Two suggestions for Wideband OFDM Systems using frequency diversity

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Purpose: This presentation presents the concept for the proposed new diversity scheme feature.

Two suggestions for Wideband OFDM Systems using frequency diversity

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Objective

Idea

Efficient utilized methods
of frequency diversity
in OFDM system

Problem of STBC-OFDM

- Limitation in Performance
- Complexity increase
  as Number of Antenna increase
- Transmission rate decrease
  as Number of Antenna increase

Advantage of STFBC-OFDM

- enhancement in BER
(using Frequency Diversity)
- simple structure
(do not increase number of antennas)

STBC: space time block code

STFBC: space time frequency block code

Introduction

- Diversity Techniques
  - Time Diversity : Channel Coding, Interleaving
  - Frequency(Path) Diversity : Coded-OFDM, Spread Spectrum
  - **Space(Antenna) Diversity**
    - Transmit Diversity
      - **Space-Time Code (Space-Time Trellis Code, Space-Time Block Code)**
    - Receiver Diversity
      - Rake Receiver, Selection Diversity
- MIMO Systems
  - Spatial Multiplexing
    - Capacity → increase in transmission rate (BLAST)
  - **MIMO Diversity**
    - **Diversity gain** → **Performance Improvement** (Transmit Diversity using Space-Time Code)

Space-Time Block Coding - I

- Space-Time Block Code
  - STBC is one of the **simplest** STC schemes.
    - Only **simple linear processing** at the receiver is required.
  - **Maximum diversity gain**
    - # of Tx antenna × # of Rx antenna

- Space-Time Block Coded OFDM (STBC-OFDM)
  - **OFDM: robust in channel Environments**

    + STBC: Diversity Gain

Space-Time Block Coding - II

- **Encoding Process**

Transmitted Signal

$$\begin{bmatrix} c_1 & c_2 \end{bmatrix} \longrightarrow \begin{bmatrix} c_1 & c_2 \\ -c_2^* & c_1^* \end{bmatrix}$$

- **Decoding Process**

Received Signal

$$r_1 = h_1 c_1 + h_2 c_2 + n_1$$
$$r_2 = -h_1 c_2^* + h_2 c_1^* + n_2$$
$$\longrightarrow \mathbf{r} = \begin{bmatrix} r_1 & r_2^* \end{bmatrix}^T = \mathbf{Hc} + \mathbf{n}$$

Channel Matrix

$$\mathbf{H} = \begin{bmatrix} h_1 & h_2 \\ -h_2^* & h_1^* \end{bmatrix} \longrightarrow \mathbf{H}^H \mathbf{H} = \rho \cdot \mathbf{I}, \quad \rho = |h_1|^2 + |h_2|^2$$

ML Decoder

$$\hat{\mathbf{c}} = \arg \min_{\hat{\mathbf{c}} \in \mathcal{C}} ||\mathbf{r} - \mathbf{H} \cdot \hat{\mathbf{c}}||^2 \longrightarrow \hat{\mathbf{c}} = \arg \min_{\hat{\mathbf{c}} \in \mathcal{C}} ||\tilde{\mathbf{r}} - \rho \cdot \hat{\mathbf{c}}||^2,$$

where $\tilde{\mathbf{r}} = \mathbf{H}^H \mathbf{r} = \rho \cdot \mathbf{c} + \tilde{\mathbf{n}}$

Space-Time Block Coding - III

- Some STBC Examples for Multiple Transmit Antennas

- **In the case of using more than three transmission antennas, simultaneously satisfy code orthogonality and transmission rate of STBC as 1, do not exists (Proved by V. Tarokh)**

Num. of Tx. Ant.	Space-Time Block Code		BW
2	STBC Coder	• (2×2) Matrix : 2 symbol transmission in $2T_s$ (Proposed by Alamouti)	1
3	STBC Coder	• (8×3) Matrix : 4 symbol transmission in $8T_s$ (Proposed by Tarokh)	1/2
4	STBC Coder	• (8×4) Matrix : 4 symbol transmission in $8T_s$ (Proposed by Tarokh)	1/2

