Agenda Item 4: 5 GHz Band Planning

Transmission Experiment of STBC-AF Relay Protocol for Unmanned Aircraft Systems (UAS)

Presented by Tohoku University and NICT

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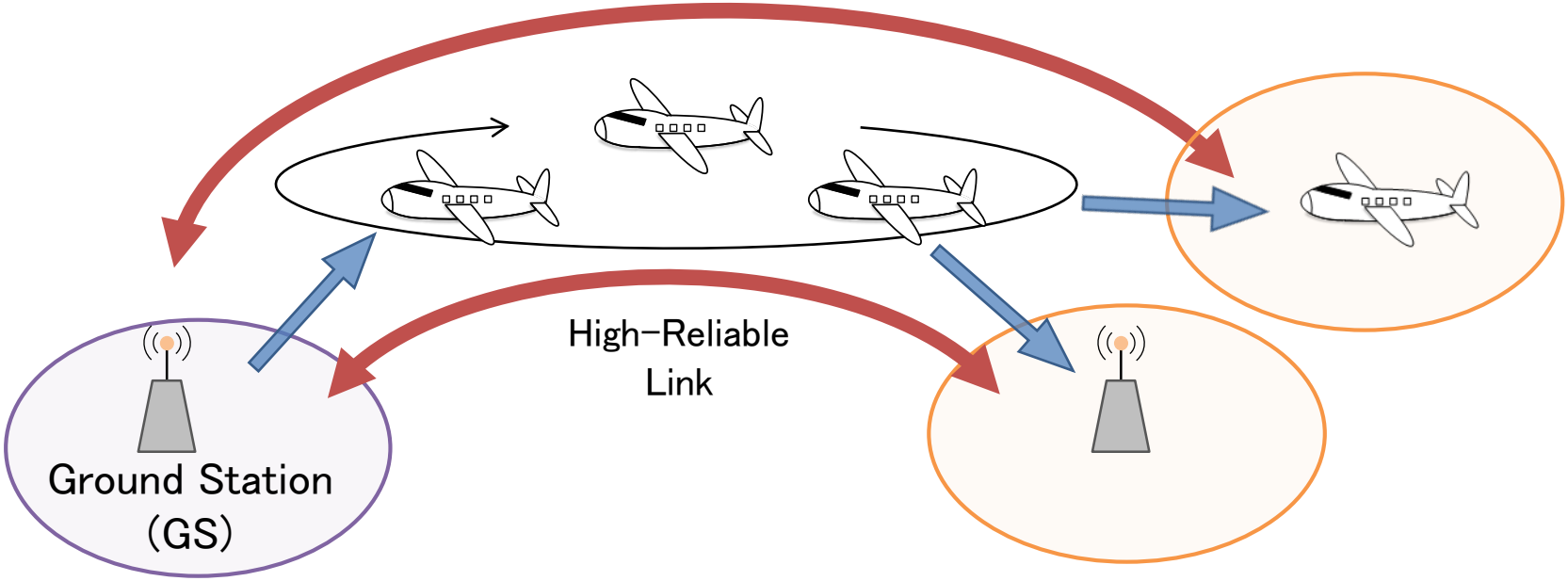
This study was being conducted as a part of R&D on cooperative technologies and frequency sharing between UA based wireless relay systems and terrestrial networks supported by Ministry of Internal affairs and Communications (MIC), Japan.

Background

[1] R. Miura et al., IEICE General conference, BI-2-6, March, 2013.

