R&D Activities for Future Mobile Communications

- On Frequency Sharing Type Cognitive Radio Technologies -

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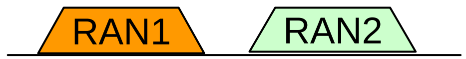
Development of Spectrum suitable for Mobile Communications

(1) Development of Higher Frequency (> 5GHz)

(2) Utilization of Multiple Existing Spectrum

- E.g. Hybrid Cellular and WLAN
- Heterogeneous Cognitive Radio



(3) Secondary Use of Unused Spectrum

- E.g. White Space

(4) Collaborative Spectrum Sharing among Multiple RANs

- Inter Operator (e.g. ISM band)
- Intra Operator (e.g. Migration of Cellular Generation)

(5) Efficient Spectrum Use for a single RAN

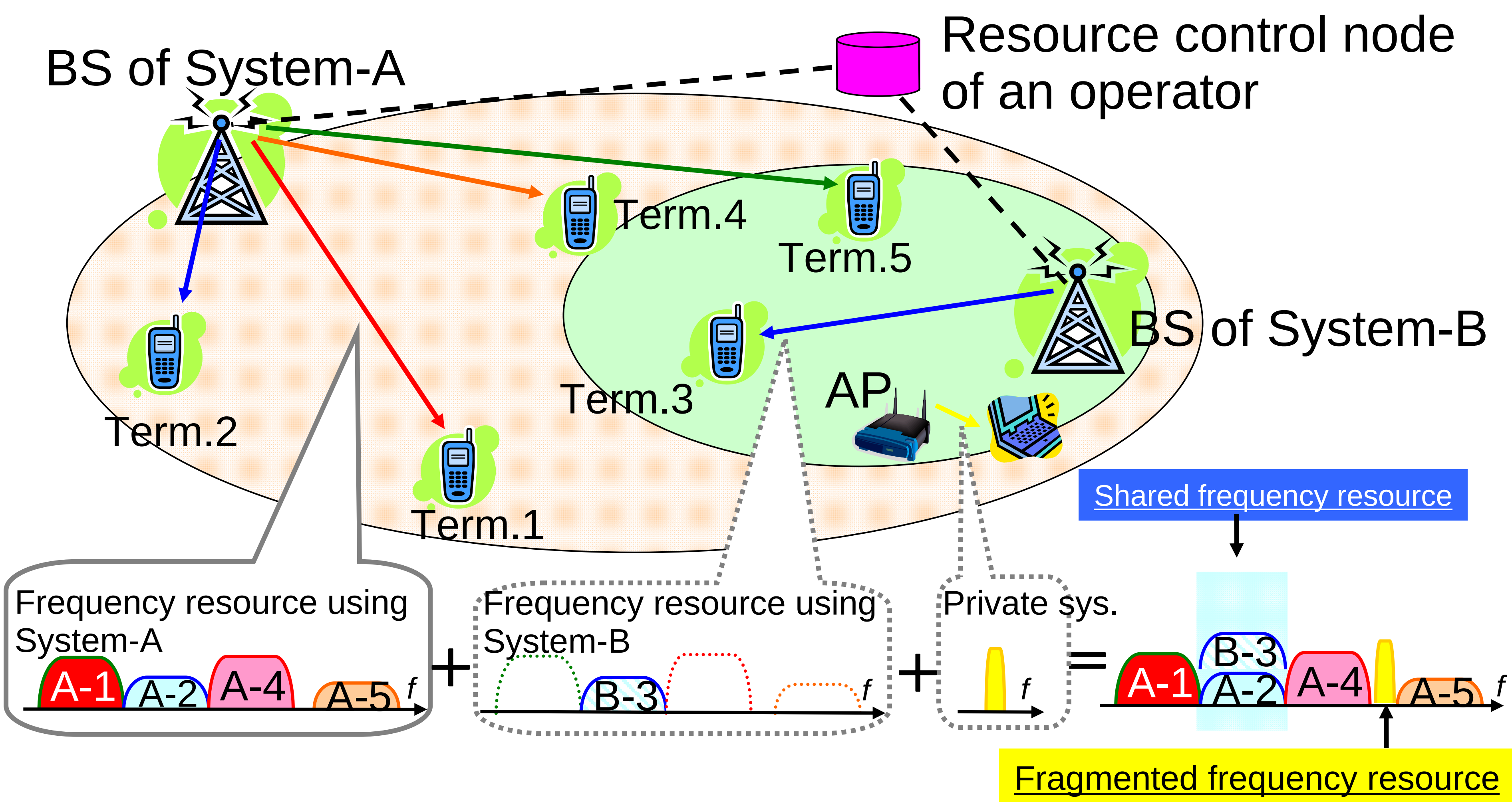
- HSDPA, LTE, 4G, etc.