- V. Tarokh, N. Seshadri, and A. R. Calderbank, "Space -time codes for high data rate wireless communication: Performance analysis and code construction," IEEE Trans. on Inform. T heory, vol.44, pp.744 -765, Mar.1998.
- Vahid Tarokh, Hamid Jafarkhani, and A. R. Calderbank, "Space-Time Block Codes from Orthogonal Designs," IEEE Trans. on Inform. Theory, vol.45, Jul.1999.
- V. Tarokh, H. Jafarkhani, A. R. Calderbank, "Space-time block coding for wireless communications: performance results," IEEE Journal on Selected Areas in Communications, IEEE Journal on, vol. 17 no.3, March 1999.

Space-Time and Frequency Block Coding for Wideband OFDM - I

- Motivation
  - Request More reliable system in next generation comm. system
    - Request of higher Diversity Gain → should increase the number of antennas
  - Diversity Gain of STBC Depends on number of Tx antennas
    - To improve in performance **should increase number of tr antenna**
    - Of number of antenna increase **HW load** seriously increases.
    - Especially, In the case of STBC-OFDM compare to single carrier system, operational complexity increases depends on sub-carrier number. → **operational complexity greatly increases**

    ➡ In OFDM, an STBC-OFDM system that have more than 3 tx antennas is not easy in implementation.
  - The STBC using more than 3 tx antennas transmission rate decreases.
  - OFDM can obtain **frequency diversity in simple method**.

Space-Time and Frequency Block Coding Wideband OFDM - II

Design consideration

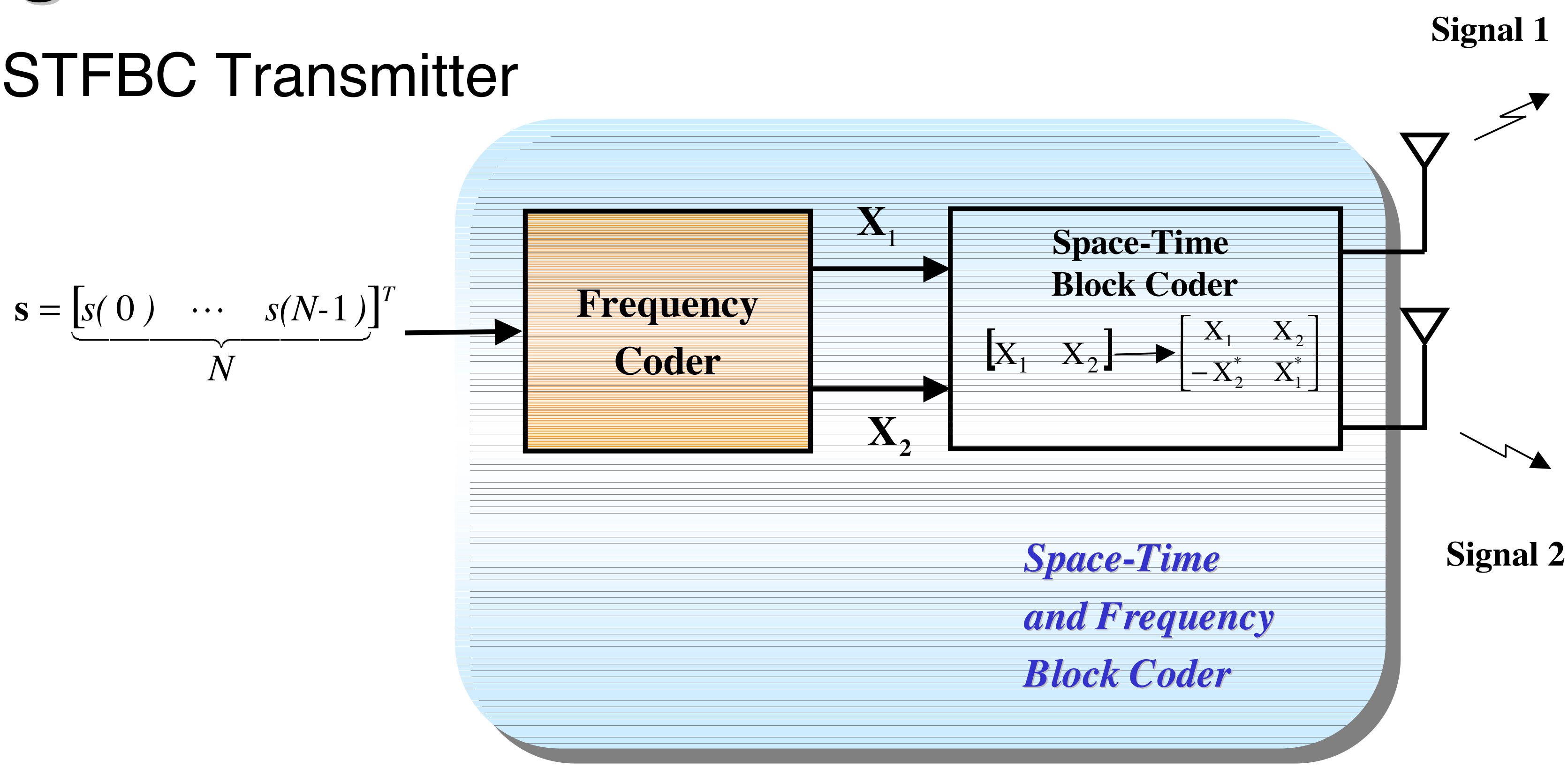
- **Maximum Frequency Diversity Gain**
  - # of Tx antenna × # of rx antenna × frequency gain
- **Simple Structure**
  - Should not increase number of transmission antenna.
  - To earn frequency Diversity Gain in Decoding process it should be incorporate with Linear Processing
- compatibility with **STBC-OFDM system**