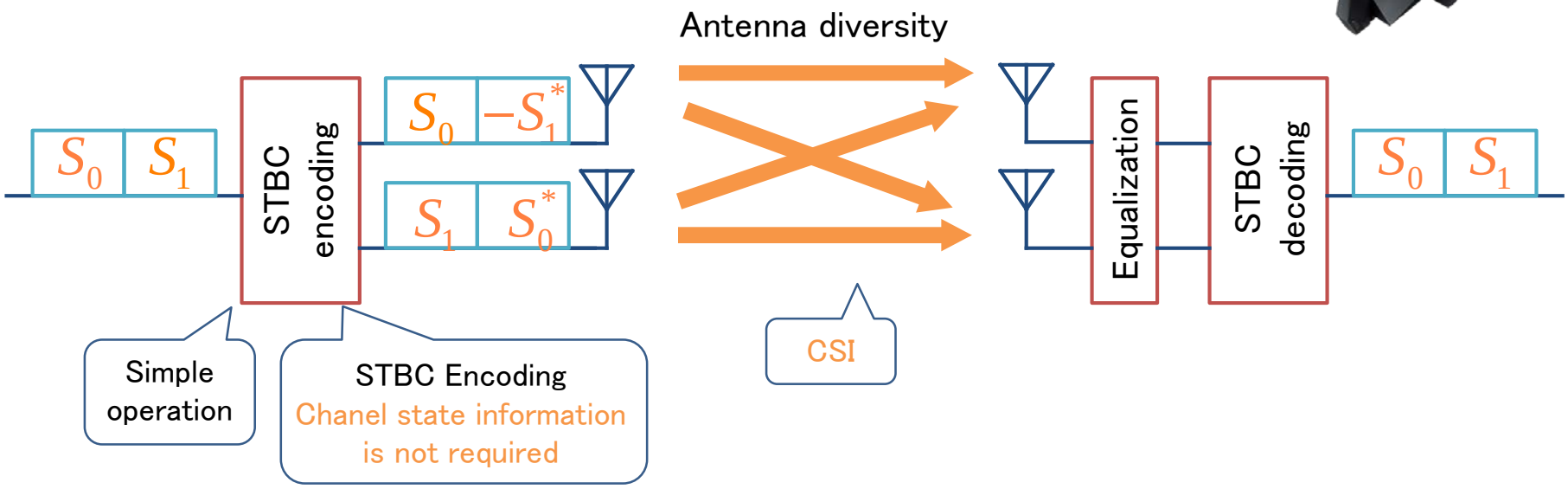
- Wireless relay system using unmanned aircraft(UA)[1]
  - Ground Station(GS)-UA link may be unreliable
    - Power is limited at the UA
      - High quality and high stability system is required with keeping UA structure simple



Background

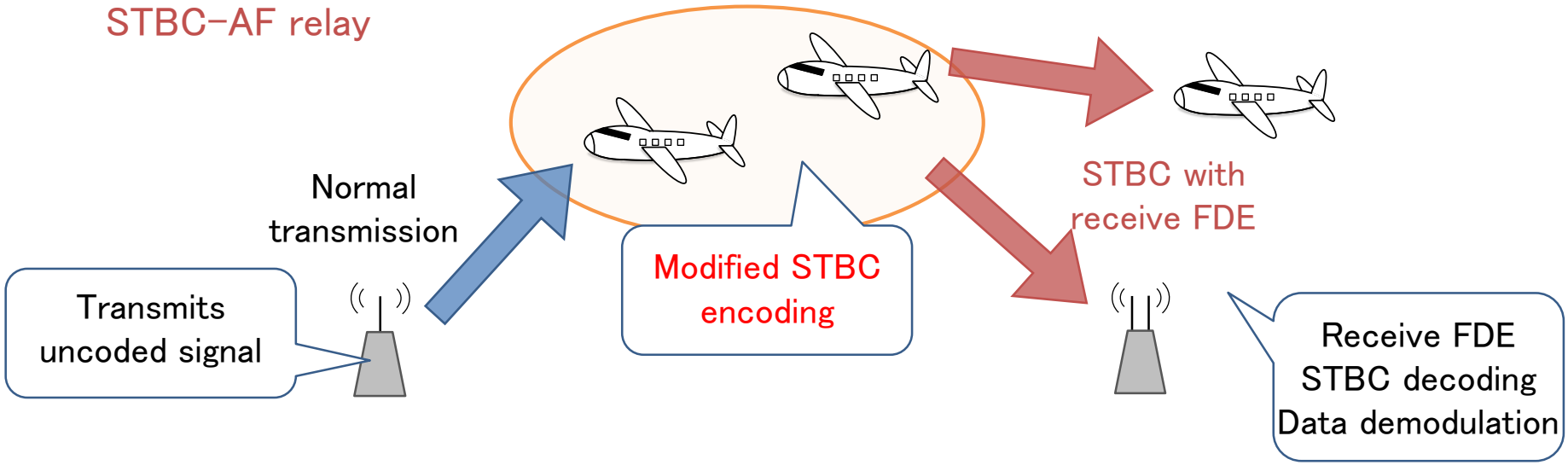
[2] S. M. Alamouti, “A simple transmit diversity technique for wireless communications,” IEEE J. Sel. Areas Commun., Vol. 16, No. 8, pp. 1451-1458, Oct. 1998.

