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Advanced Tech. for Communications

A New Concept of Baseband Radio

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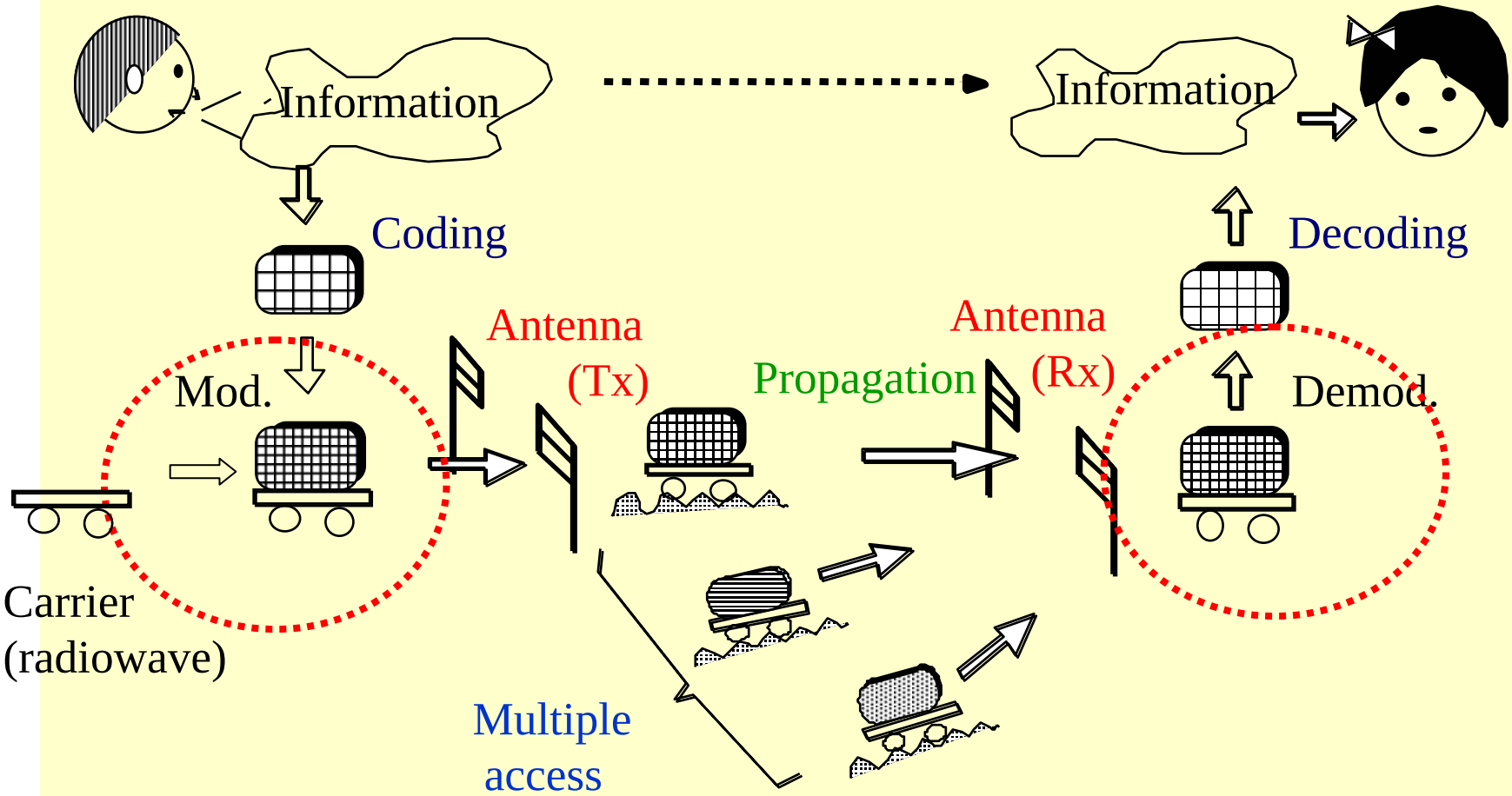
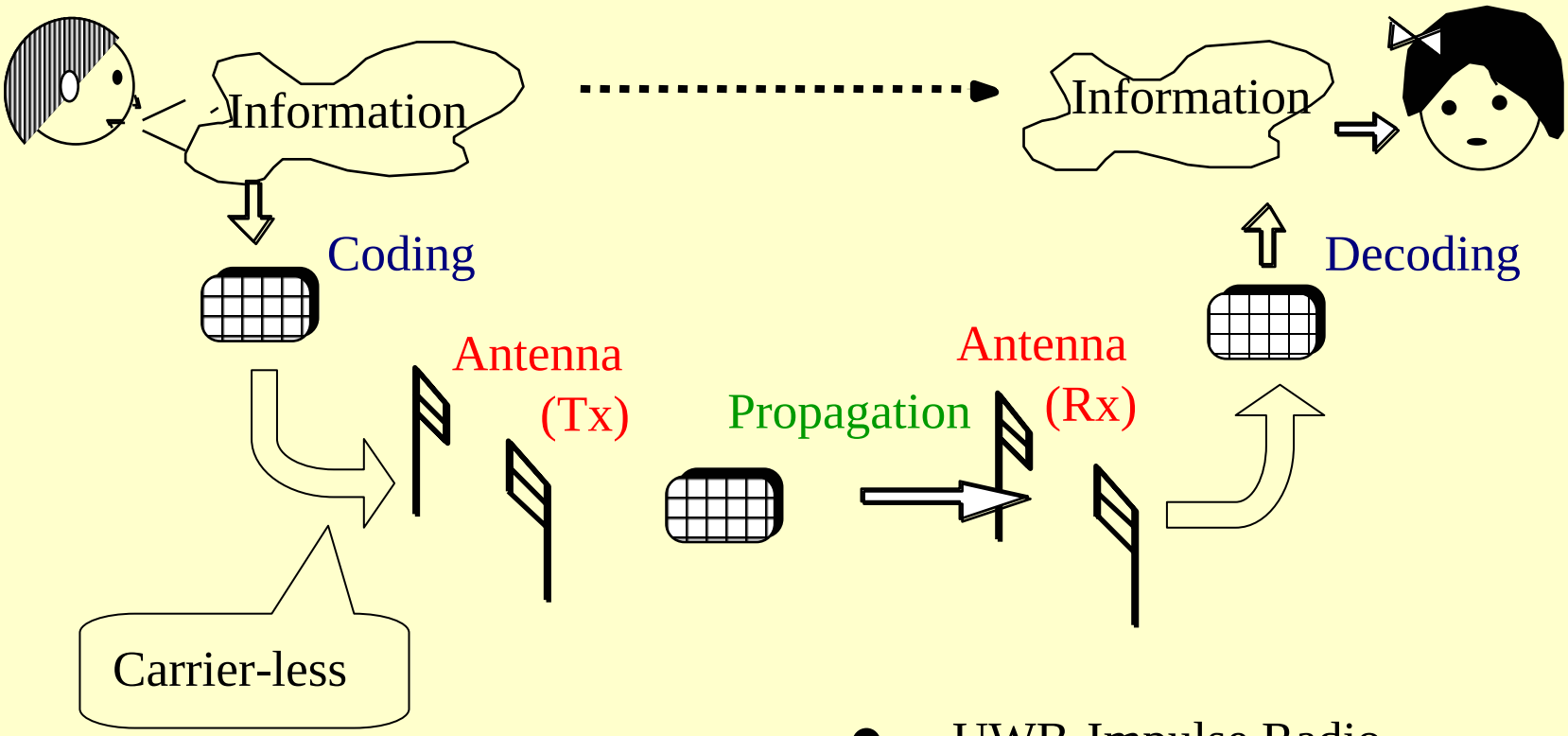
Presentation Topics

1. Baseband Signal vs Bandpass Signal
2. Wireless Baseband Transmission (WBT)
3. Experiment on Baseband Radio
   Adapting to Environmental Change
4. Radio Signal Processing Adaptive Array
   for Terrestrial Digital TV Signal
   under Multipath Environment

Wireless Transmission Scheme

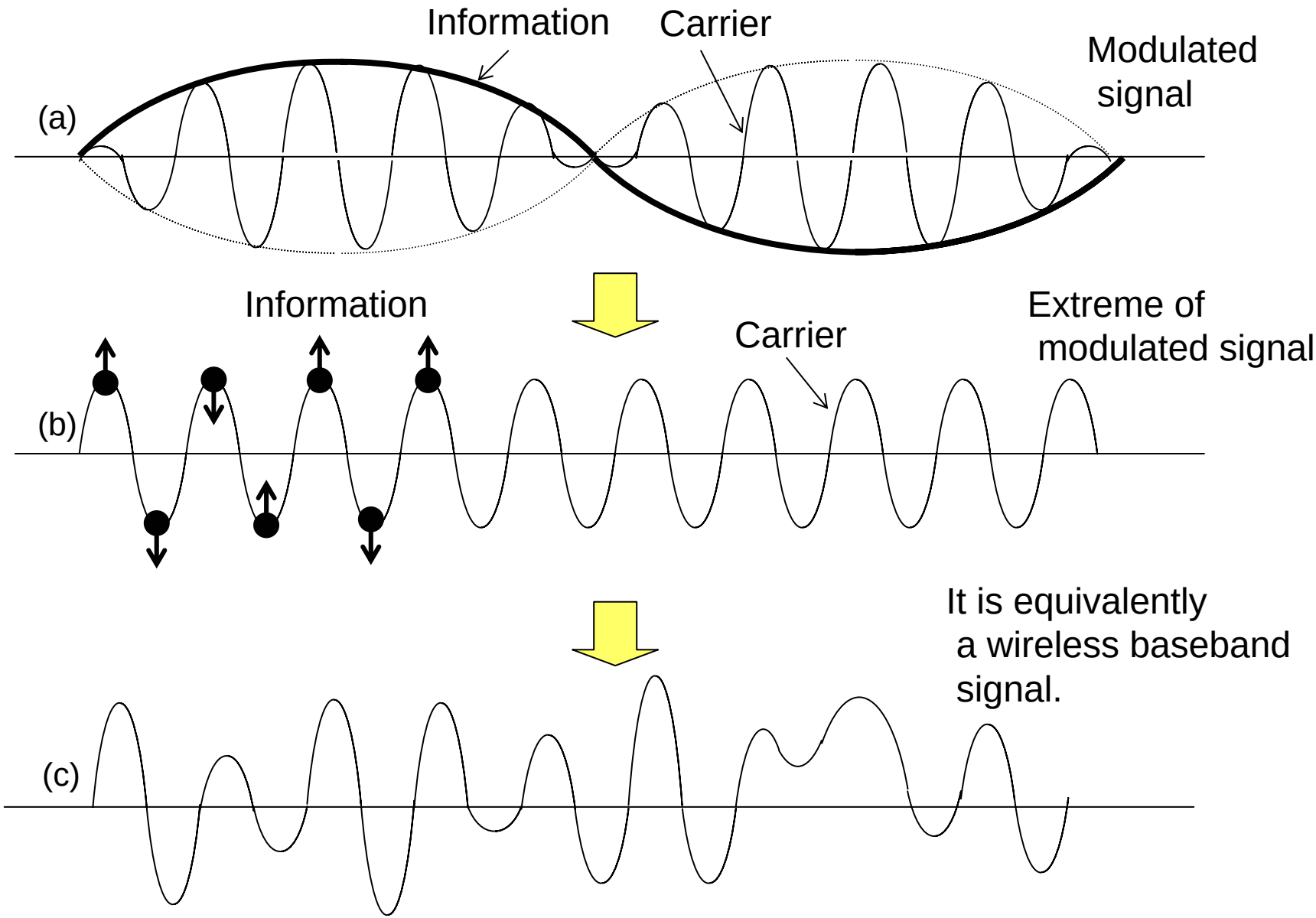


Wireless Baseband Transmission



- UWB-Impulse Radio
  (wireless impulse transmission)
- Wireless waveform transmission

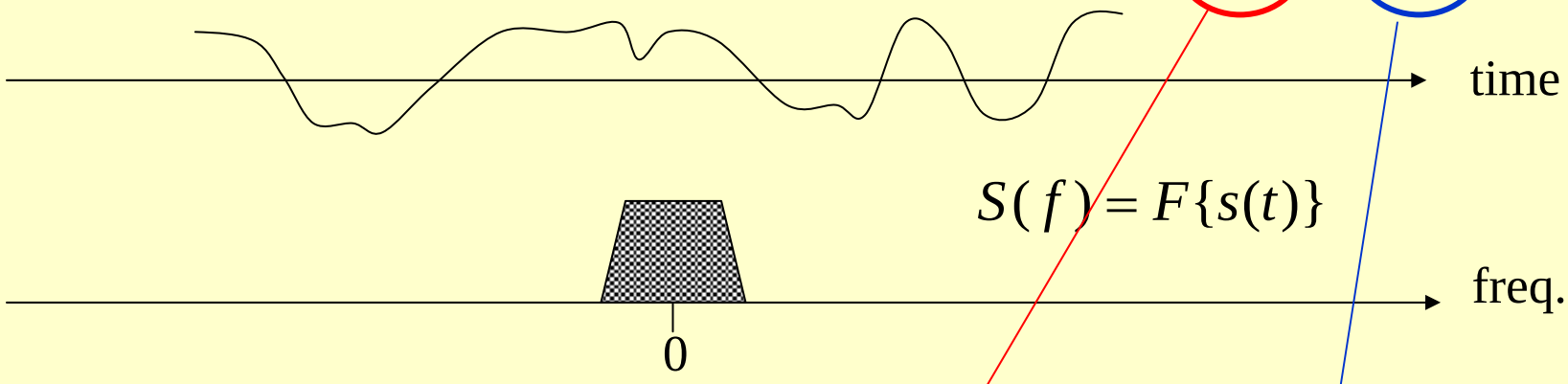
Data Transmission Scheme



Baseband Signal vs. Bandpass Signal

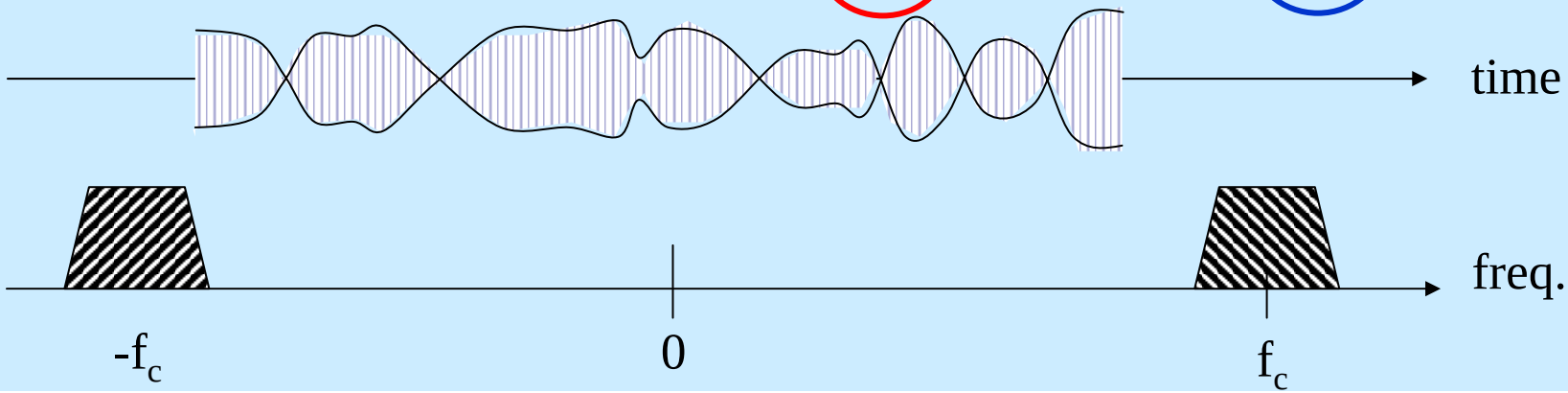
Baseband signal (complex signal)

$$s(t) = s_I(t) + j s_Q(t)$$



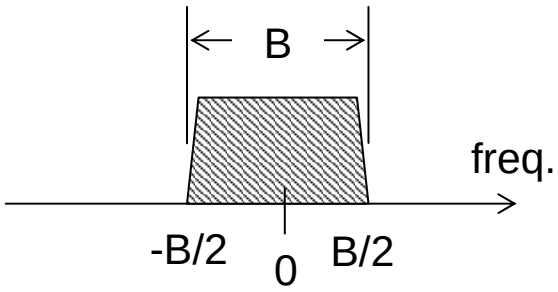
Band-pass signal (real signal)

$$s_{RF}(t) = \mathrm{Re}\{s(t)\}$$
$$= s_I(t)\cos(2\pi f_c t) - s_Q(t)\sin(2\pi f_c t)$$