Interest for a Mobile Operator

Target Application of Cognitive Radio Technologies

Purposes of "radio resource control technologies among multiple RANs on same frequency band"

(A) Reducing interference under a single operator -> Centralized approach
(B) Reducing unused spectrum shared with multiple operators -> Autonomous approach



Signal Recognition Independent from Wireless Systems

Target

Second order cyclostationality based signal detection algorithm that can identify plural RANs within 1 frame time.
Implementation and evaluation of the detection algorithm in a real time test bed

•With different cyclic auto-correlation function (CAF) pattern, the radio source can be identified without decoding each signal

Low hardware impact and reliable signal recognition

Challenges

1. Receiver side:
   - Cyclostationality is a statistical characteristics, and requires relatively long observation time
   - Efficient and reliable CAF peak pattern recognition algorithm based on χ^2 test
2. Transmitter side:
   - Efficient injection of cyclostationality, especially for the system identification of the similar modulation (i.e. identification of OFDM based systems)

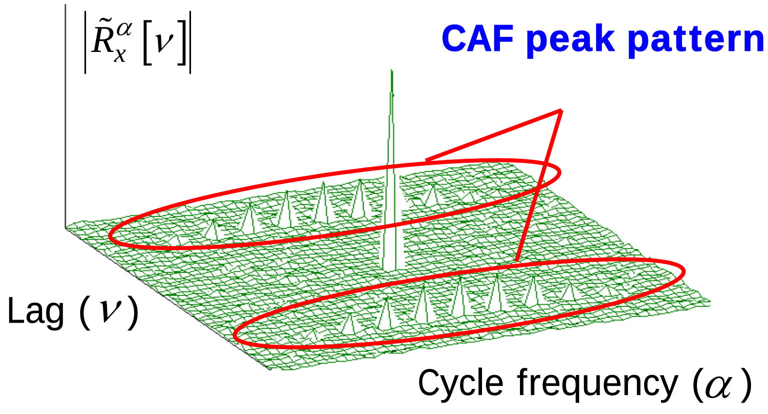
Second Order Cyclostationality

- Cyclic Auto-correlation Function (CAF) based signal identification

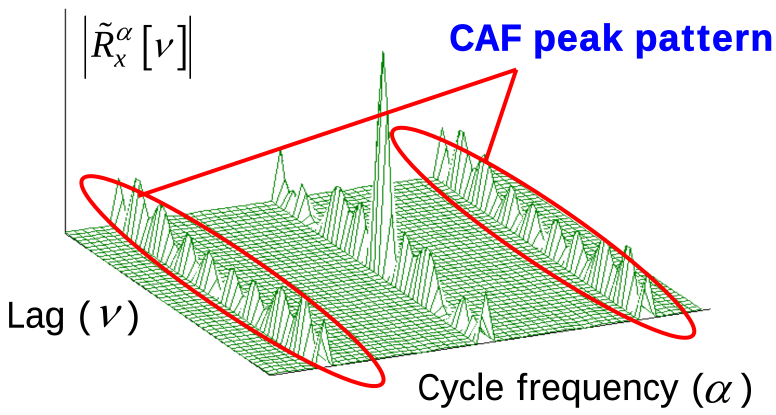
《Definition》 CAF of signal **$x[i]$**

$$\tilde{R}_x^{\alpha}[\nu] = \frac{1}{I_0}\sum_{i=0}^{I_0-1} x[i]x^*[i+\nu]e^{-j\alpha i T_s}$$