- MIMO (Multiple Inputs Multiple Outputs) System
  - A MIMO system consists of several antenna elements, plus adaptive signal processing, at both transmitter and receiver to increase the capacity or to gain better transmission quality by exploiting the spatial dimension of the mobile radio channel.
- Space-Time Block Coding (STBC)[2]
  - STBC can obtain spatial diversity gain using multiple transmit / receive antennas.
    - ➢ improve transmission performance
  - Channel state information (CSI) is not required at the transmitter
    - ➢ Transmitter structure can be kept simple



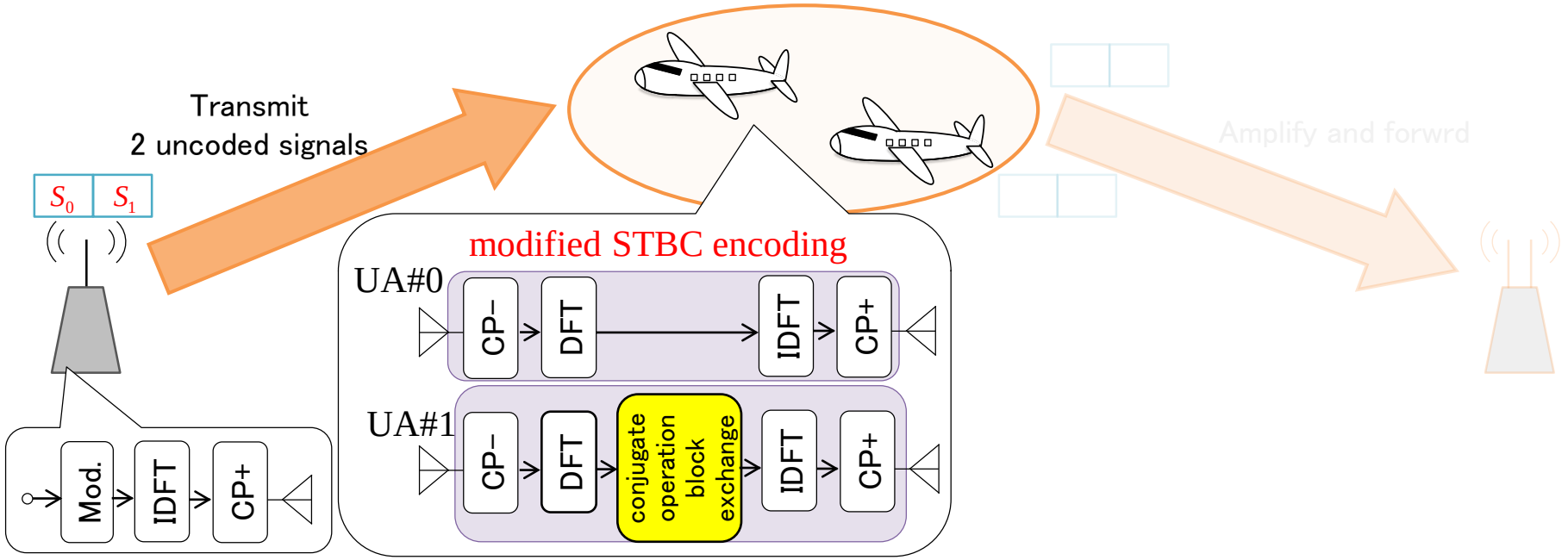
Background

- Proposed method
  - STBC Amplify-and-Forward (AF) relay with frequency domain equalization (FDE) for UAS
    - Data exchange is not required between UA relays
      - ➢ Keeping high transmission efficiency ○
    - STBC-AF relay does not require data exchange between UA relays
      - ➢ UA's structure can be kept simple ○