Baseband signal

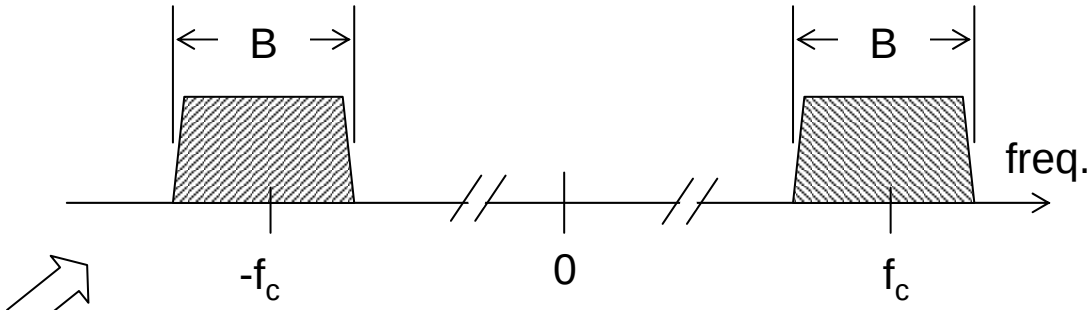
- time domain: complex
- freq. domain: complex



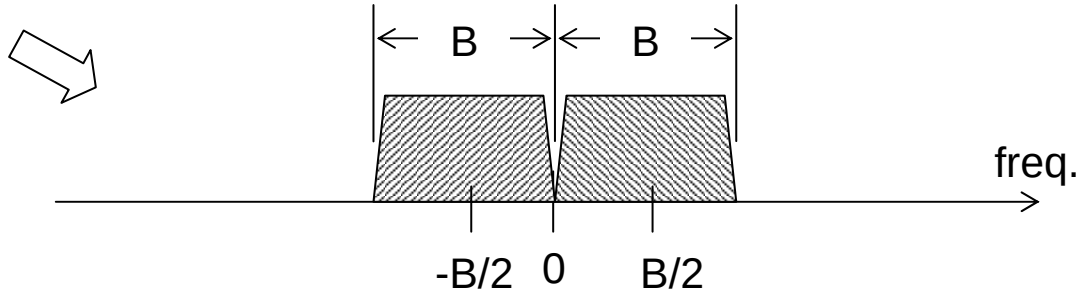
(a) Baseband signal

Wireless transmission signal

- time domain: real
- freq. domain: complex

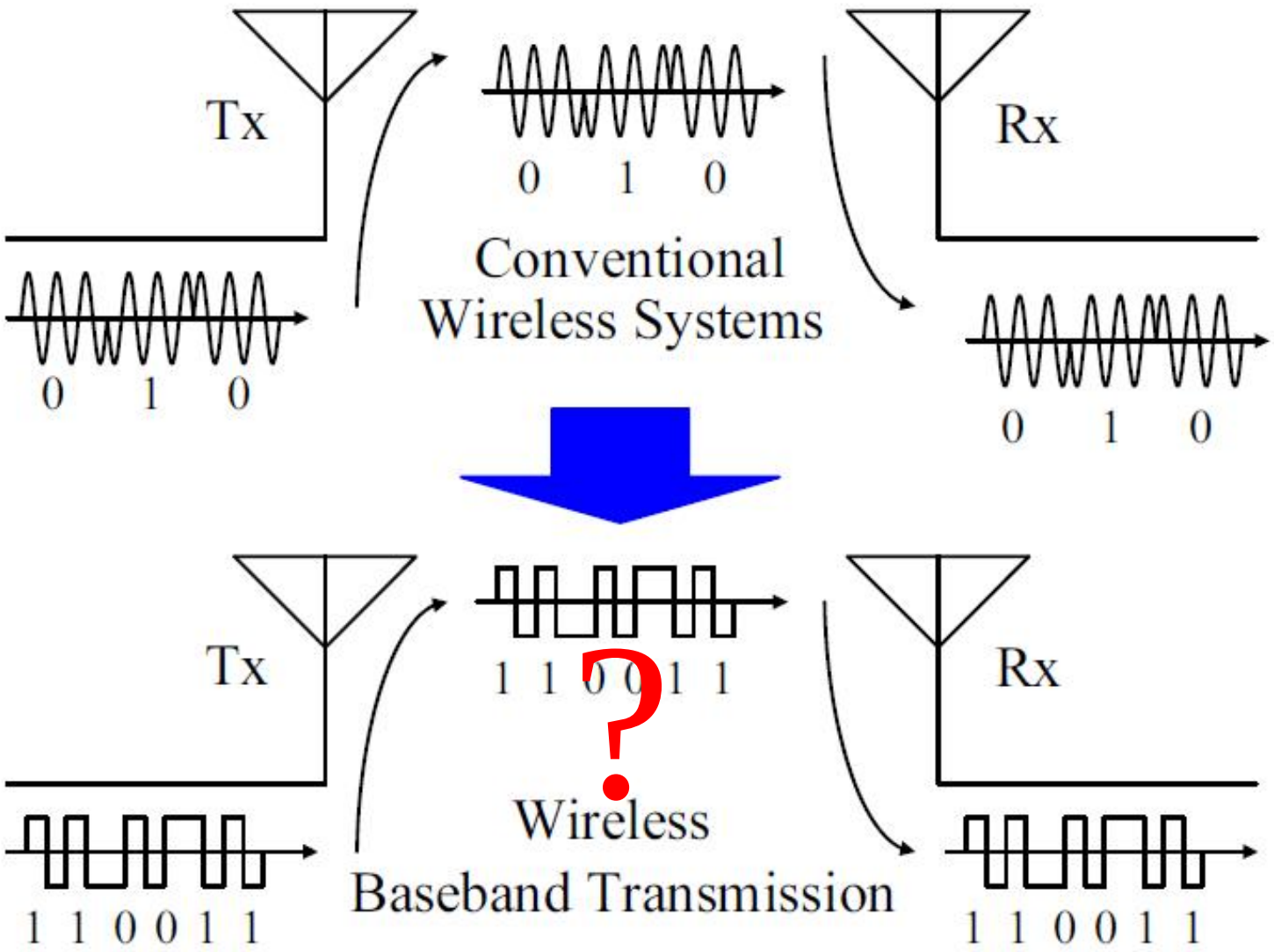


(b) RF signal transmission



(c) Baseband signal transmission

The First Step:
Wireless Baseband Transmission (WBT)

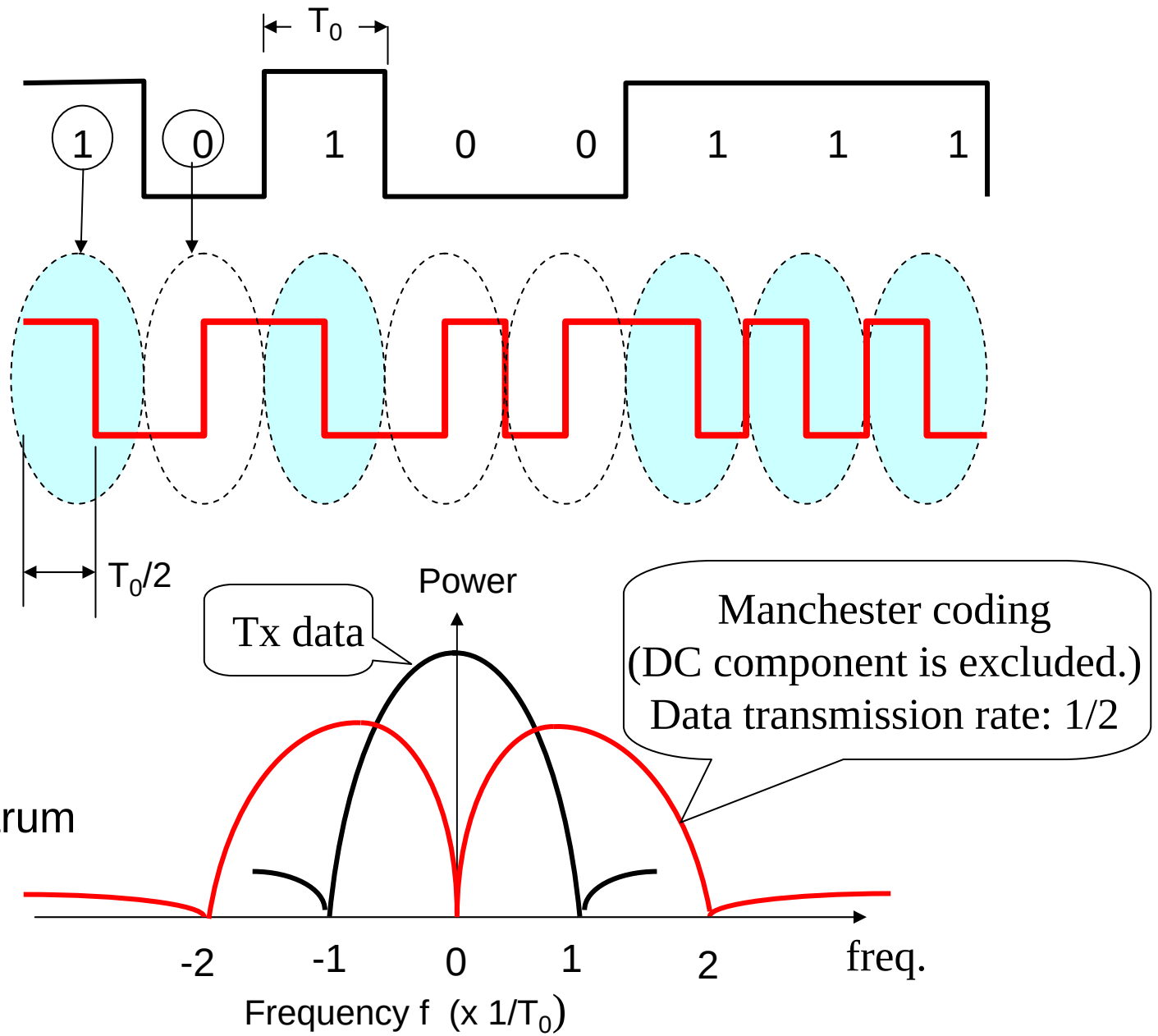

Tx
0 1 0
Conventional
Wireless Systems
Rx
0 1 0
Tx
1 1 0 0 1 1
?
Wireless
Baseband Transmission
Rx
1 1 0 0 1 1
1 1 0 0 1 1

