Outline

1. What is the Baseband Radio?
   - Baseband Signal vs. Bandpass Signal

2. Frequency-Domain Packet Communications

3. Experiment on Baseband Radio
   Adapting to Environmental Change

4. Future Topics
Baseband Radio

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

*) Kaleidoscopic change of configuration (reconfigurable)
**) Recognition of radio environment (intelligent)
What is the Baseband Radio?

In the case of transmission:

- **Baseband Signal** \( I(t), Q(t) \)
- **Modulation & Up conversion**
- **Carrier signal**
- **Conventional Wireless Transmission Scheme**

**Baseband Radio**

- **Digital Signal Processing**
- **Information on Communication Environment**
- **Frequency-Domain Packet Signal**
  - Radiowave is directly created by digital signal processing.
  - BR seems promising in the days when GHz speed processing is commonly available for DAC, ADC and DSP devices.
**Baseband signal**
- time domain: complex
- freq. domain: complex

**Wireless transmission signal**
- time domain: real
- freq. domain: complex

(a) Baseband signal

(b) RF signal transmission

(c) Low-IF signal transmission
from Low-IF OFDM Transmission to Baseband Radio Transmission

**Low-IF OFDM** (real signal in time domain)

This signal is directly created based on digital signal processing.

Activation of necessary subcarriers

\[ f_{\text{max}} = \text{GHz freq.} \]
Baseband Radio with Cognitive Radio Function

Time-varying usable frequency bands

Transmission Data → Coding & Modulation → DAC → Time-varying Propagation Environment → ADC → Demod & Decoding

Environment Recognition

0 → $f_{L1}$ → $f_{H1}$ → $f_{L2}$ → $f_{H2}$ → $f_{L3}$ → $f_{H3}$ → Freq.
Creation of Transmission Signal

Frequency band to be used in this communication

Data allocation in the data block: $a$

Data to be transmitted

Signal to be transmitted $\text{Re}\{\text{IFFT}(a)\}$

Baseband OFDM

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

DAC
A transmission Scheme Suitable for Baseband Radio: Frequency-Domain Packet Communication

Frequency-domain packet signal

Time-domain block signal
A transmission Scheme Suitable for Baseband Radio:
Frequency-Domain Packet Communication

All necessary information about each data block configuration is given in this control channel.

Block configuration is changed block-by-block based on environmental change.
Experimental Validation of Adaptive Baseband Radio

- Anechoic chamber
- Reverberation chamber
- Wired connection (for system check)

DAC: 4GSps
ADC: 6GSps

QPSK or 16QAM
OFDM subcarrier space: 100kHz
Usable bandwidth: 30MHz (adaptive)
Frequency range: 1GHz-2GHz(max)
Wired Connection (for System Check)

BW of 10MHz having 100 subcarriers (randomly assigned)

Frequency-domain packet communication is successfully demonstrated.

[16QAM received: SNR>30dB]
Experiment in a radio anechoic chamber

Broadband antenna
1.1GHz-1.9GHz (VSWR <2.0)
Broadband Antenna used for the experiment

(back)

(front)
Results of the Experiment in the Anechoic Chamber

![Graph showing BER vs CNR for QPSK and 16QAM](image-url)
Experiment in our reverberation chamber (multipath-rich environment)

Size: 4(m) x 2(m) x 2(m)
Amplitude:
Rayleigh distribution
Delay spread: 90ns
(controlled using radio absorbing sheets)
Results of the Experiment in the Reverberation Chamber (1)

Part 1: Without adaptation
  Tx power level: Fixed (without TPC)
  Subband allocation: Random

- Pilot signal: 1MHz spacing
- Pilot signal: 100kHz spacing

QPSK
Results of the Experiment in the Reverberation Chamber (2)

Part 2: After adaptation

Tx power level: Controlled based on CSI
Subband allocation: Optimally selected

Very good performance corresponding to fading-free condition is obtained.
Merits (○) and Demerits (●) of BR

○ Extremely Adaptive for Environmental Change
  (Frequency-domain packet communication)

○ Almost all digital signal processing
  matching with future SDR and CR

● Requirement of ultra high speed DAC, ADC and DSP
  ( →Future technologies will overcome this requirement.)

● Non-linear problem for strong interference signal incidence
  ( →One countermeasure is given in the next slide.)
BR receiver is waiting for incoming signals with broadband range.
Non-linear problem of front-end receiver for strong interference signal incidence

Not necessary to cancel the interference perfectly
Operation Image of Countermeasure for Strong Interference Incidence

1) Reduction of interference power by adaptive notch filter
2) Relocation of wanted signal to other frequency
to avoid the effect of the notch filter
An Example of Interference reduction using adaptive filter and data relocation

![Graph showing BER vs CNR for different cases: 1. No interference, 2. Signal Only, 3. Signal + Interference, 4. Signal + Filtered interference, Relocated signal + Filtered interference.](image)

- OFDM 16QAM Theory
- Signal Only
- Signal + Interference
- Signal + Filtered interference
- Relocated signal + Filtered interference
The Three Radios

Ultimate Adaptive Communication

**Baseband Radio**
Radio signal is directly generated or analyzed as if it is baseband signal

**Software-Defined Radio**
All functions are realized based on software programming

**Cognitive Radio**
Available resources are utilized flexibly based on environment recognition
Thank you very much for your kind attention.

The contents in this presentation are given in
2) Y. Morimoto, et al., “Experimental validation of adaptive radio,”
   IEICE Trans. Electronics (Japanese Ed.), (accepted).