Behavior of STBC-AF relay

- 1st time-slot
  - Source GS broadcasts 2 uncoded transmit signals to UAs
  - UA #0 keeps the received signal as it is
  - UA #1 performs conjugate operation and block exchange on the received signal
- 2nd time-slot
  - UAs amplify and forward the transmit signal to the destination GS
  - Destination GS performs the receive FDE, STBC decoding, data demodulation



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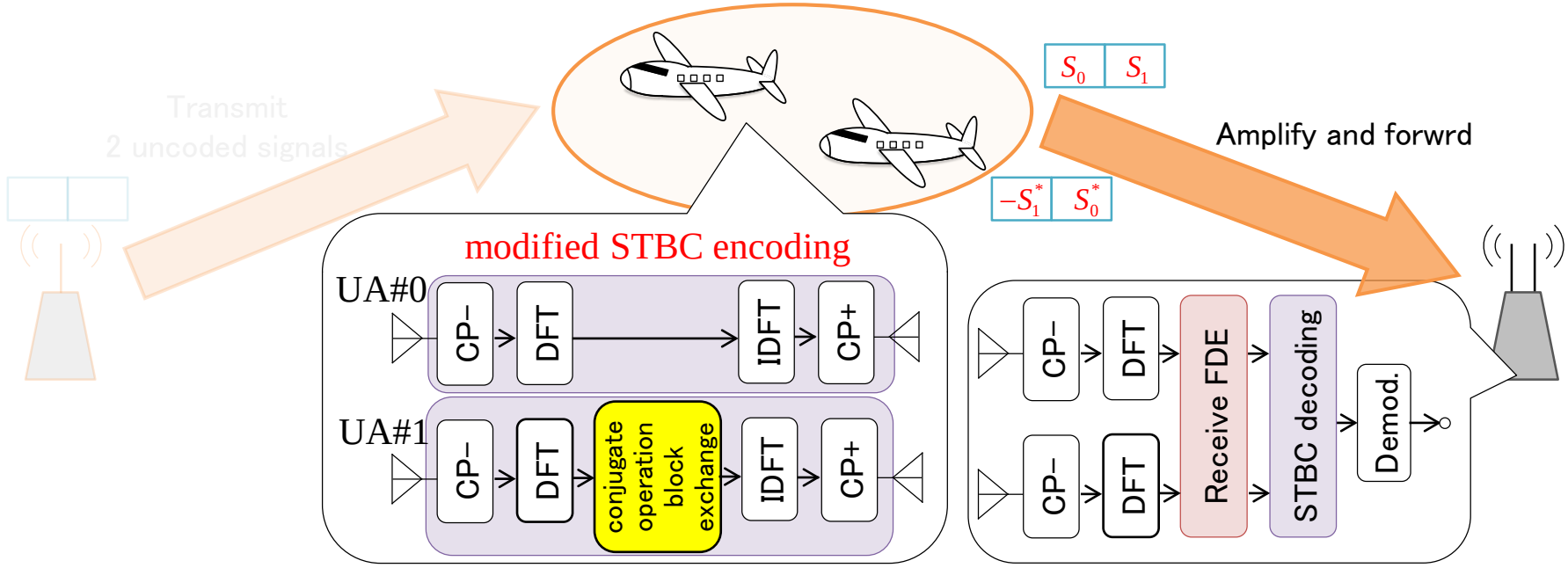
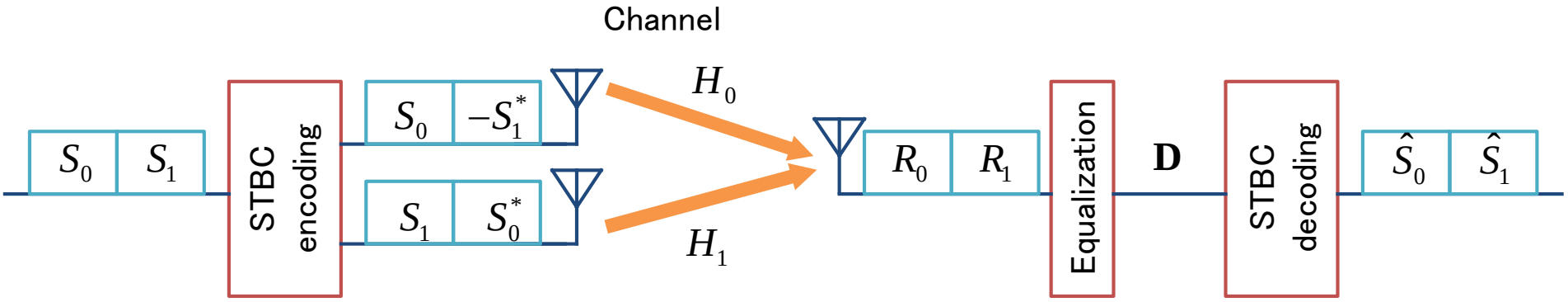