Wireless Transmission Scheme

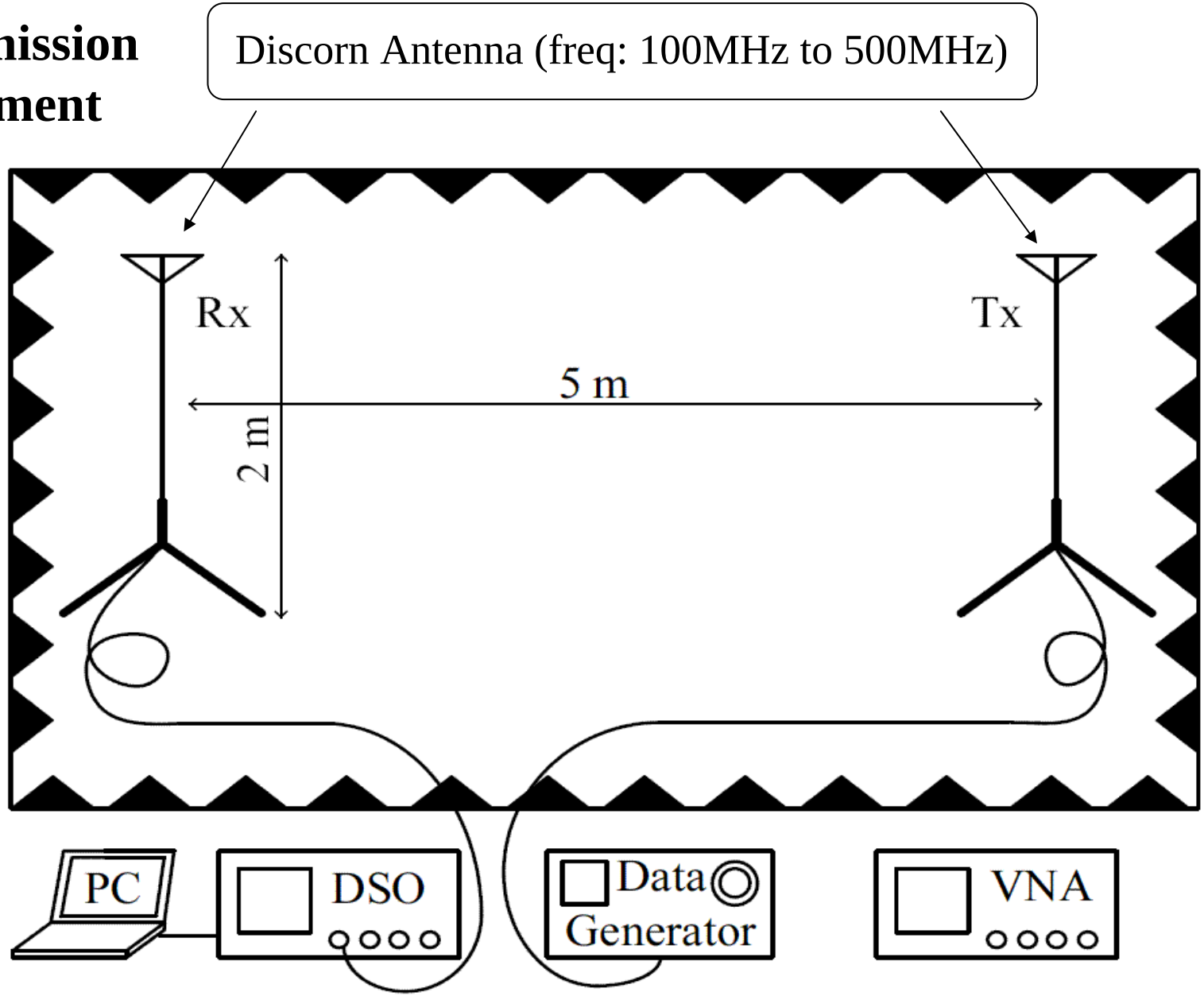
(a) Tx Data

(b) Manchester Coding

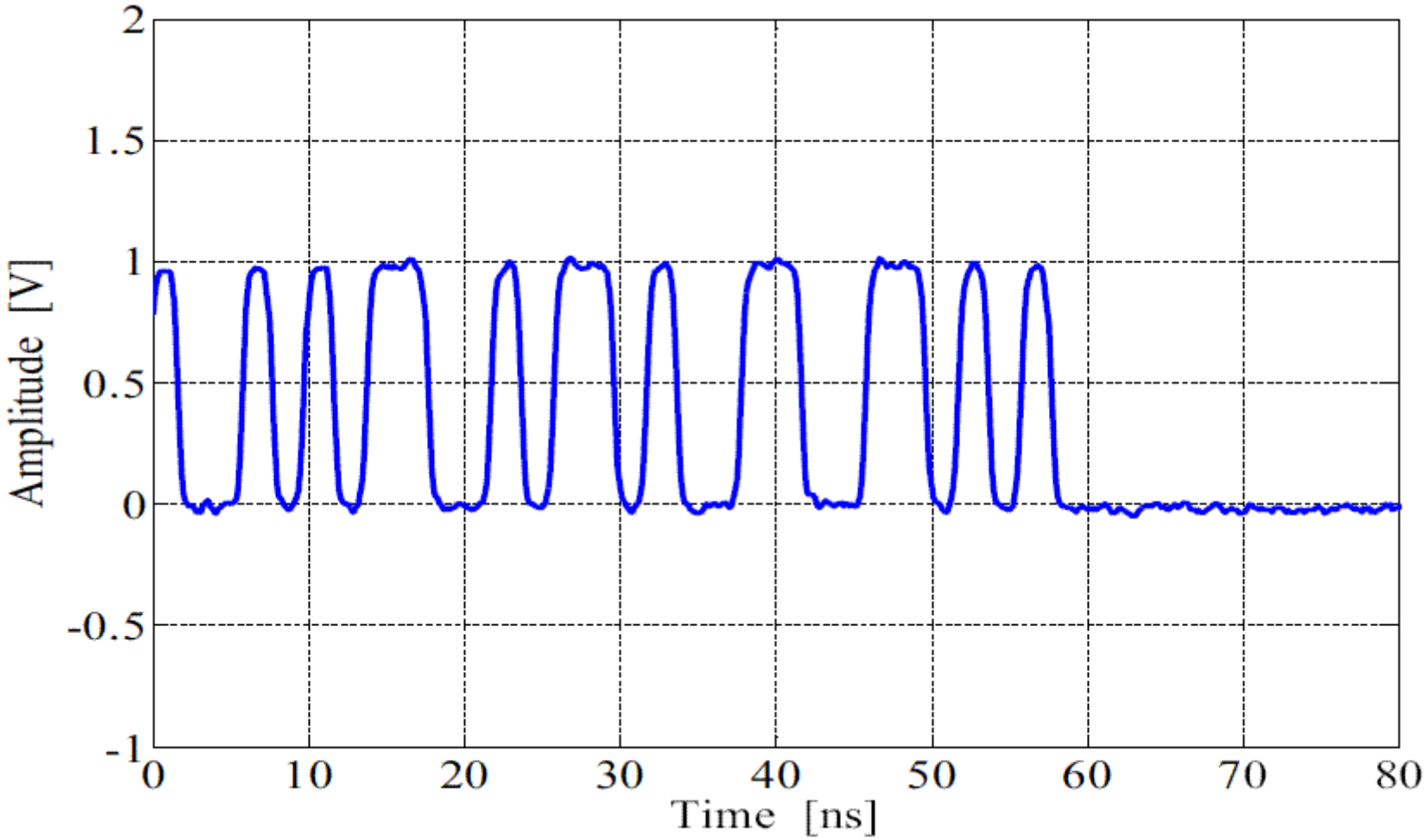
(c) Power Spectrum



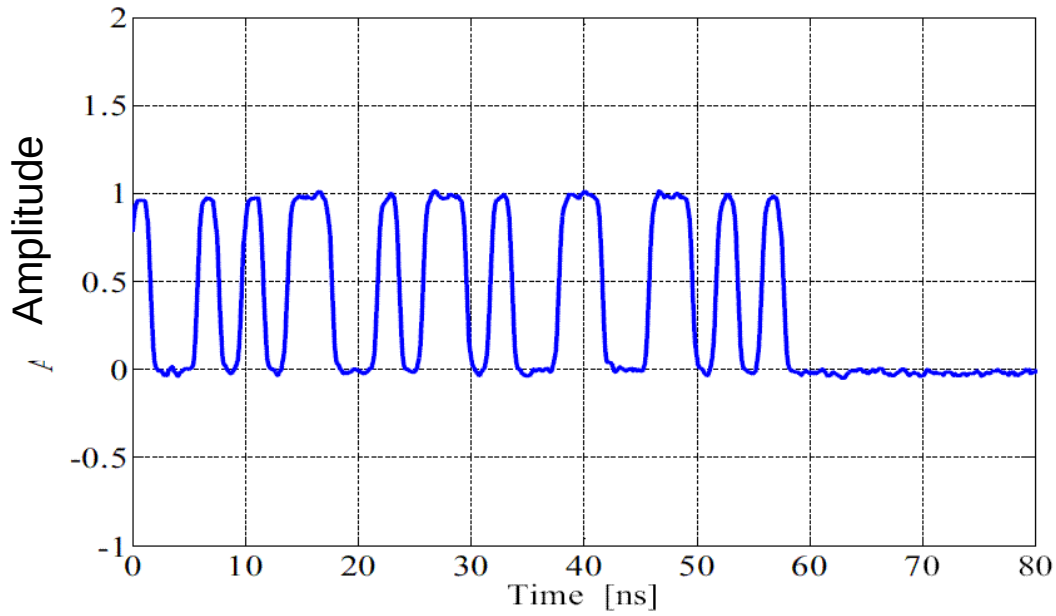
Transmission Experiment



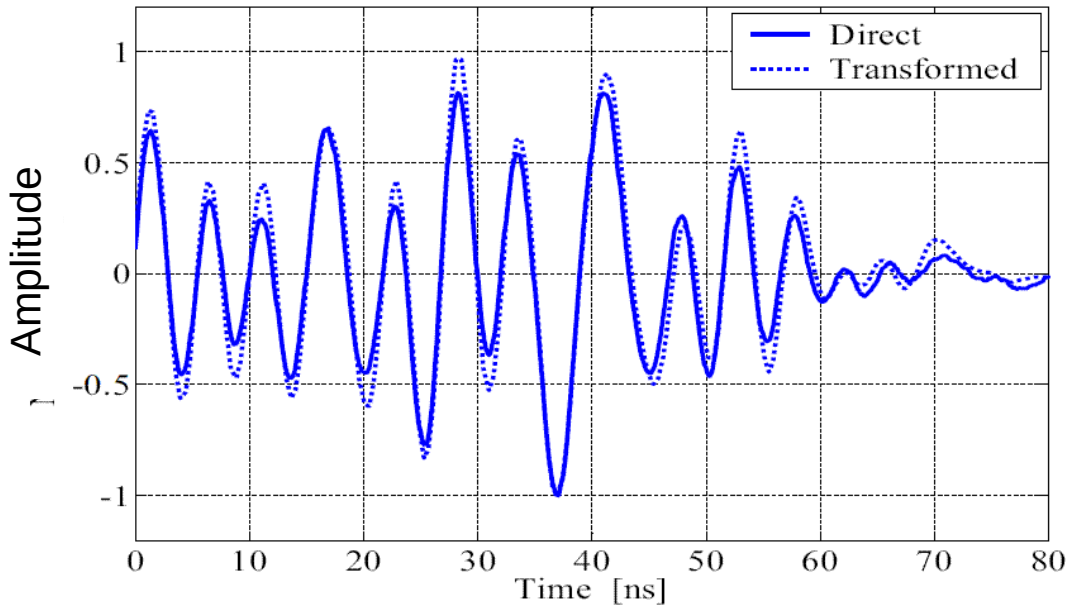
Generated Signal to be Transmitted (after Manchester Coding)



Transmitted

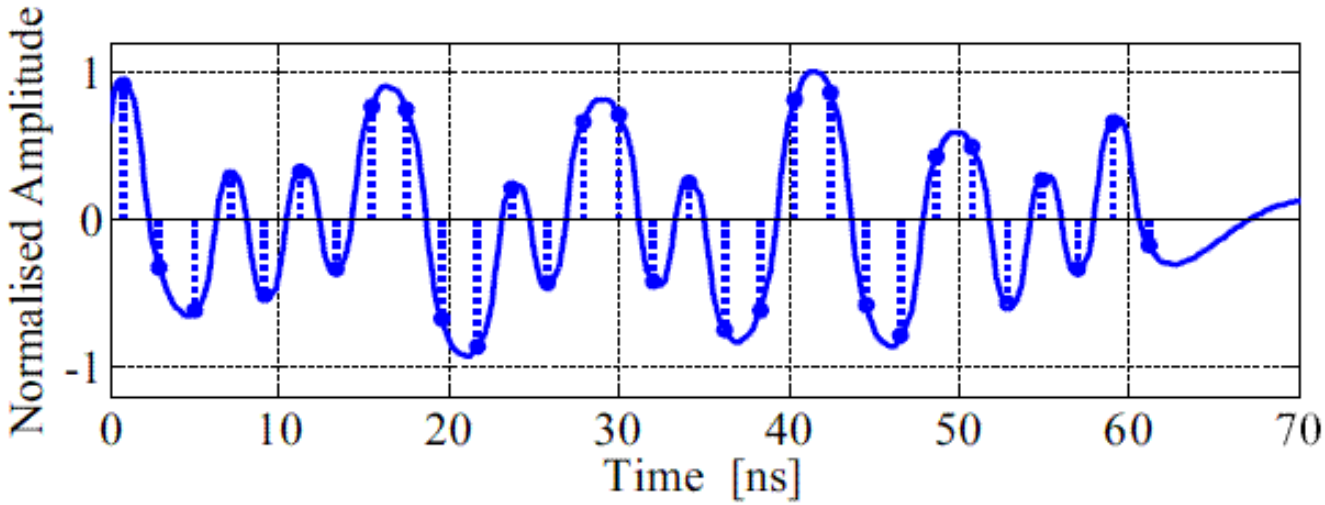


Received

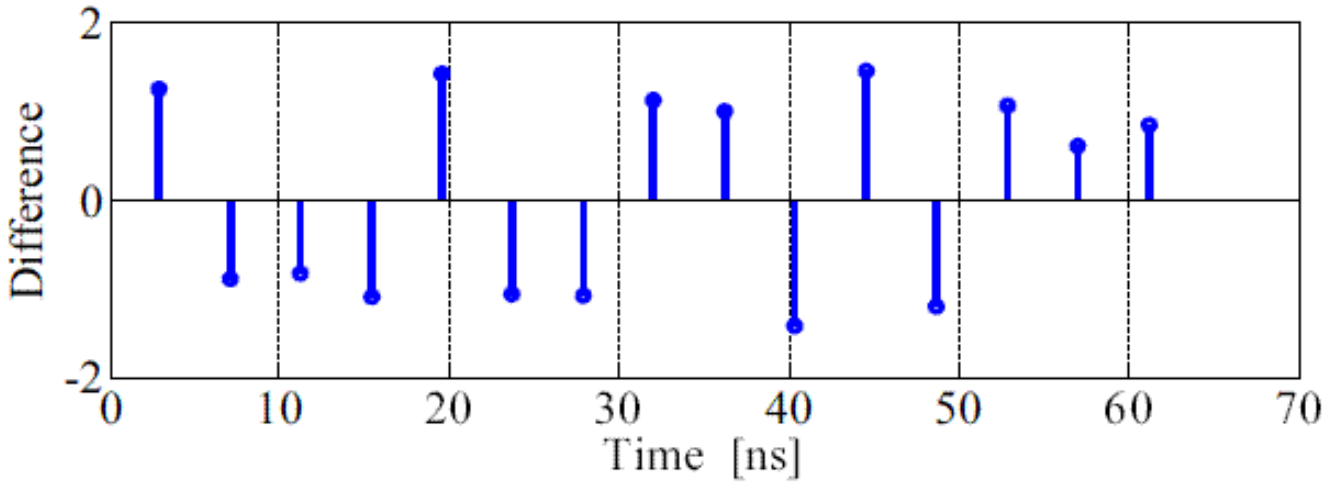


Data Detection

Received signal

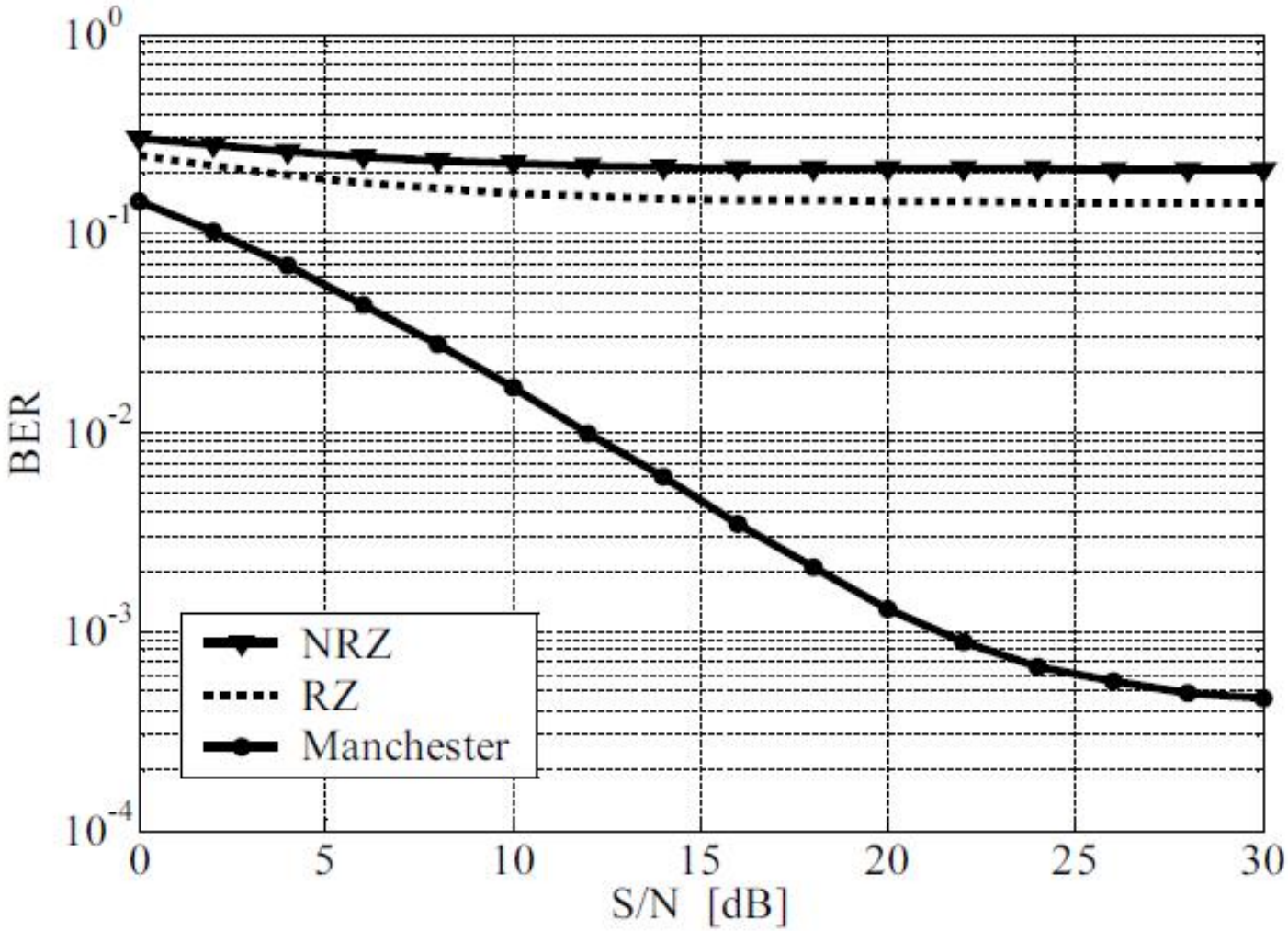


after Manchester decoding



Error-free detection can be confirmed.

BER Characteristics of WBT

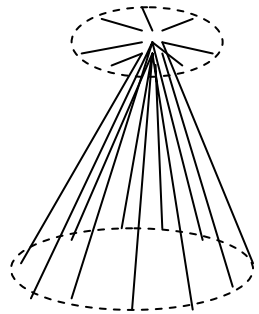


Result

Possibility of WBT has been demonstrated.

Positive feature of WBT

GHz frequency signal can carry Gbit data.