$x[i]$	:	signal sampled by time iT_s
T_s	:	sampling time interval
α	:	cycle frequency
ν	:	lag parameter
I_0	:	observation time



(a) CAF signature of an OFDM signal

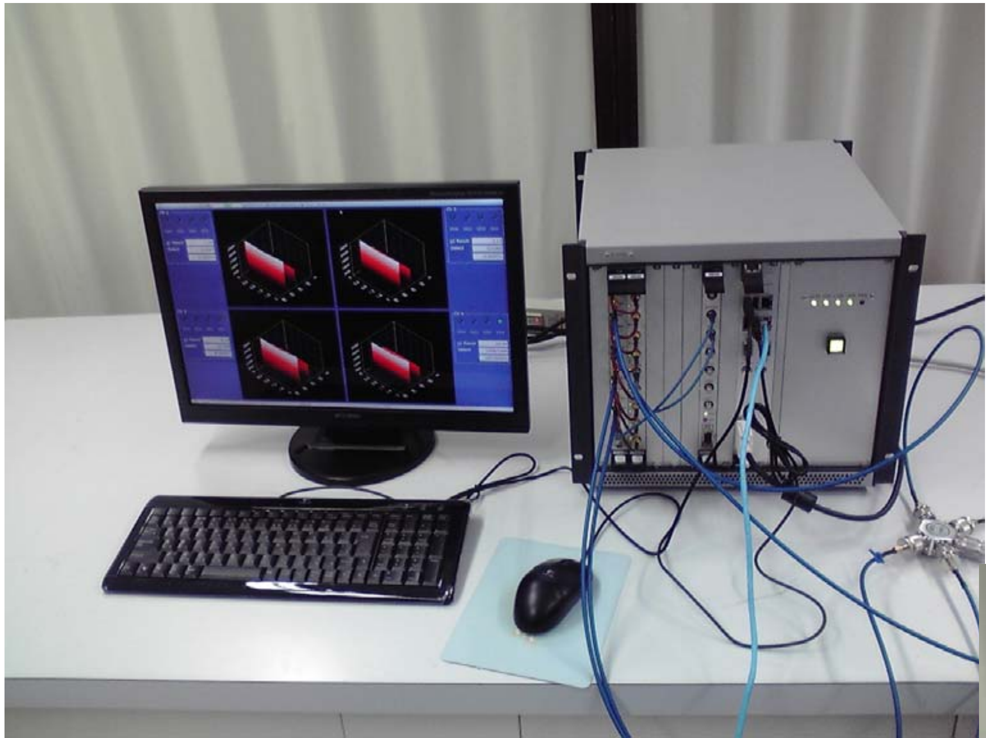


(b) CAF signature of a CDMA signal

Different Signal Source has Different CAF peak pattern

➔ ***Signal Identification without decoding each signal***

Experimental test bed for radio signal detection by using CAF



Appearance of experimental equipment

Spectrum Analyzer

Signal Generator

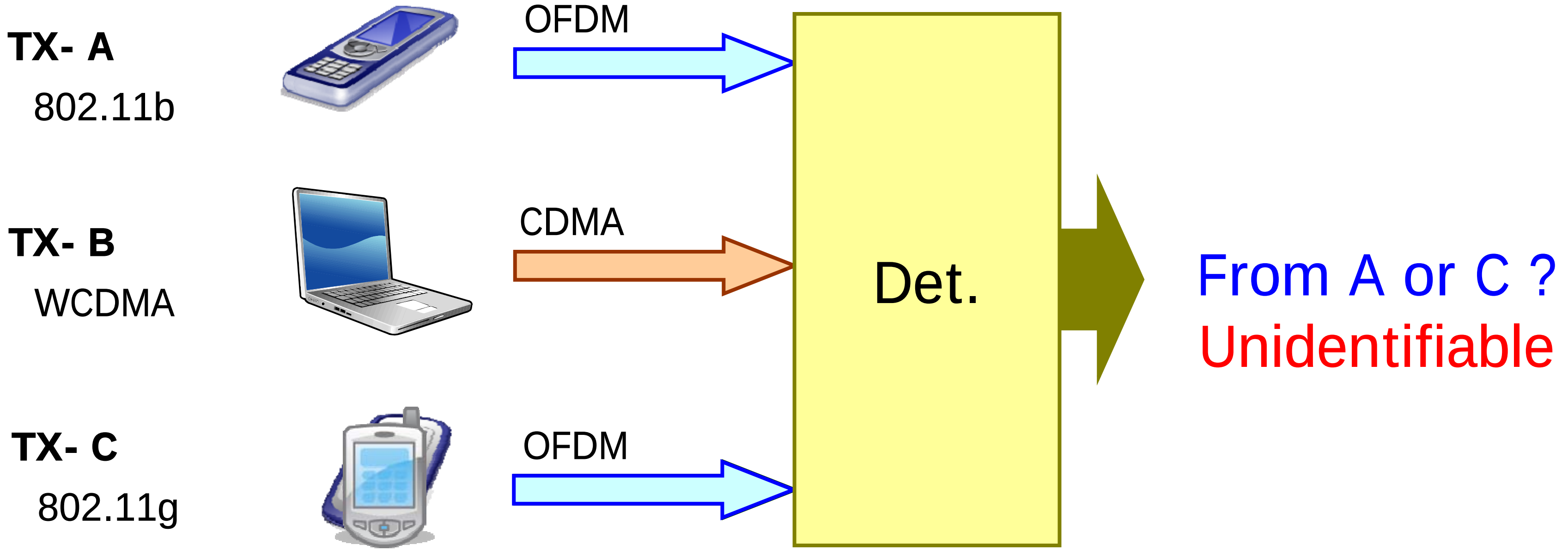
RF test signal is detected by the trial equipment by using CAF method

Signal detection technique applicable to multiple radio systems