- **Minimize complexity increase**
- **Maximize Diversity Gain**

→ **Space-Time and Frequency Block Coding Technique**

Space-Time and Frequency Block Coding Wideband OFDM - III

- STFBC Transmitter



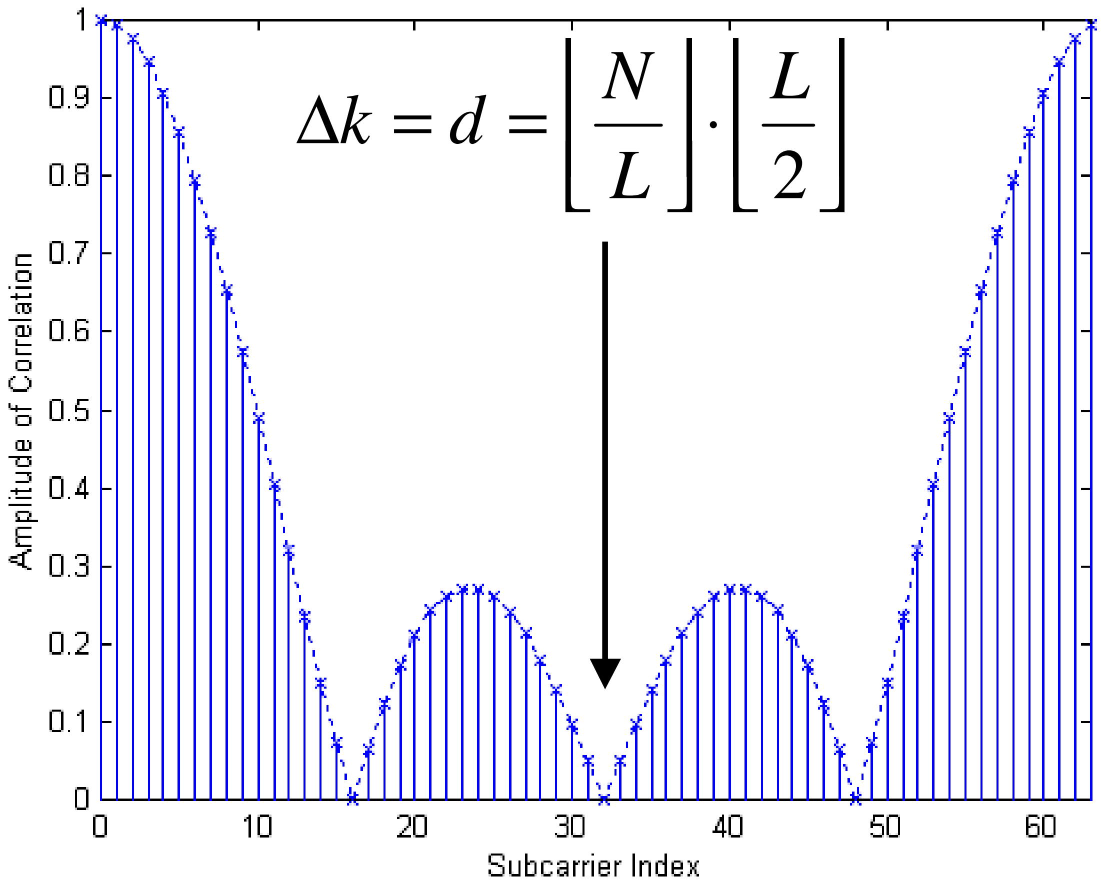
Frequency Coder : Frequency diversity enabling part in STBC-OFDM system