Antenna size of $(10cm)^3$ can realize 2.5Gbps transmission.
(confirmed)

Antenna size of (1cm)3 can realize 25Gbps transmission.
(estimated)

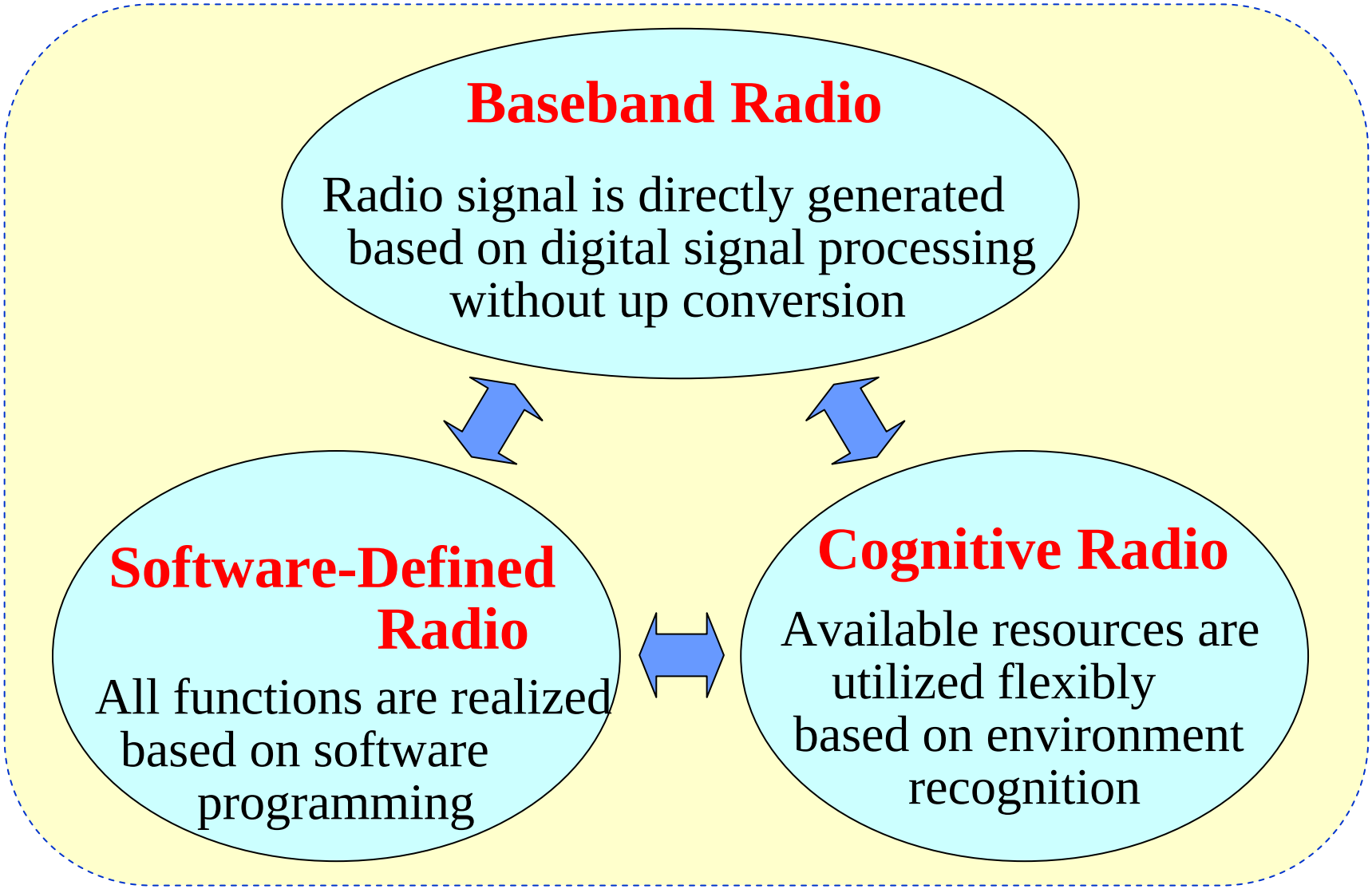
Problem to be solved ⟹ Baseband Radio

There is an substantial interference problem like UWB-IR
due to wide frequency band occupation.
Accordingly, this scheme restricts application fields very strictly.

The Second Step: Baseband Radio

Three Radios

Adaptive Communication



Cognitive Radio (CR)

"cognitive" ⇨ Recognition, Process of Understanding

Cognitive Radio (CR)

- Access method
- Modulation scheme
- Frequency
- Data rate

} Adaptive radio system which can change its system parameters autonomously, based on environmental sensing and intelligent judgement

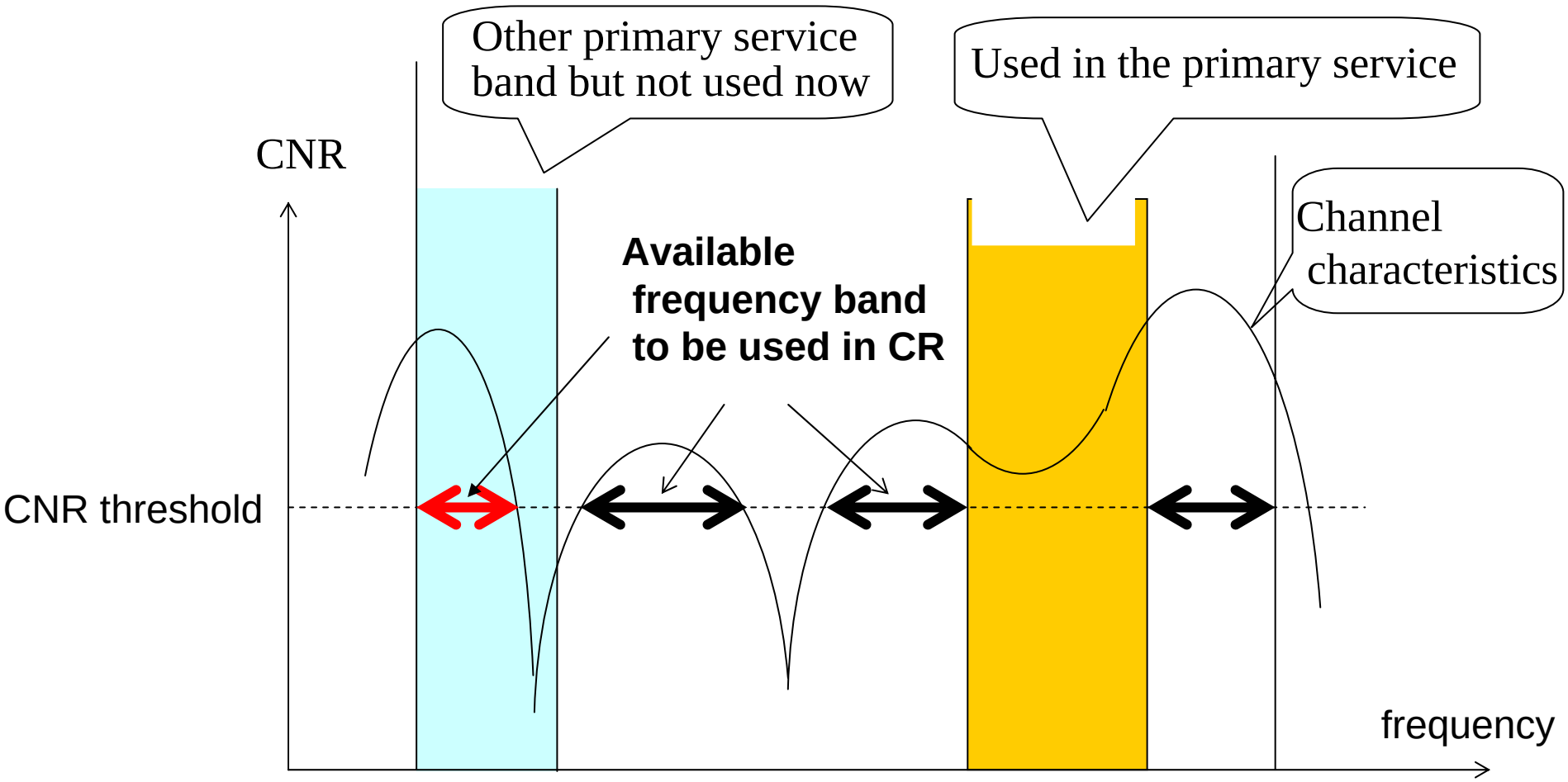
Ultimate Efficient Use of Radio Frequencies
Avoiding Radio Congestion

Baseband Radio

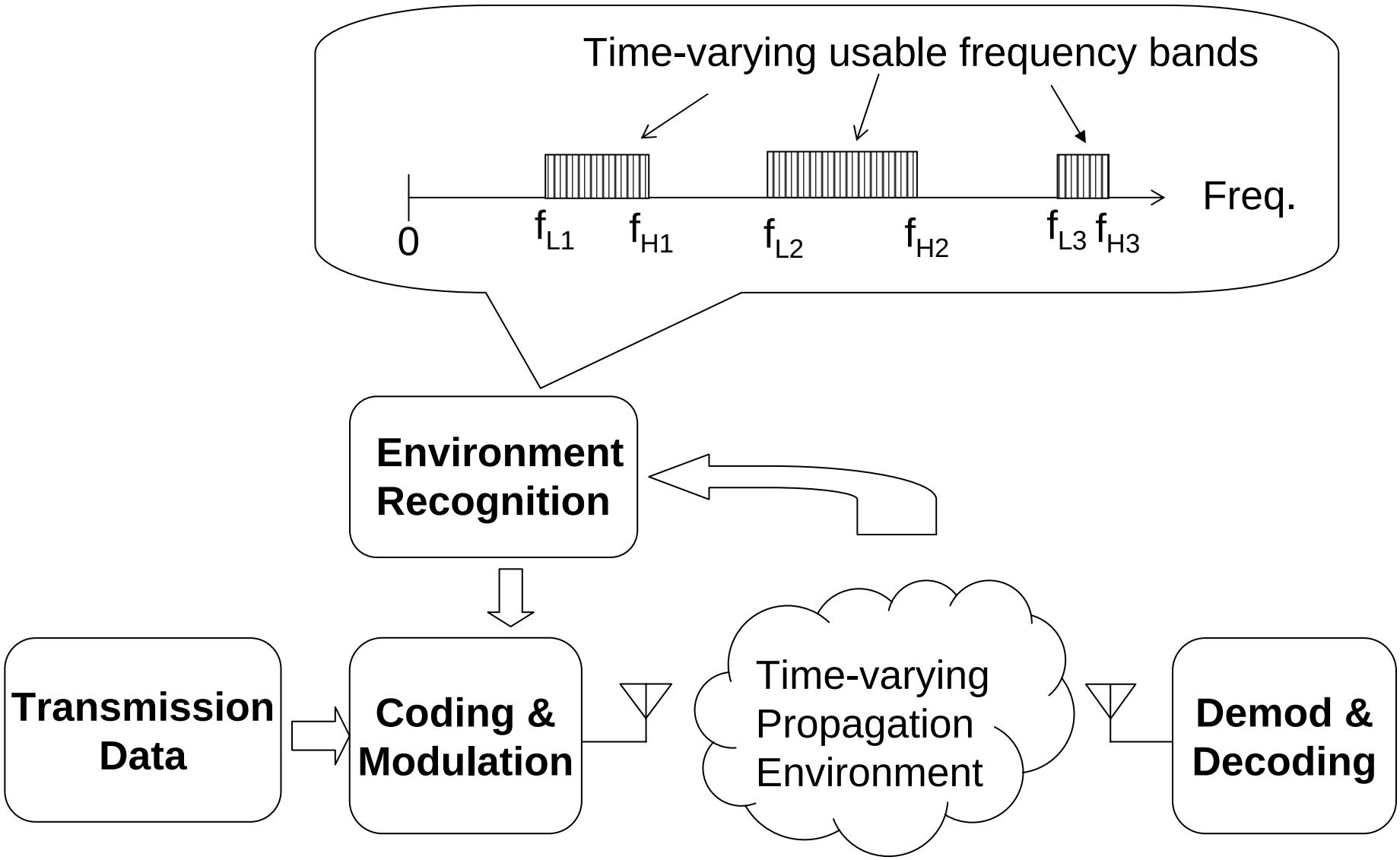
with Software-Defined Radio(*)
and Cognitive Radio(**)
functions

*) Kaleidoscopic change of configuration
(reconfigurable)
**) Recognition of radio encironment
(intelligent)

Cognitive Radio avoiding Radio Traffic Congestion based on Recognition of Radio Environment Change