３ : Efficient Injection of Cyclostationality to the same modulation signals

Detection of difference modulation signal is relatively easy

However, to identification among the same modulation...



➔ Method of different CAF characteristics to same OFDM modulation signals ware proposed [*]

※ It needs enough frame length and observation period.

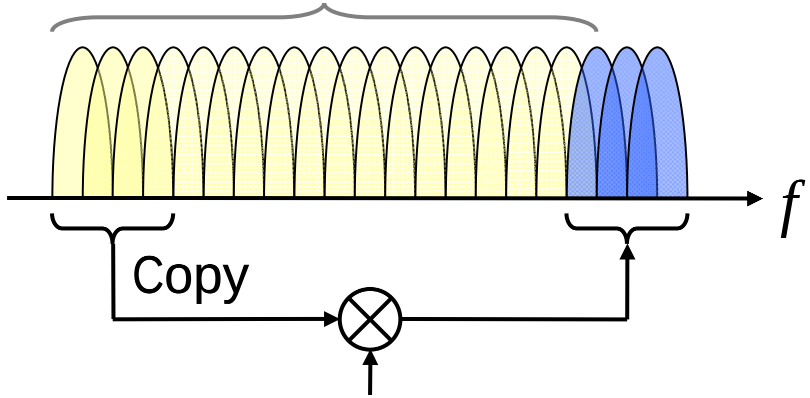
[*] EURASIP JWCN, vol. 2008, Article ID 586172

Signal detection technique applicable to multiple radio systems

Proposed CAF injection method

1) Make a copy a part of data transmission symbols
2) The symbols are artificially phase rotated and added as CAF sub-carriers