Frequency Coder

- Replicate original signal
- Cyclically shift sub-carrier X_1 produce X'_1
- X_1 and X_1' is get into the original STC symbol mapping such as
- $X_1=s=[s(0), \ldots s(N-1)]^T$
- $X_2=X_1'=[s(N-d),\ldots s(N-1), s(0),\ldots s(N-d-1)]^T$
- The shift term d can be obtained as following

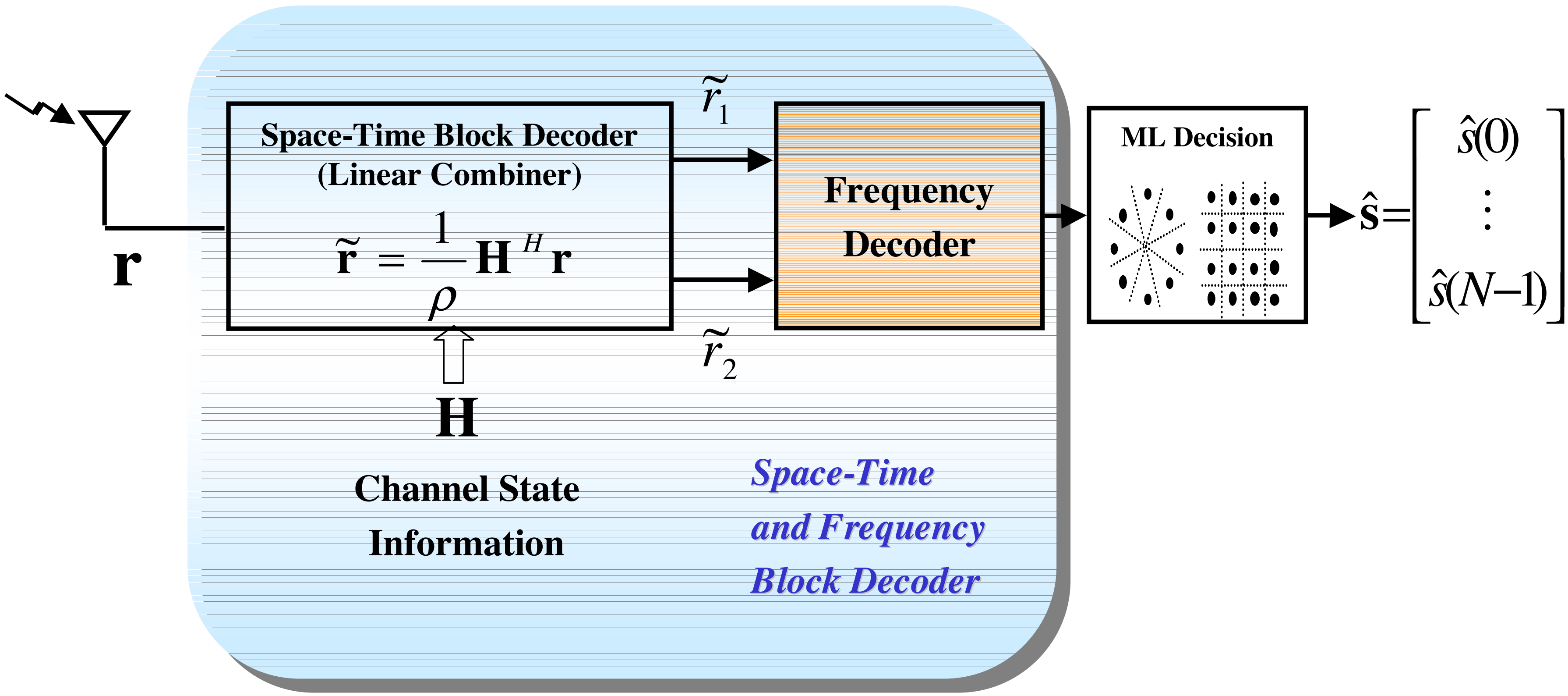
$$\Delta k = d = \left\lfloor \frac{N}{L} \right\rfloor \cdot \left\lfloor \frac{L}{2} \right\rfloor$$