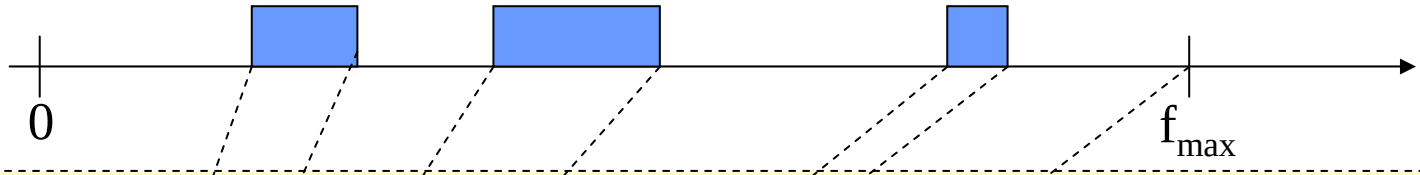


Baseband Radio with Cognitive Radio Function

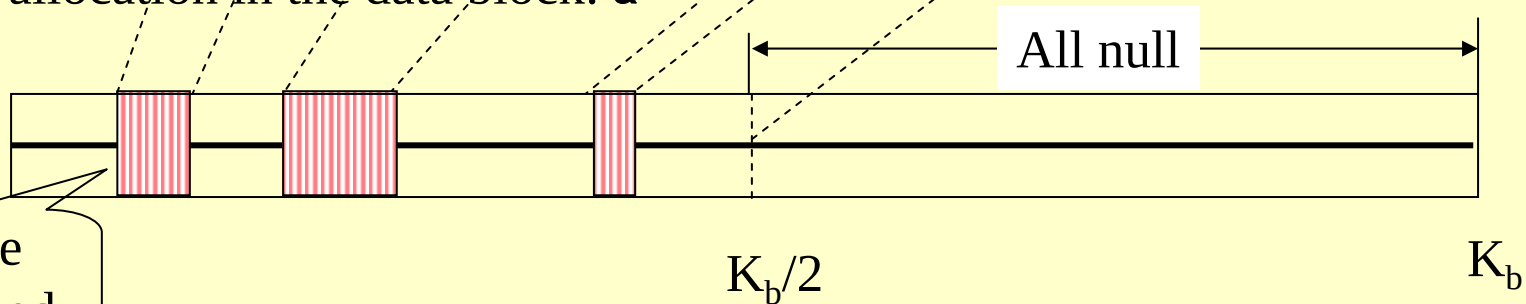


Creation of Transmission Signal

Frequency band to be used in this communication

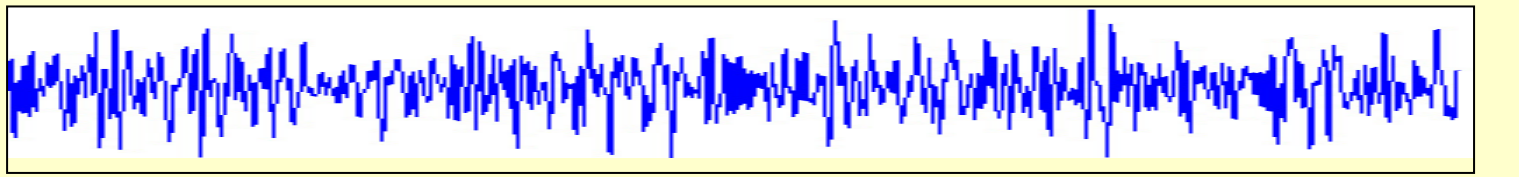


Data allocation in the data block: **a**



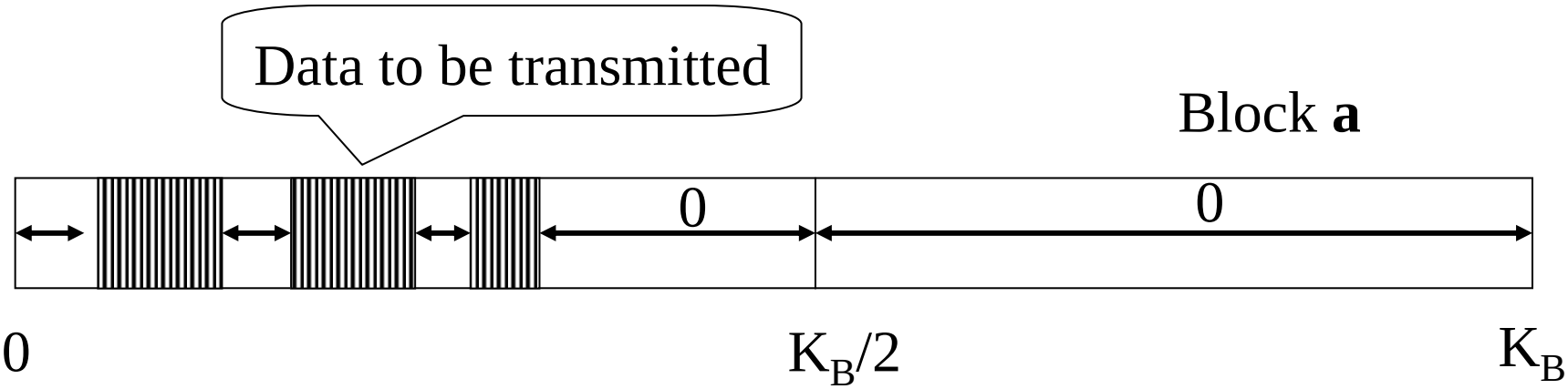
Re{IFFT(**a**)}

Signal to be transmitted

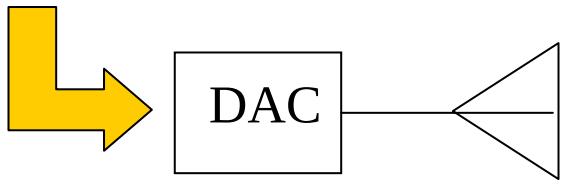


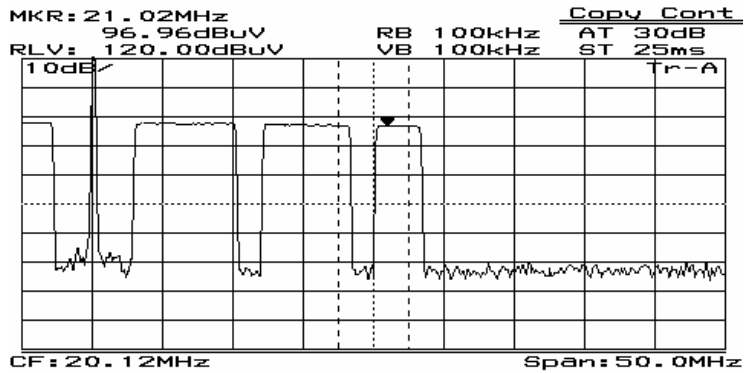
Baseband OFDM

Baseband OFDM



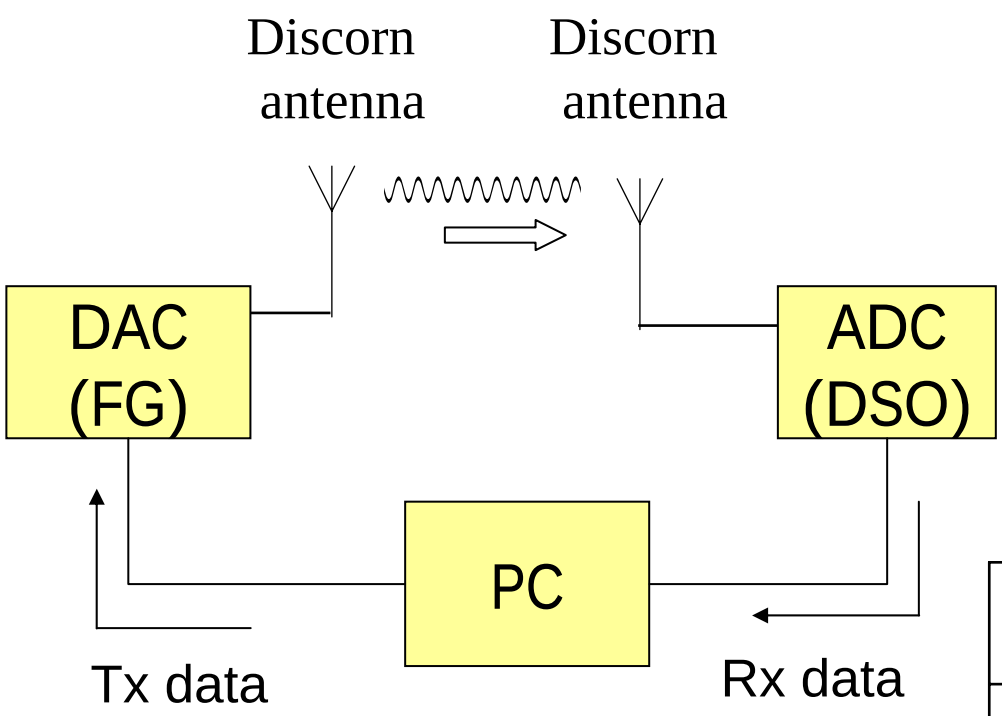
b = Re {IFFT (**a**)} Block **b**





Block b Signal is directly transmitted from the antenna without up conversion.

Basic Experimental Configuration and Procedure



DSO: Digital storage oscilloscope
FG: Function Generator

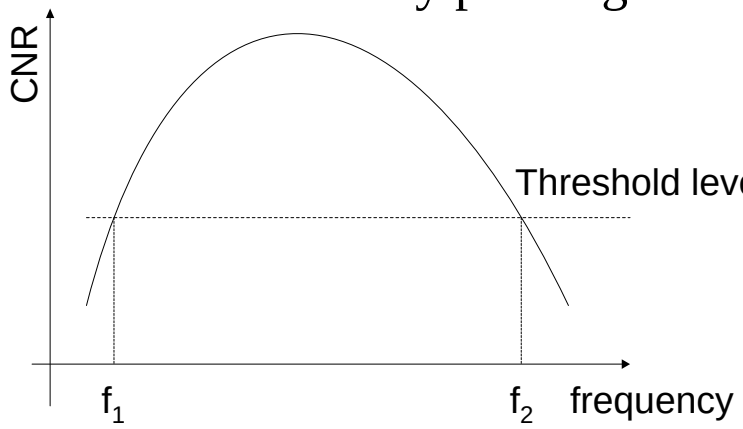
Experiment procedure
1 Environment recognition
2 Channel sounding
(using pilot signal)
3 Coding and Pre-distortion
4 Data transmission
5 Signal detection and analysis

Performance of DAC & ADC

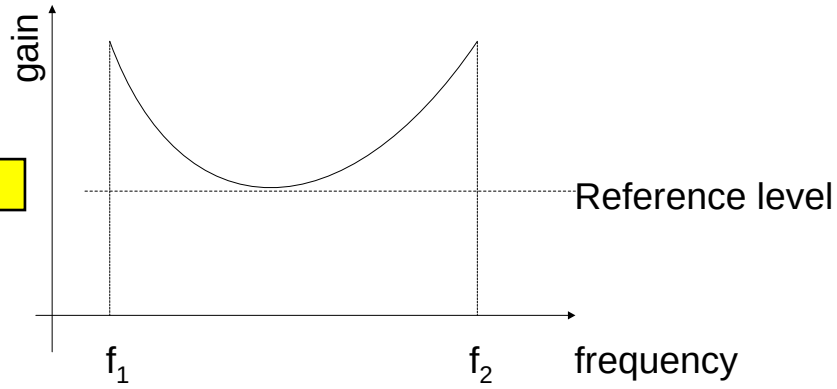
Sampling rate of DAC in FG	250MH z
Resolution of DAC	14bit
Sampling rate of ADC in DSO	250MH z
Resolution of ADC	8bit

Pre-Distortion

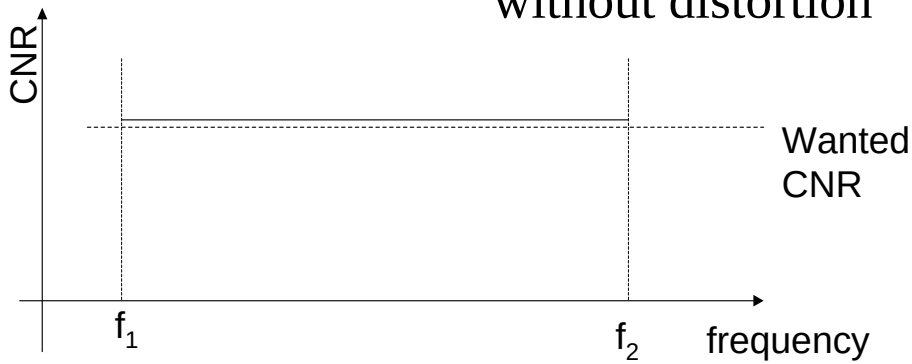
Channel characteristics
measured by pilot signal