STBC

- STBC



- Received signal

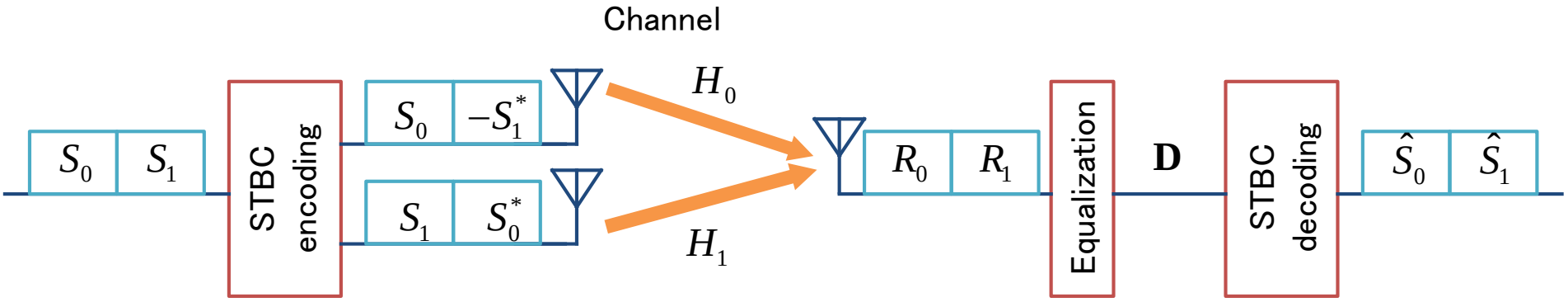
$$\begin{pmatrix} R_0 & R_1 \end{pmatrix} = \begin{pmatrix} H_0 S_0 + H_1 S_1 & -H_0 S_1^* + H_1 S_0^* \end{pmatrix}$$

- Equalized signal

$$\mathbf{D} = \begin{pmatrix} D_{00} & D_{01} \\ D_{10} & D_{11} \end{pmatrix} = \begin{pmatrix} H_0^* \\ H_1^* \end{pmatrix} \begin{pmatrix} R_0 & R_1 \end{pmatrix} = \begin{pmatrix} |H_0|^2 S_0 + H_0^* H_1 S_1 & -|H_0|^2 S_1^* + H_0^* H_1 S_0^* \\ H_0 H_1^* S_0 + |H_1|^2 S_1 & -H_0 H_1^* S_1^* + |H_1|^2 S_0^* \end{pmatrix}$$