Correlation of sub-carriers with 0_{th} sub-carrier



Space-Time and Frequency Block Coding Wideband OFDM - IV

- STFBC Receiver

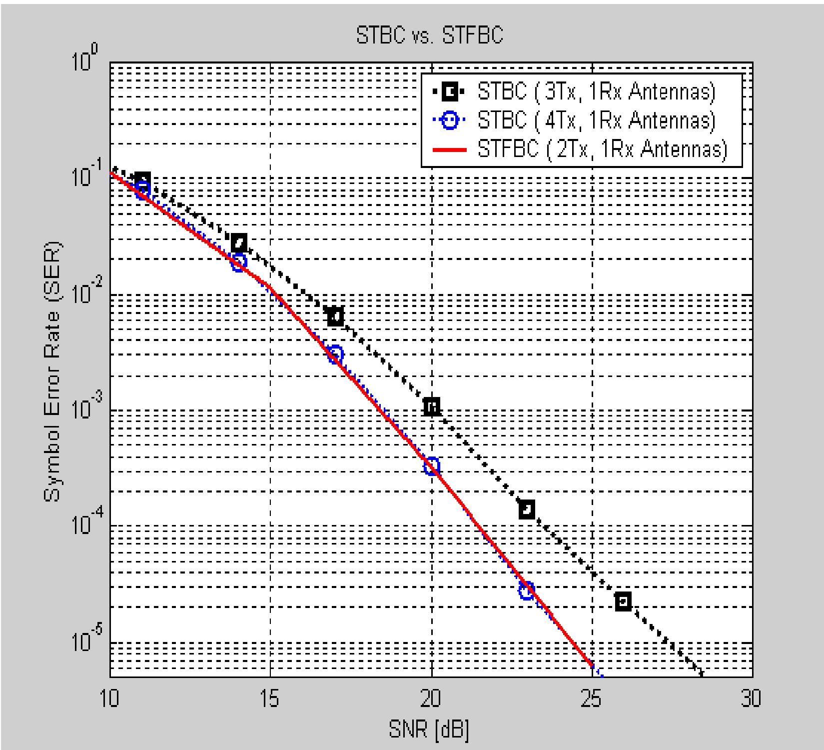


Frequency Decoder

- Inverse cyclically shifted sub-carrier of the esti mated symbol X_2 to produce the "replication" of symbol X_1.
- X_1 and X_2' is combined as frequency diversity manner such that
- $X_1 = s = [s(0), \ldots s(N-1)]^T$
- $X'_2 = X_1(k-d)_{\text{mod } N} = [s(0), \ldots s(N-1)]^T$
- The inverse shift term d can be obtained from chan nel estimation process, proportional to **Channel im pulse response L.**