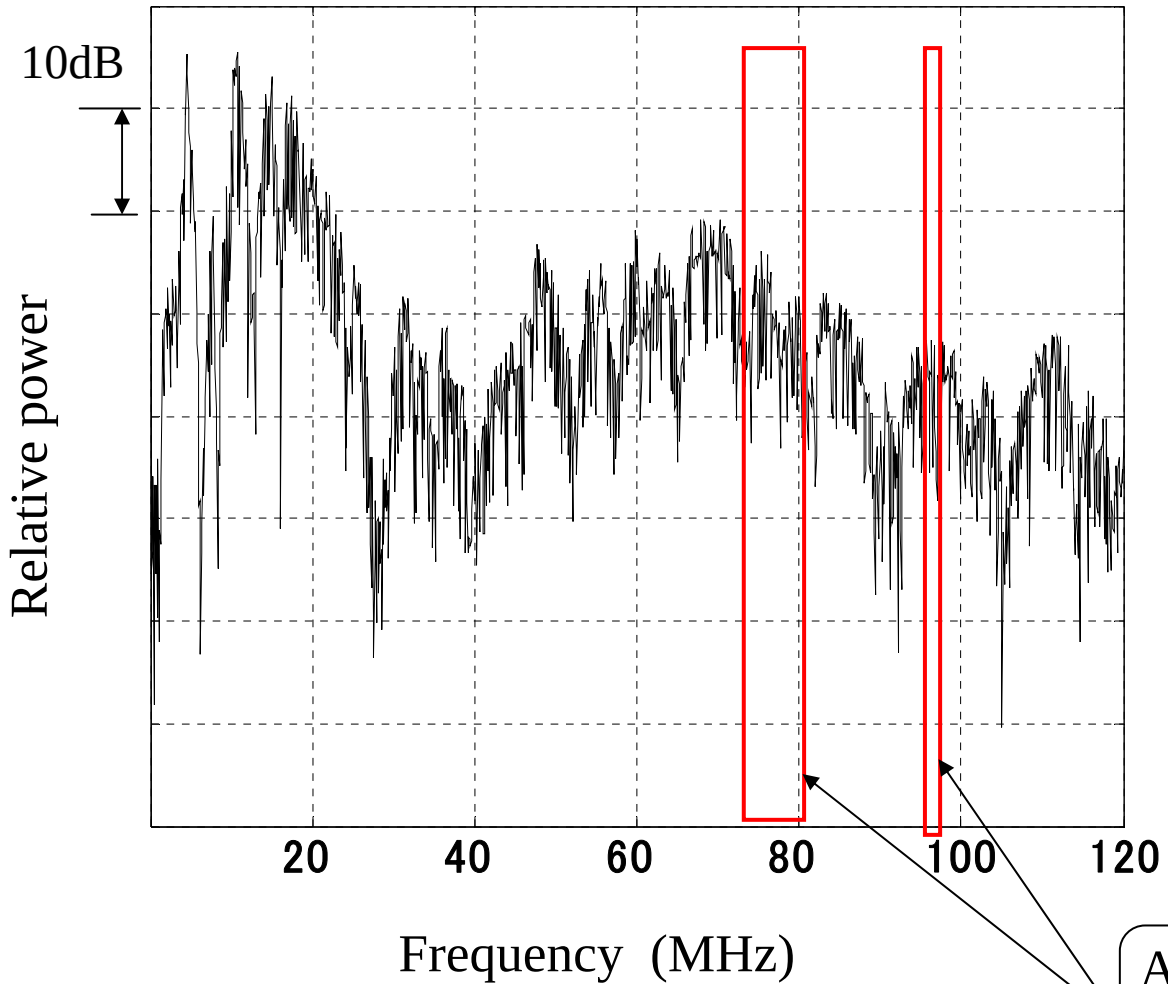
Pre-distorted
Tx signal

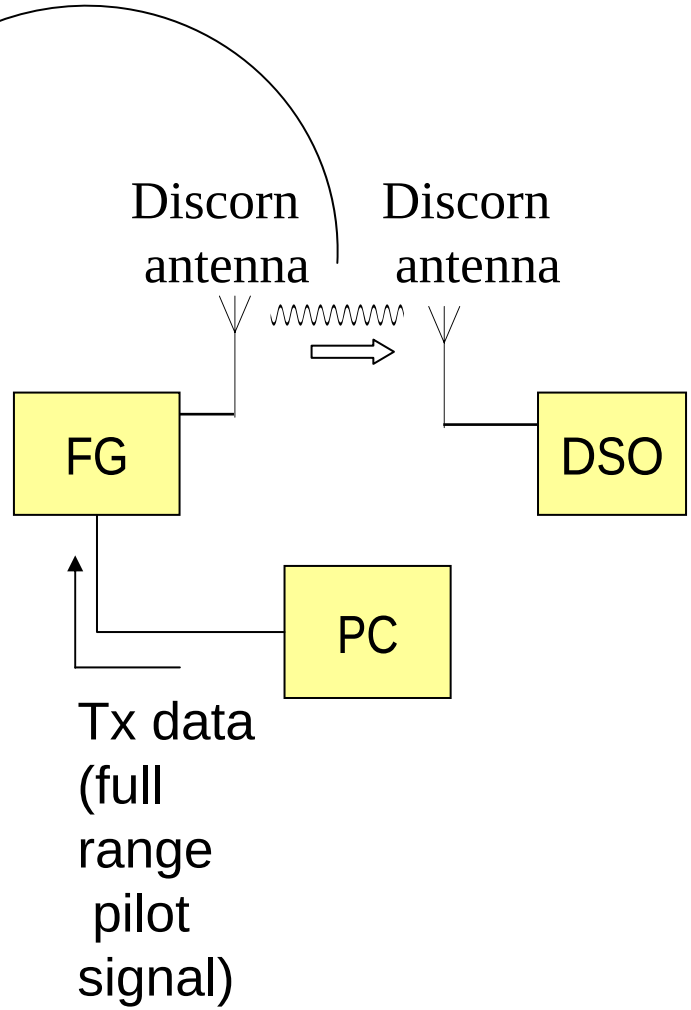


Received signal
without distortion



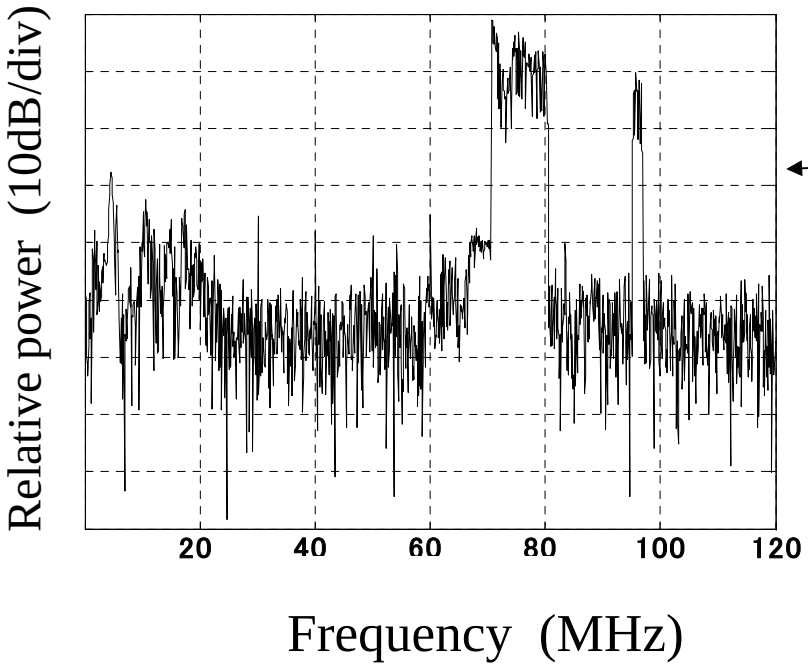
Full range channel monitoring

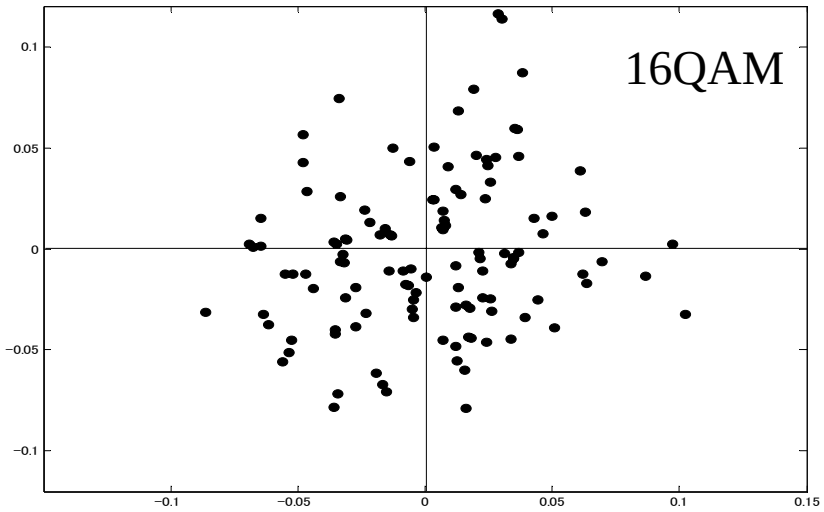


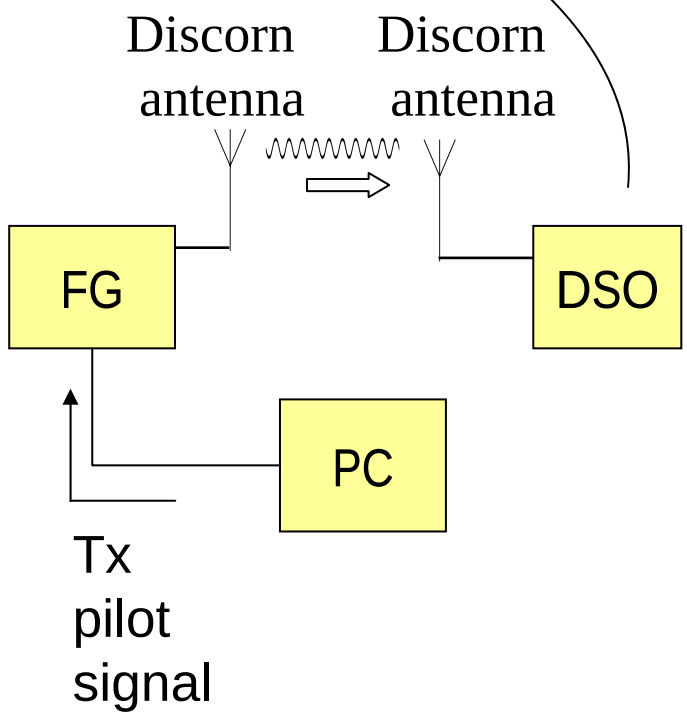


Allocated transmission frequency range

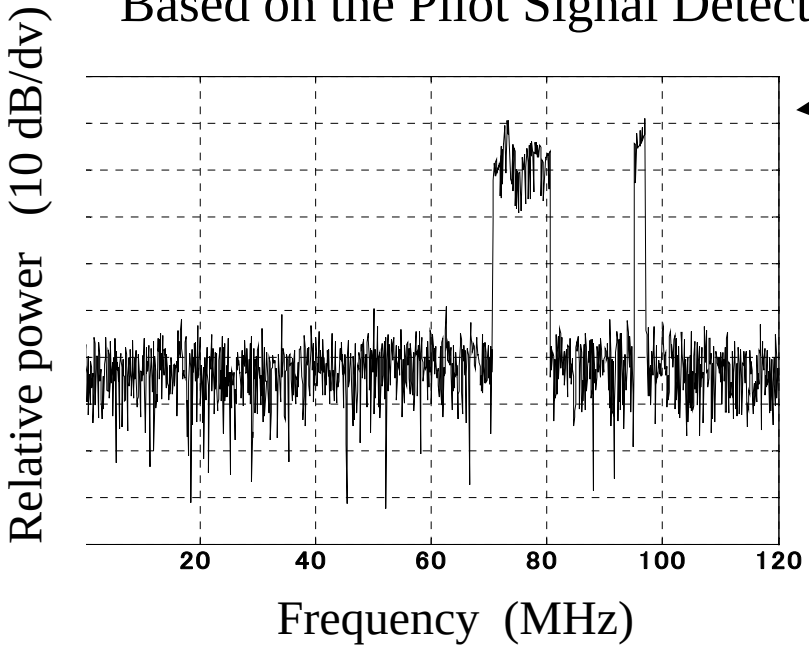
Pilot Signal Detection

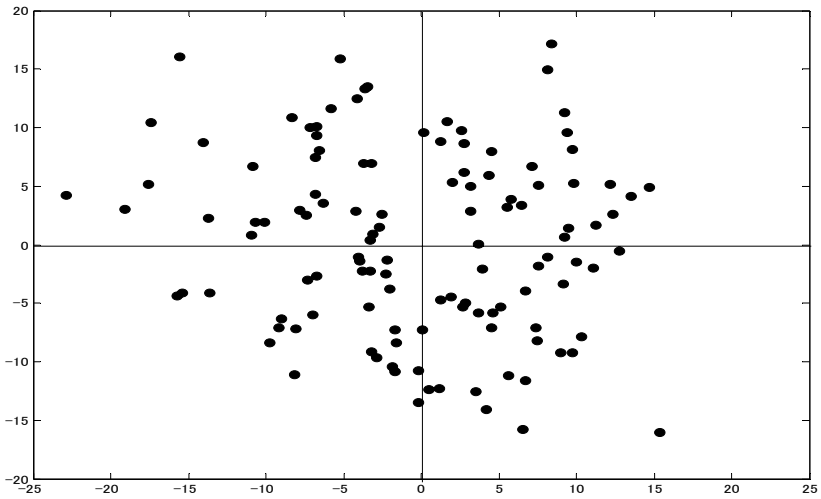


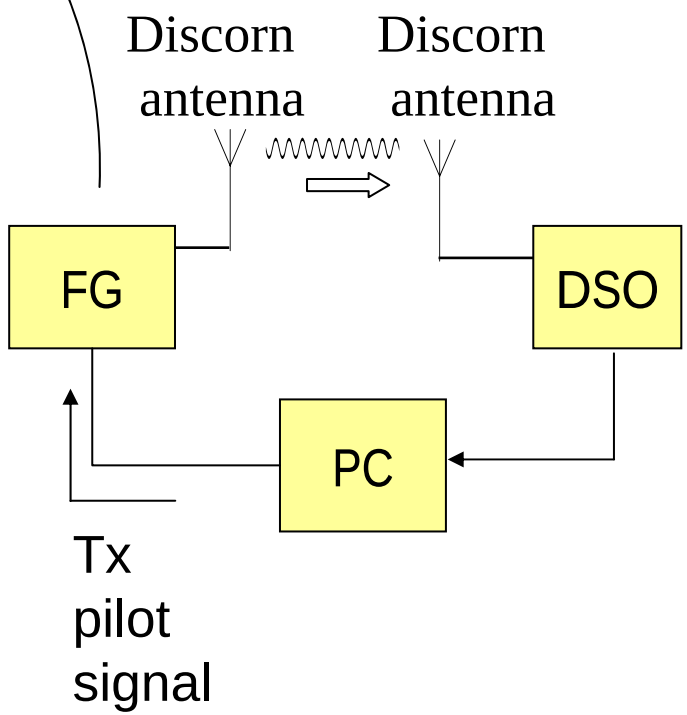




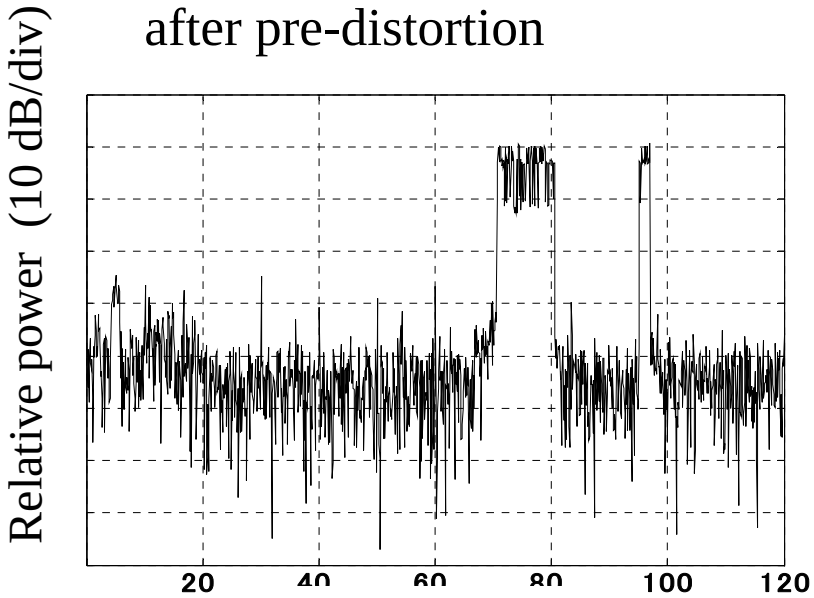
Pre-Distorted Tx Signal Based on the Pilot Signal Detection

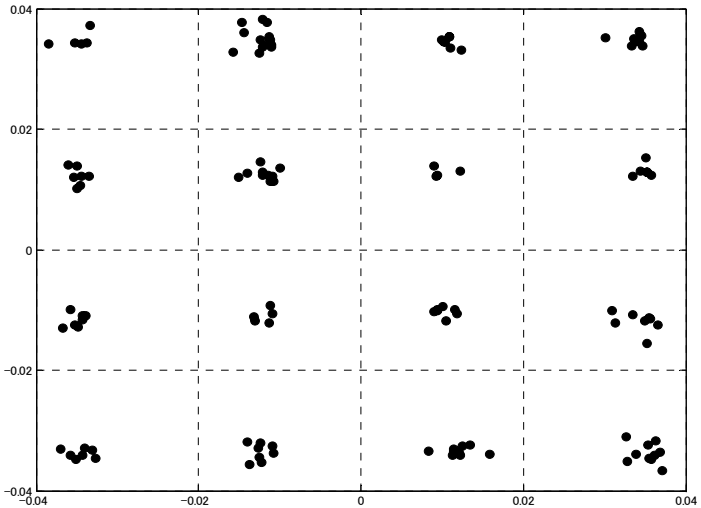


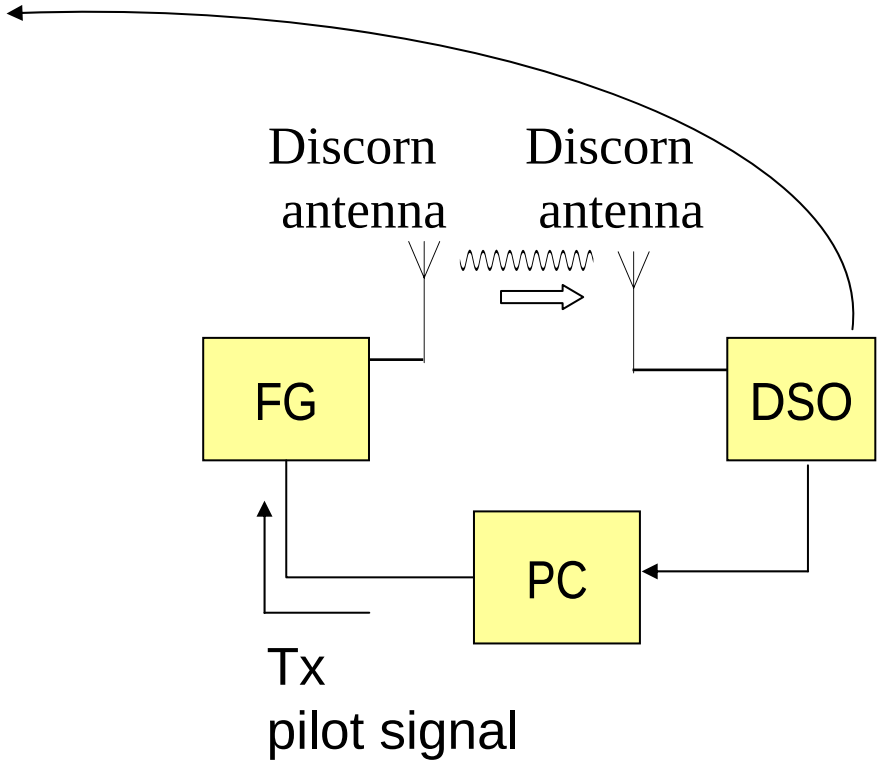




Received signal
after pre-distortion







Successful transmission of 16QAM based on “Baseband Radio” can be demonstrated!!

Evolution of Wireless Terminal

Software-Defined Radio

All necessary functions are created by software programing

Cognitive Radio

Environment recognition avoiding frequency congection

Hardware Technology

Importance of RF circuit technologies is kept forever.

