 Filed Verification for Realization of Long Radio Area by Simultaneous Transmission Diversity

Roadside Antenna Setup

◇ Simultaneous Transmission from Both Antennas

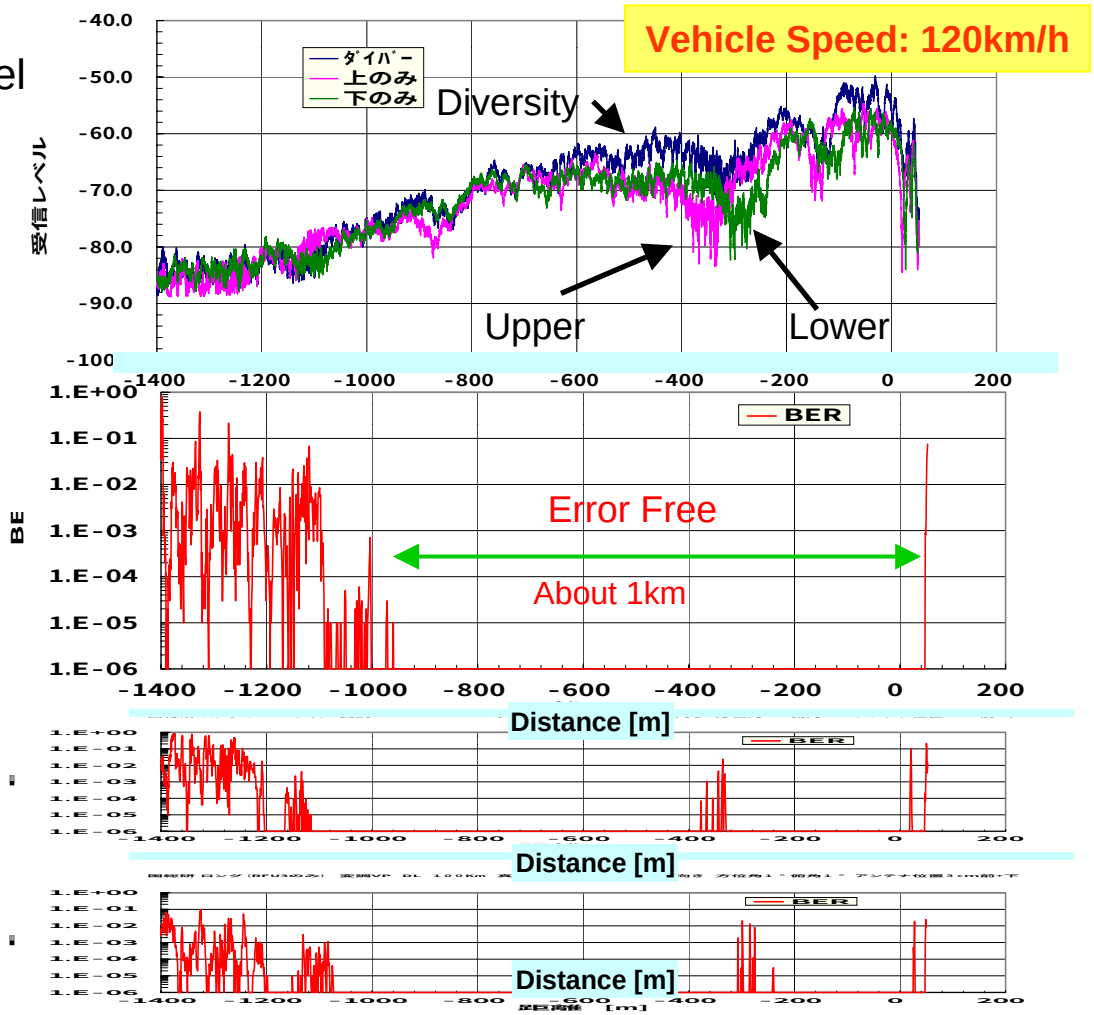
◇ Single Transmission

from Upper Antenna

from Lower Antenna

Level

BER



5.8 Feature of PSK-VP in DSRC Application

- Applicable to simultaneous transmission
  in downlink by anti-multipath feature
- Robust for rapid fading
  by no adaptation process and highly-maintained symbol-rate
- Simple structure without large-scale circuit like equalizer or FFT
- Easy realization of multimode modem
  by swapping waveform tables / common detector for PSK and PSK-VP
- Easy extension from existing PSK-based standard of ARIB STD-T75
  - Full compatible in higher layer
  - Major differences are in Downlink / RSU.
    (multiple RF units and additional waveform table for PSK-VP)
  - Differences in OBU are minimized.
    (No change in transmission / A common detector is used for PSK-VP)

6. CONCLUSION

- New technologies have been studied
  for the Next generation ITS Radio communications In Japan.

- Simulation results showed
  "802.11a based OFDM technology has performance problem
  under high mobility Situation".

- Field test evaluation has already finished
  for OFDM and PSK-VP scheme.