Space-Time and Frequency Block Coding Wideband OFDM - V

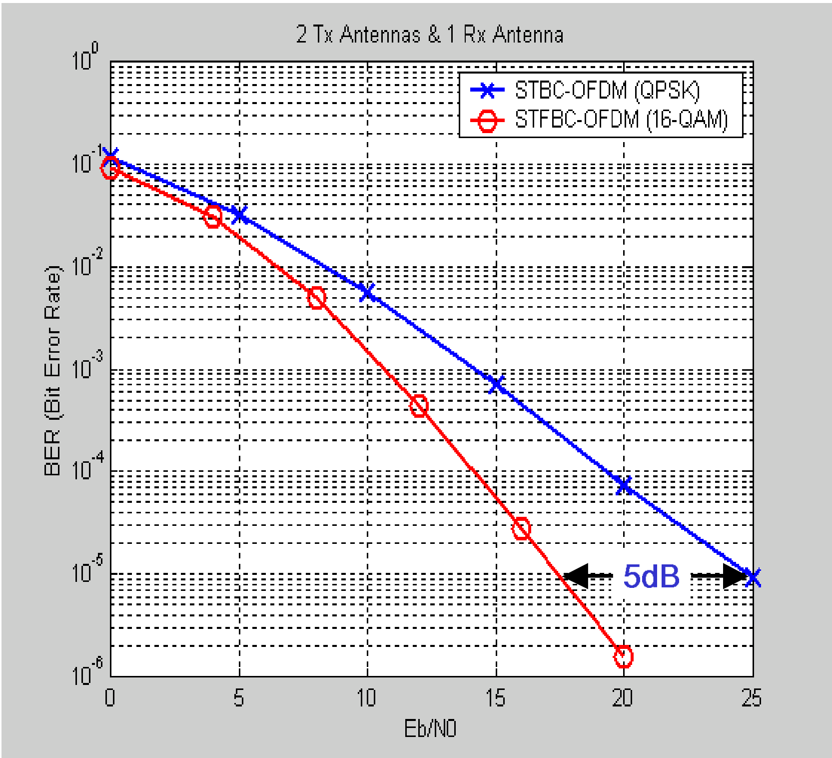
- Performance Result (1)



- **Simulation environments**
  - Channel Order : 10
  - 16-QAM
  - Independent Rayleigh Fading Channel
  - Pefect Channel & Order Information
  - **4 tx antenna using STBC and 2 tx antenna using STFBC shows same performance**
  - Compare to 3 **tx antenna using STBC in** 10^{-4} SER shows **approx. 2.5dB** SNR gain

Space-Time and Frequency Block Codi ng Wideband OFDM - VI

- Performance Result (2)



- **Simulation environments**
  - Channel Order : 10
  - Independent Rayleigh Fading Channel
  - 2 tx antennas and 1 rx antenn a
  - Pefect Channel & Order Inform ation
  - 2bits/sub-carrier
  - In 10^{-5} BER **approax. 5dB** perf ormance improvements.
  - **If correlation between tx ant ennas increases, the perfor mance improves impressivel y**

Closing Comment

- **Space-Time Block Coding (STBC)**
  - Simple structure and Full space diversity gain
  - But there are many problem when using more than 3 antennas in OFDM system (HW and operational complexity, decrease in tx rate)
- **Space-Time and Frequency Block Coding (STFBC)**
  - Overcome the problem of STBC-OFDM
  - A scheme, Not only Maximize Space Diversity but also frequency Diversity gain
  - Using frequency diversity so that increase the number of tx antenna is not require d.
  - Compatible to existing STBC-OFDM
- **Two suggestion**
  - **Tx diversity scheme for OFDM system is desirable to use the S TFBC is strongly requested.**
  - **The code combining in H-ARQ is also desirable to adapt the fr equency diversity in this proposal.**