- Wideband antenna
- Antenna array (MIMO)
- Tunable RF filter
- Other RF circuits

Wireless terminal

Baseband Radio

Transmission signals are directly created by digital signal processing

AWCC

UEC Tokyo

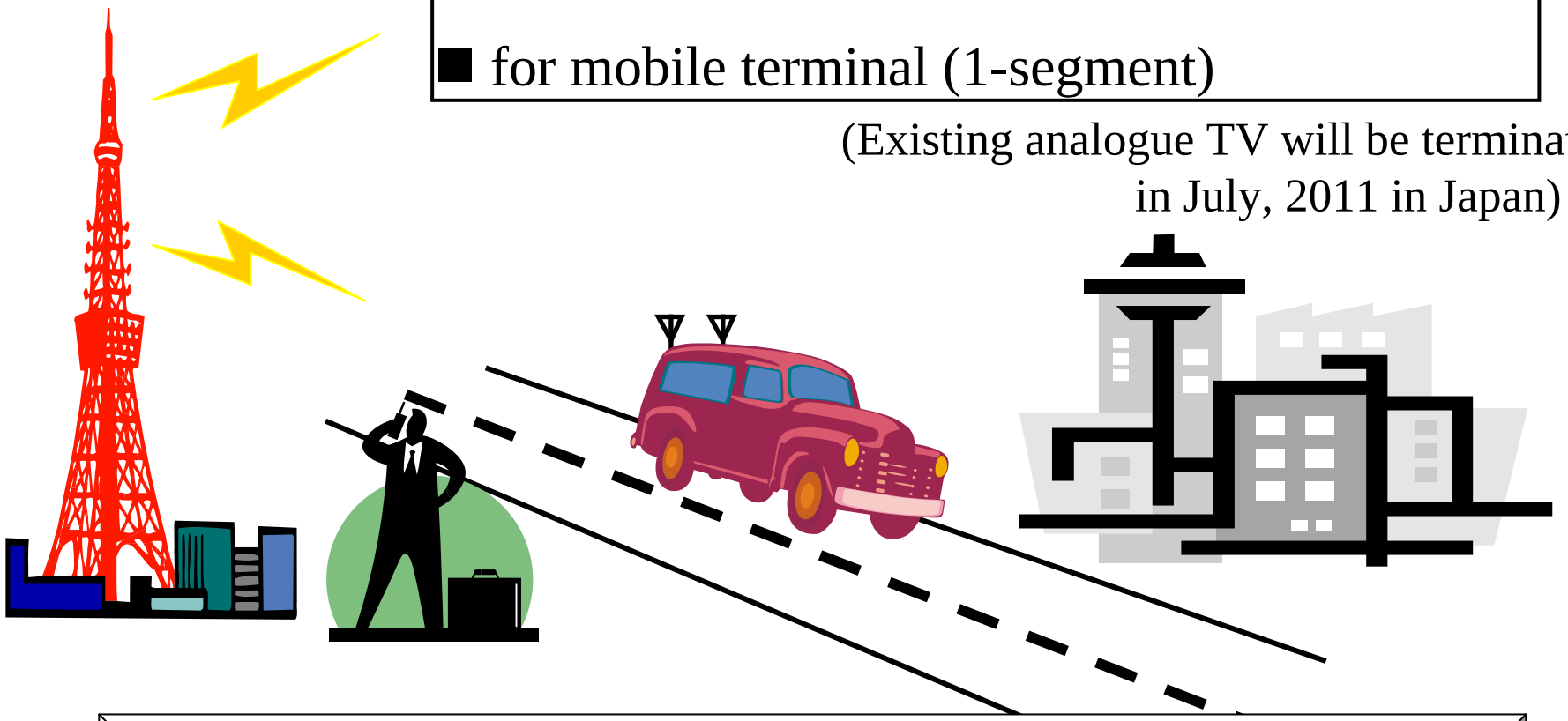
Antenna Diversity

based on **Radio Signal Processing** for Terrestrial Digital TV

Terrestrial Digital TV Service in Japan

- for In-house reception (12-segment HDTV)
- for mobile terminal (1-segment)

(Existing analogue TV will be terminated in July, 2011 in Japan)

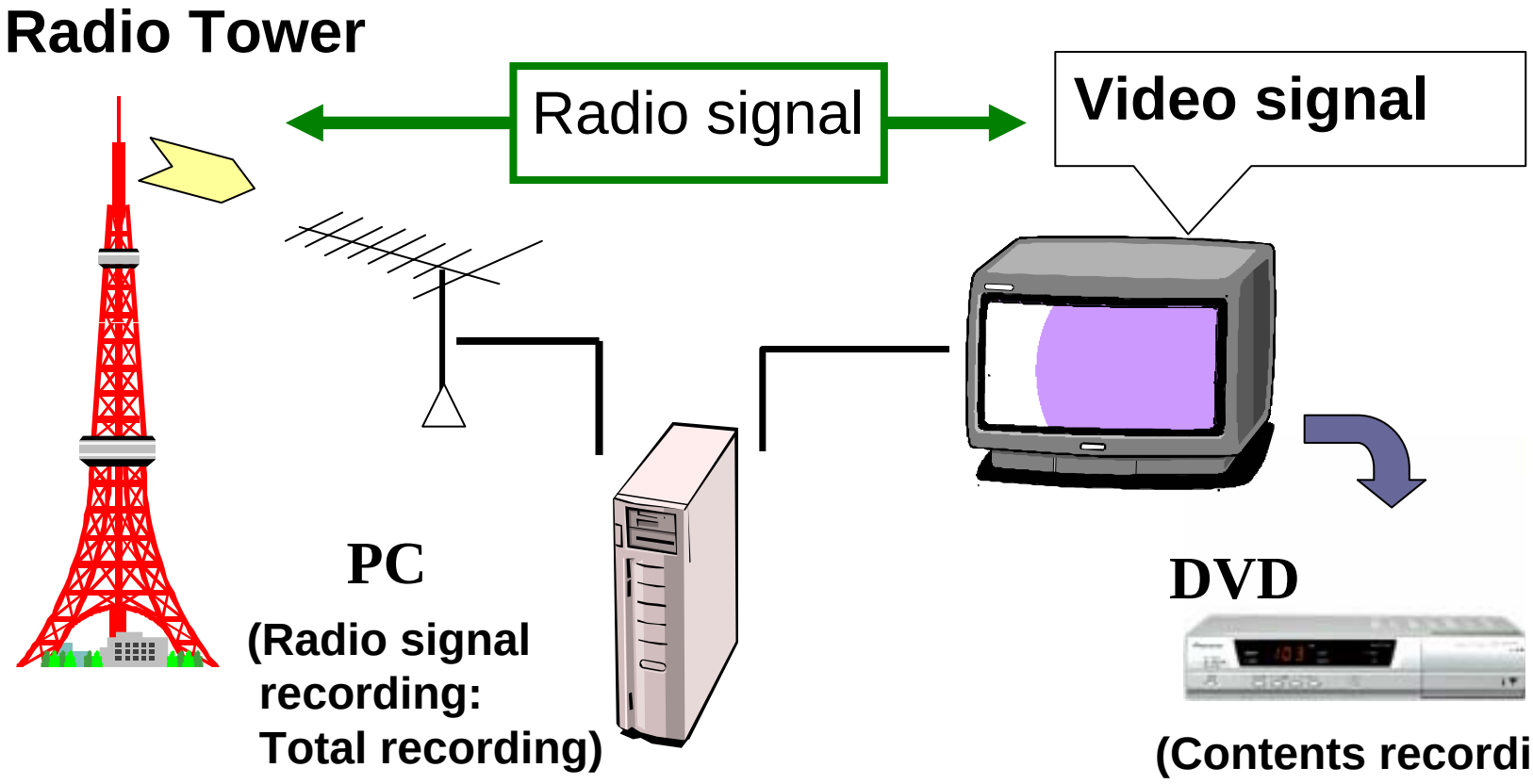


For reception in a vehicle, space diversity is indispensable.

- Specification of Digital TV (ISDB-T)

Bandwidth	5.572 MHz
OFDM symbol period (T_s)	1,008 μs
Guard Interval (T_{GI})	126 μs
The number of subcarriers	5,616
The number of segments	13
Primary Modulation	64QAM (HDTV) QPSK (1-seg.)
TV channel	27ch（NHK-G）、
Carrier frequency	557.142857MHz

Total Recording



Recording of radio signal (IF signal) directly to HDD in PC

Continuous recording of 200MB/s (=100MS/s) can be done.

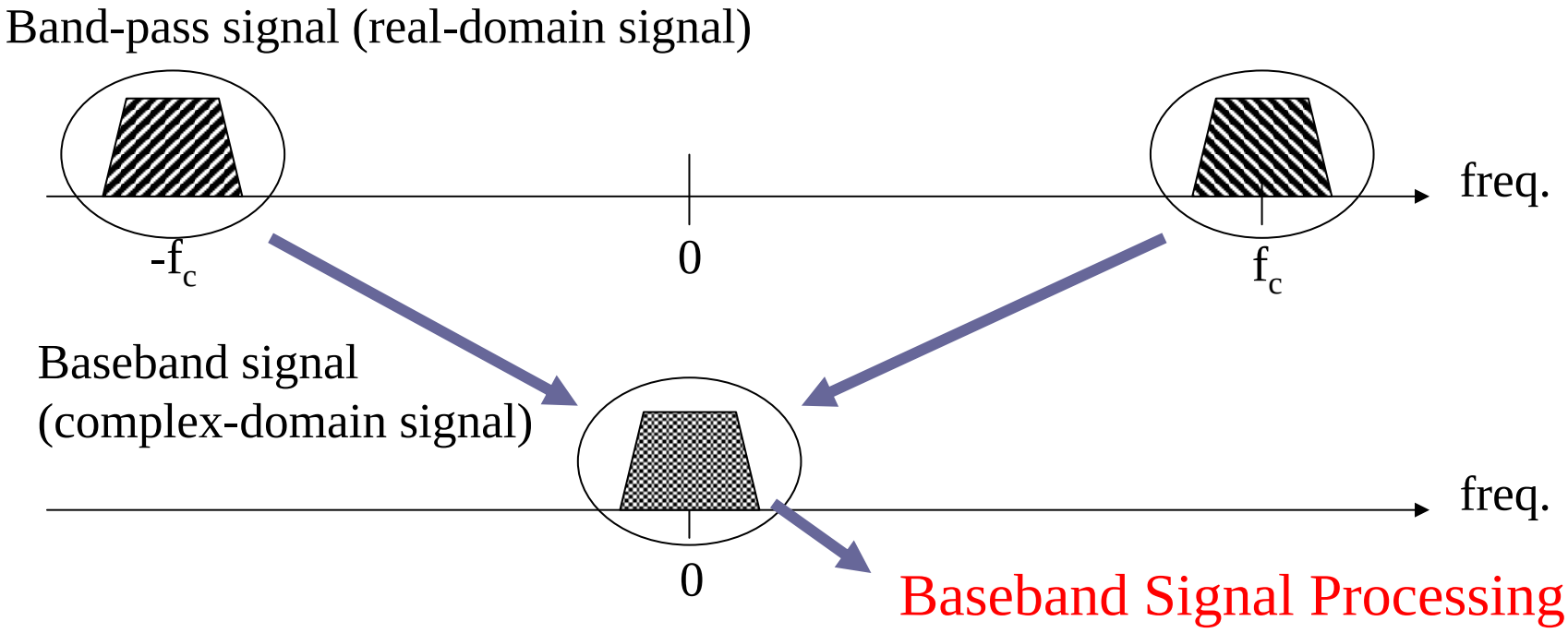
Adaptive Array based on Radio Signal Processing

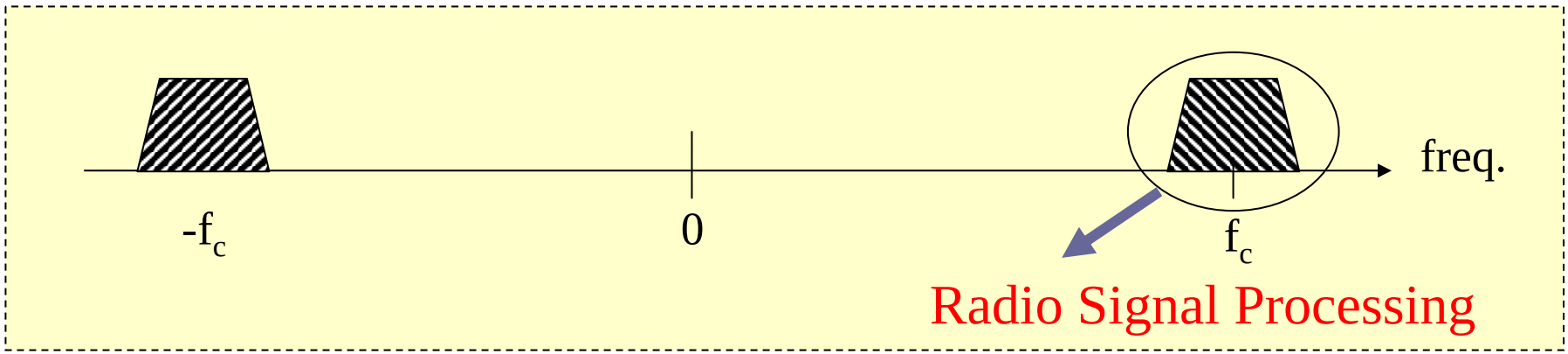
"Radio Signal Processing" which processes IF signal directly without demodulation and detection.

Application of this scheme to the maximal ratio combining diversity scheme with subband signal processing for mobile reception of terrestrial digital TV broadcasting signal

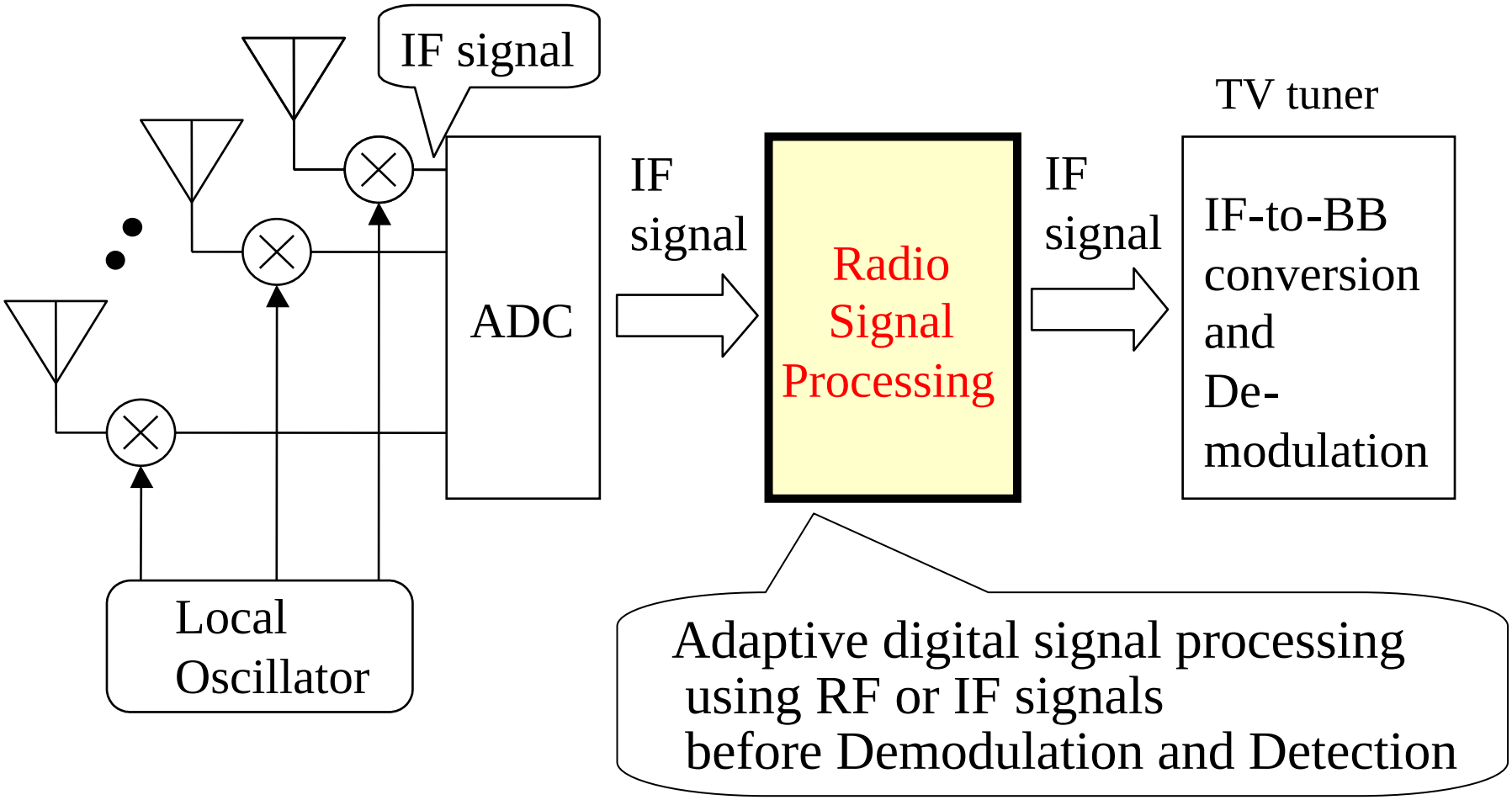
.