Sub-carriers (SCs) for data transmission



$\exp\{j2\pi mk\}$

Original SCs

K-th trans. symbol

$s_k = a_k$

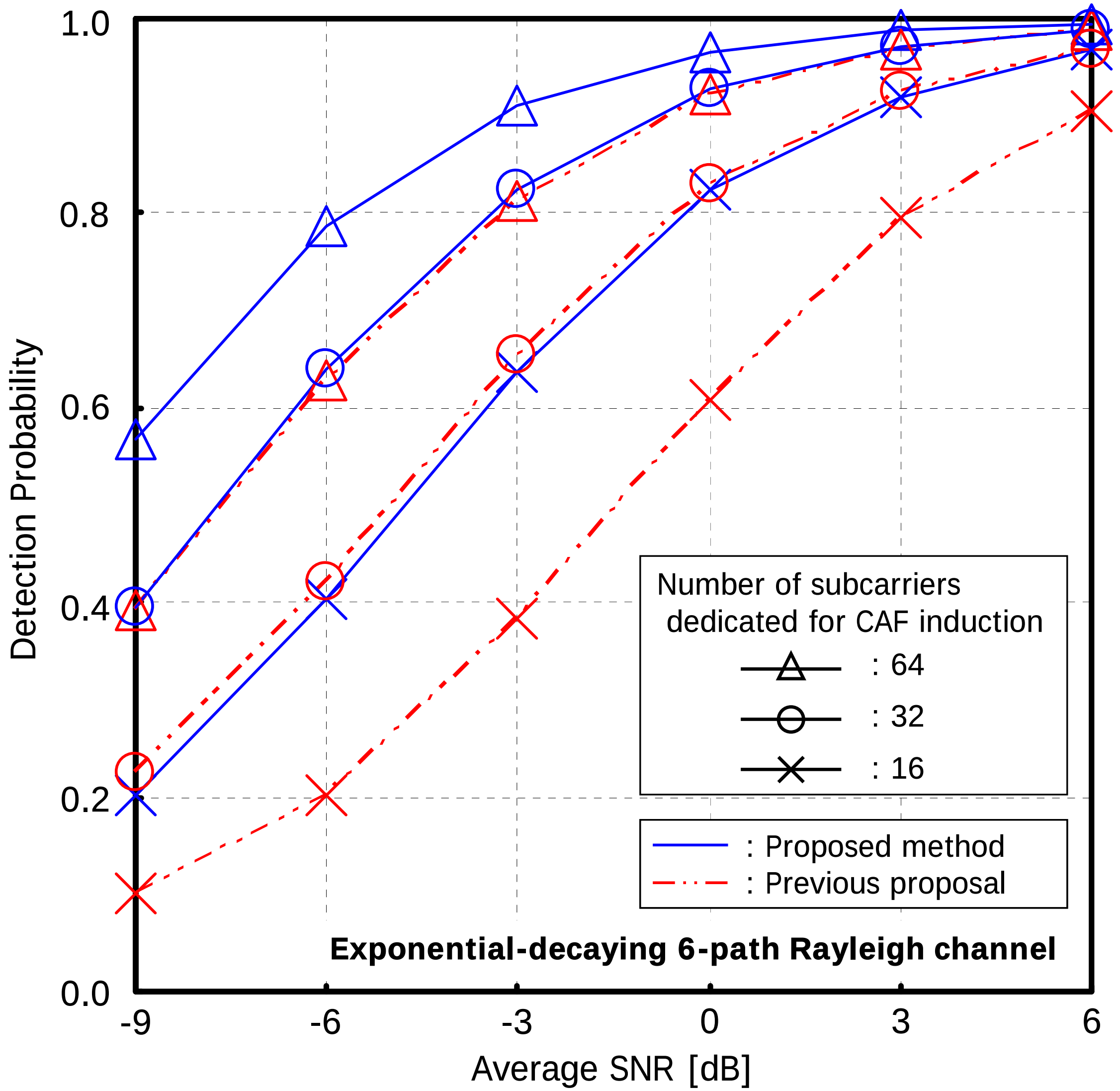
Extra SCs for CAF injection

K-th trans. symbol

$s_k = a_k \exp\{j2\pi mk\}$

Signal detection technique applicable to multiple radio systems

Signal Detection Probability under Rayleigh fading channel



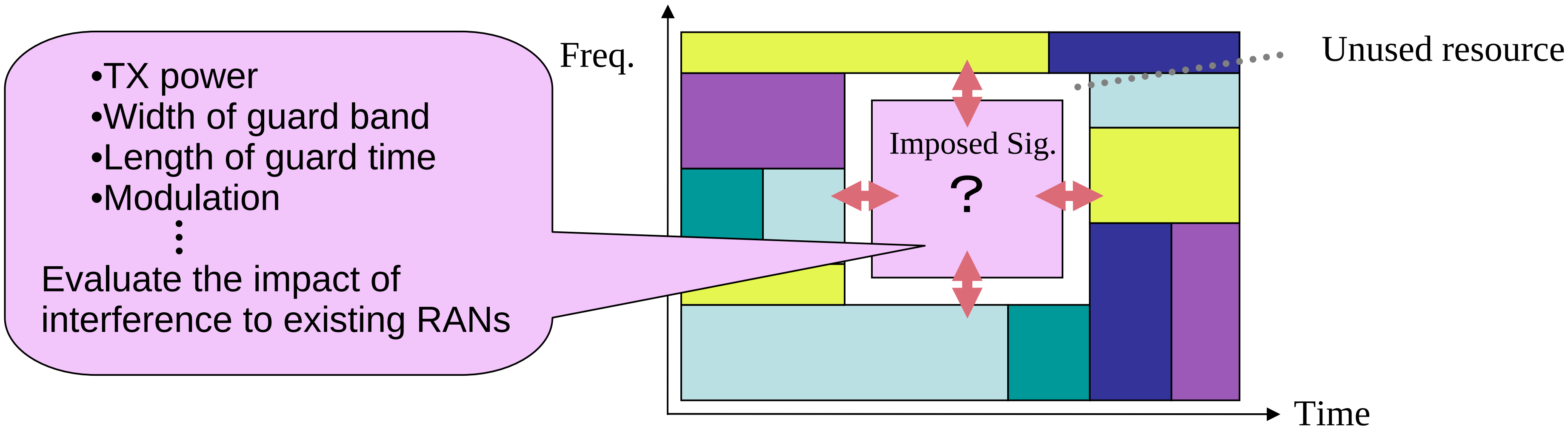
- Proposed method requires about half number of extra SCs compare to the conventional method

※conventional method: copies part of data SC without phase rotation to inject cyclostationality

Radio Resource Allocation Control Technology for Intra-operator

Target

Time-Frequency radio resource co-existence algorithms that achieve:
- low unused resource and
- low interference among RANs



Computer simulation

•Assume the superimpose of two OFDM signals, effect of interference is evaluated by BER.
•Important point are width of guard band (zitter) and SIR

Experiment by using test bed

•2 transmitters and 2 receivers
•Signal form definition and experiment is carried on under the same condition of computer simulation

Simulation Results

- Evaluate effect of interference focused on the BER of the primary system.
  - Considering the frequency offset (MAX ⊿f=±40ppm),
    - In case of over SIR=0dB, there is no need to take guard band. If there is guard band equal to a sub-carrier width, it is almost enough to avoid interference.
    - Assuming the secondary system uses OFDM signal, the effect of interference to the primary can be reduced by using narrow sub-carriers
  - Considering the effect to pilot subcarrier and phase tracking,
    - In case of SIR<5dB, large interference is observed on the pilot subcarriers. In case of SIR=10dB, degradation of BER is lower than about 2dB at BER=10^{-3}. No degradation on over SIR=15dB.
    - In case of using phase tracking with 2-pilot subcarrier that is not overwrapped between systems, BER degradation at around SIR=0dB is about 1dB at BER=10^{-3}.