STBC

- STBC



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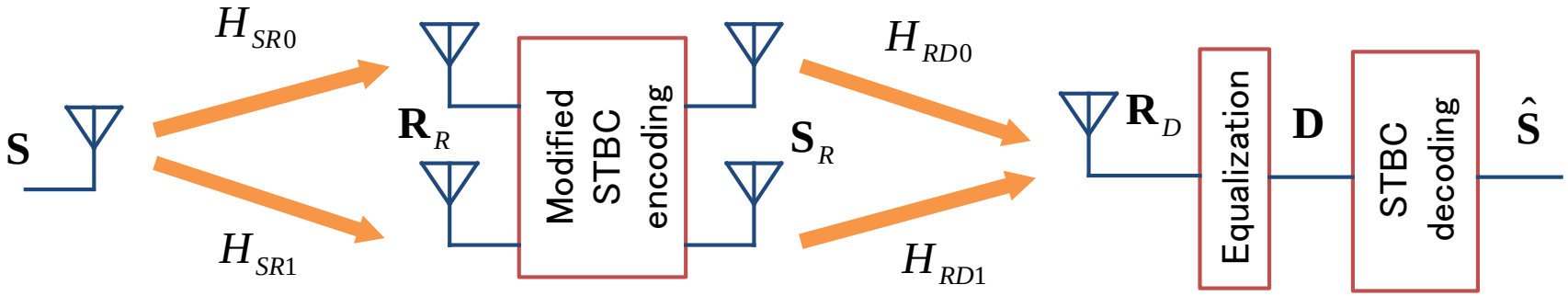
- STBC decoded signal

$$\hat{S}_0 = D_{00} + D_{11}^* = \left(|H_0|^2 + |H_1|^2 \right) S_0$$

$$\hat{S}_1 = D_{10} - D_{01}^* = \left(|H_0|^2 + |H_1|^2 \right) S_1$$

Modified STBC

- Modified STBC



  - Received signal at UA

$$\mathbf{R}_R = \begin{pmatrix} H_{SR0}S_0 & H_{SR0}S_1 \\ H_{SR1}S_0 & H_{SR1}S_1 \end{pmatrix}$$

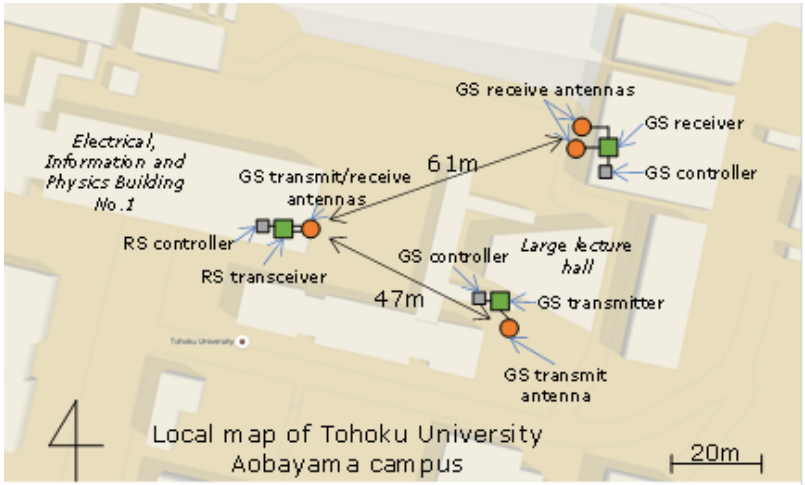
  - Modified STBC encoded signal at UA

$$\mathbf{S}_R = \begin{pmatrix} H_{SR0}S_0 & H_{SR0}S_1 \\ -H_{SR1}^*S_1 & H_{SR1}^*S_0^* \end{pmatrix}$$