Baseband Signal Processing and Radio Signal Processing



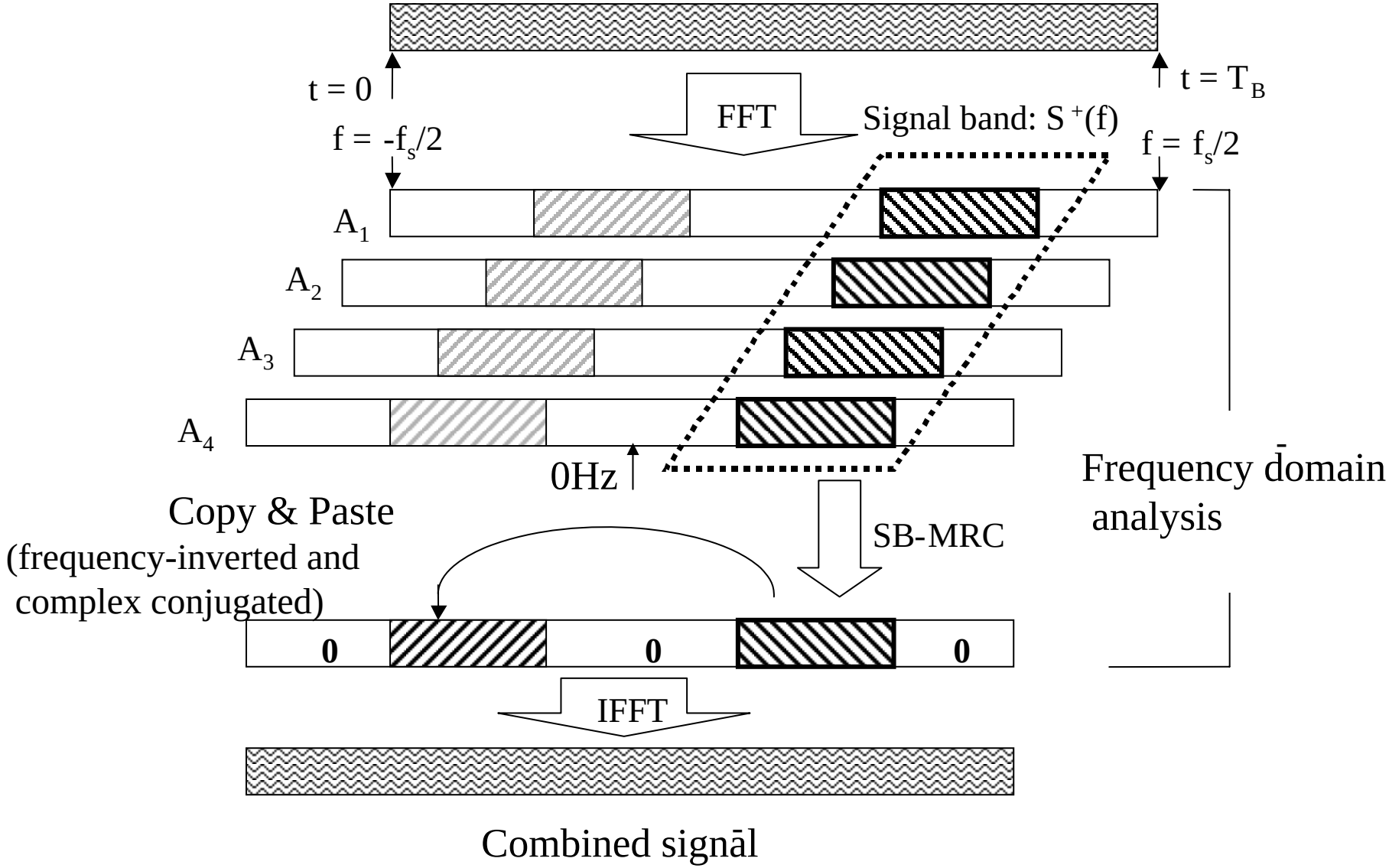


Radio Signal Processing Adaptive Array



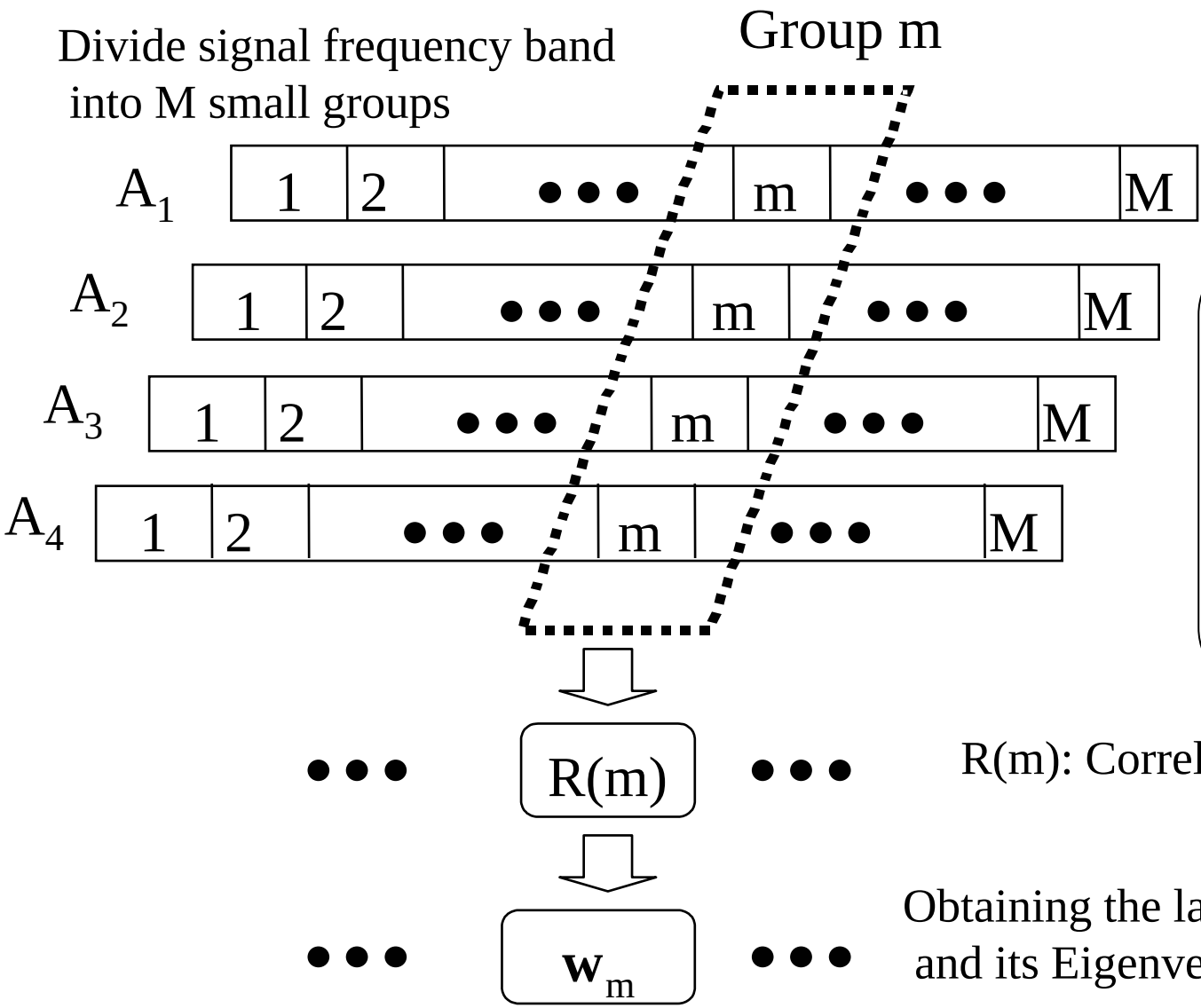
Radio Signal Processing

IF signal for antenna A_1 (real-domain signal)
(OFDM block Extracted symbol-by-symbol base)



Maximal-Ratio Combining with Subband Signal Processing

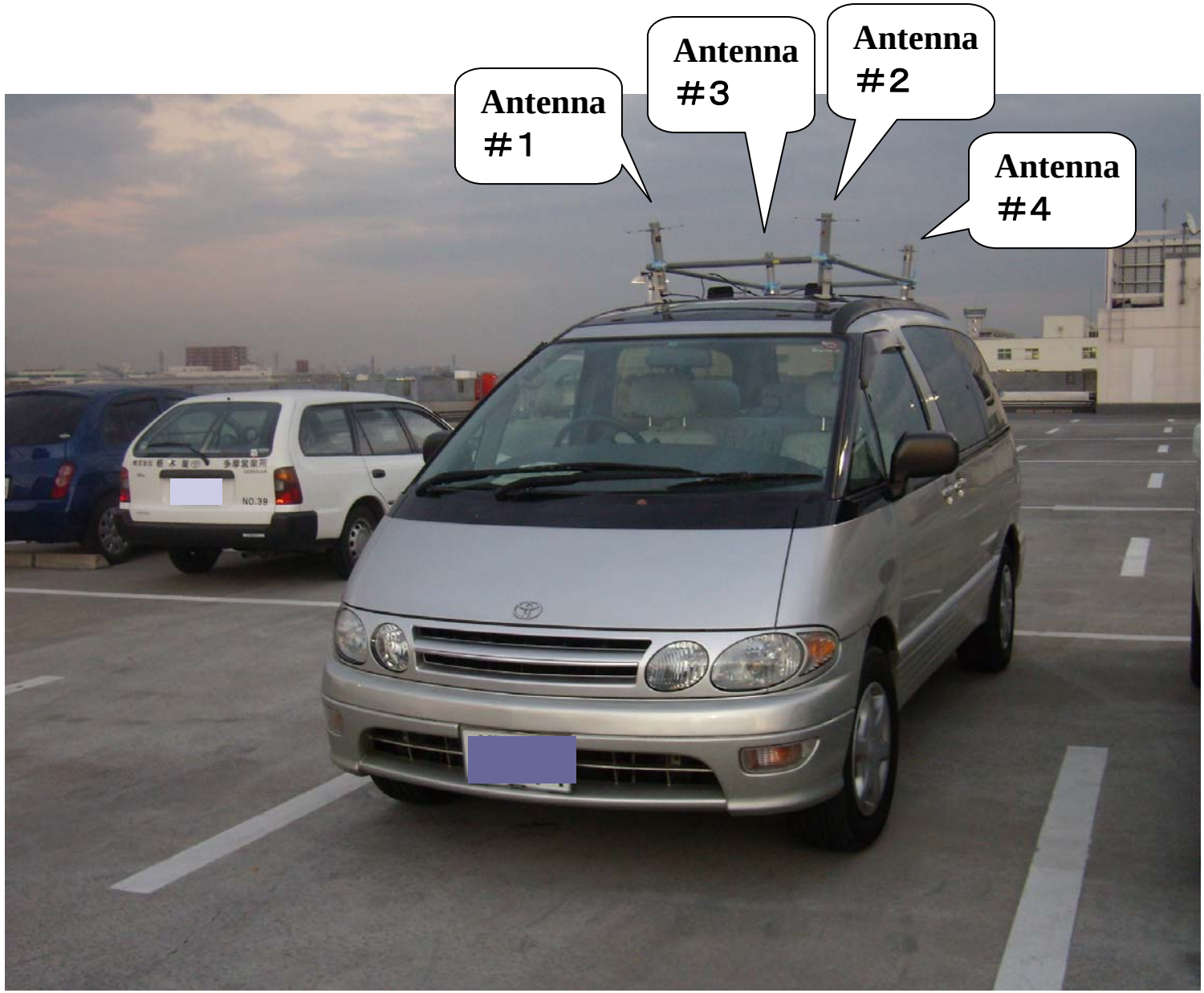
Divide signal frequency band into M small groups



The validity of the scheme has been confirmed through field experiments (off-line proc.)

R(m): Correlation matrix

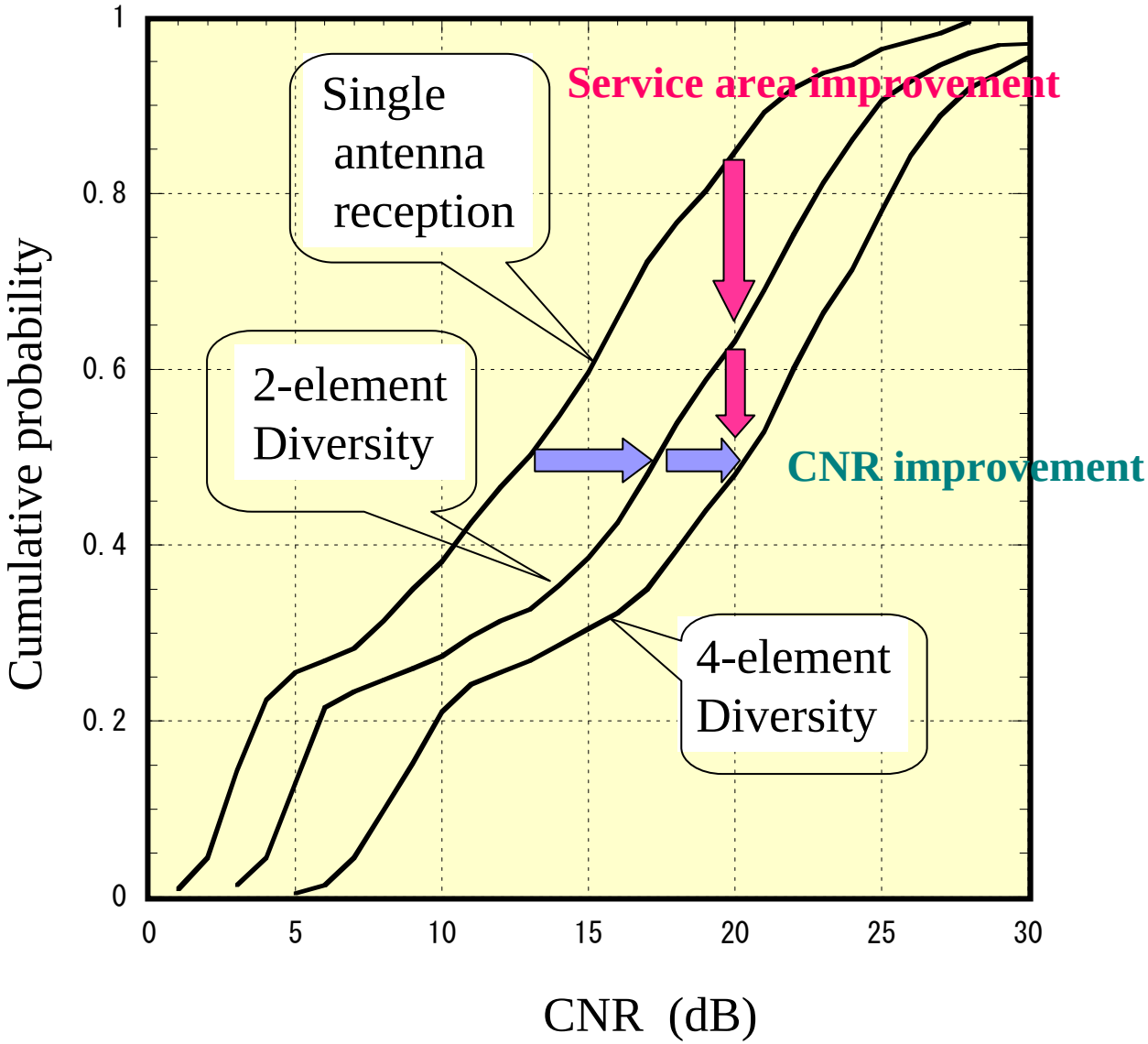
Obtaining the largest Eigen value and its Eigenvector


Antenna
#1
Antenna
#3
Antenna
#2
Antenna
#4

Demonstration of MRC reception based on Radio Signal Processing

(omitted)

Diversity Effects (Analyzed based on RSP)



The Three Radios, again

Adaptive Communication