← Conjugate operation
Block exchange

Field Experiment

- We conducted a transmission measurement of STBC AF relay protocol

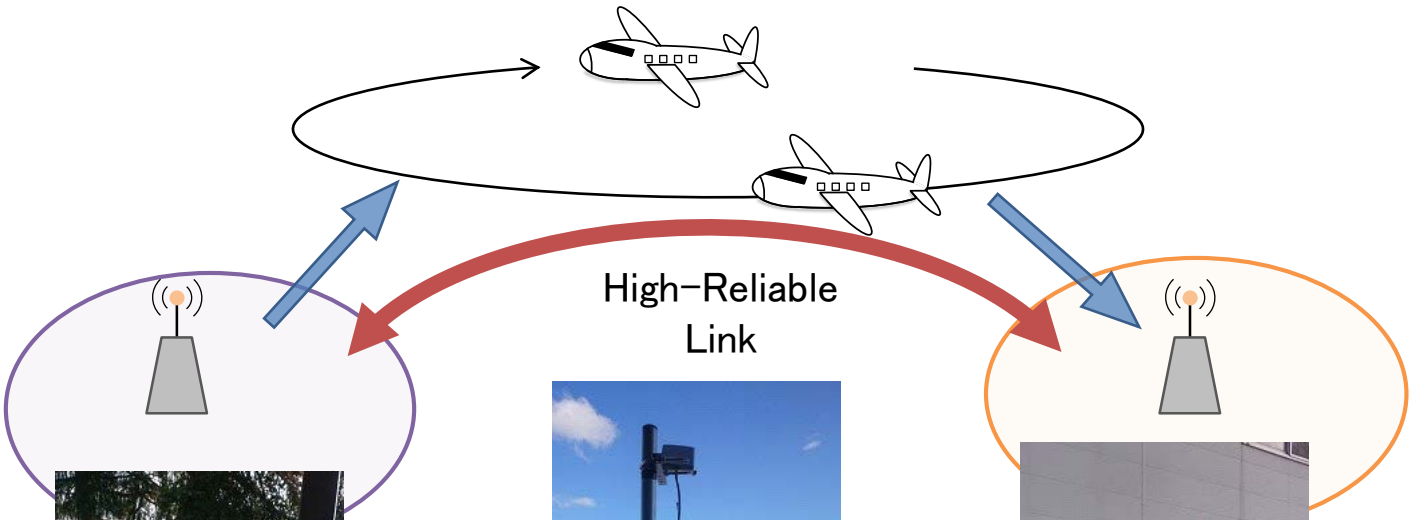


(a) Locations of GS transmitter/receiver and STBC-AF RS

Parameter setting for STBC-AF relay transmission experiment

Carrier frequency	GS transmitter: 5110MHz STBC-AF relay: 5130MHz
Subcarrier frequency separation	0.3125MHz
No. of data subcarriers	48
No. pilot subcarriers	4
FFT block size	64
Guard interval	16 samples
Data modulation	QPSK
Channel coding	None
Packet size	1440bits
Packet transmission time interval	1ms
Relay protocol	STBC-AF
	Conventional AF
Channel estimation	Pilot based
GS transmitter – RS distance	47m (RS received signal power = – 61.5dBm)
RS – GS receiver	61m

Field Experiment (continued)



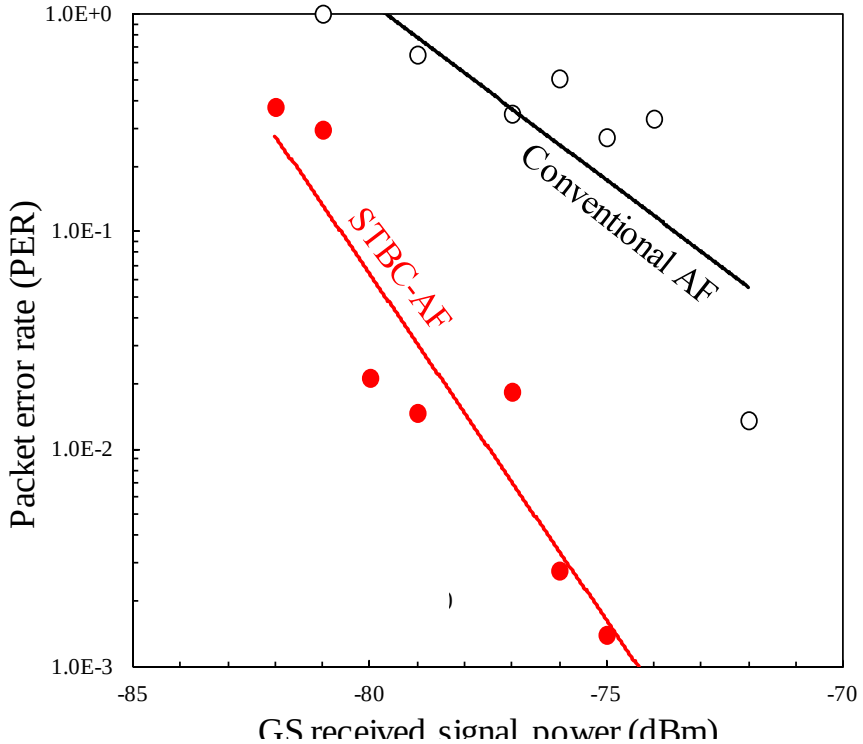
(i) GS transmitter

(iv) RS antennas

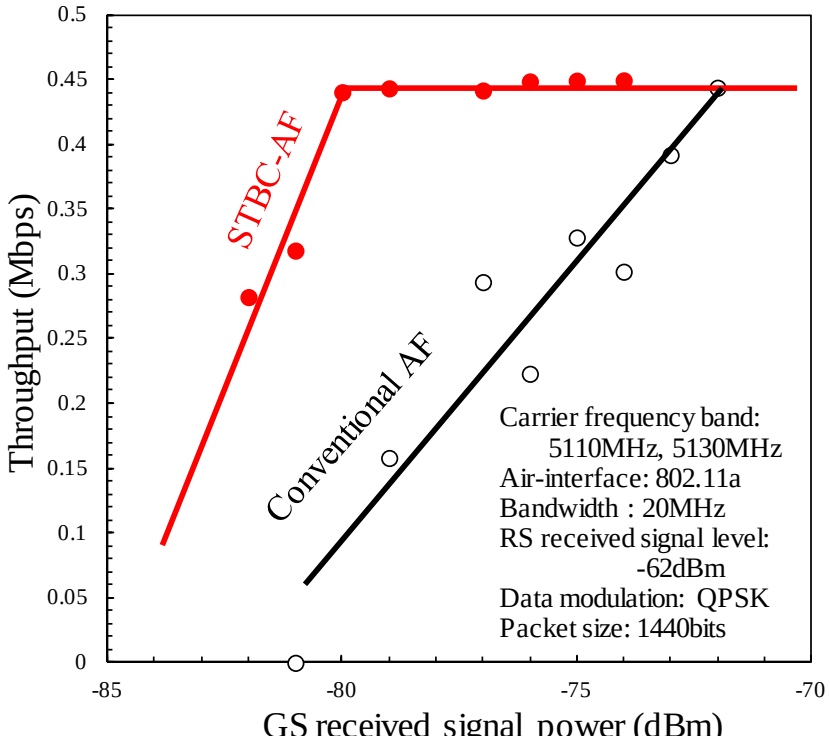
(vi) GS receive antennas

Field Experiment (results)

- It was confirmed that the use of STBC-AF relay significantly improves the PER performance and consequently, the throughput performances in a real propagation environment.



(a) PER performance



(b) Throughput performance

Conclusions

- This IP presented a summary of a transmission experiment of STBC-AF relay protocol for UAS .
  - The effectiveness of STBC-AF relay protocol for UAS was confirmed by the transmission experiment in a real propagation environment.
- UAS employing STBC-AF protocol is very useful in quickly re-establishing the communication link between GS and the network
- Furthermore, it can also achieve a reliable handover between plural ground stations in UAS.