Improvement the Performance of Helicopter Satellite Communication using 2x2 Alamouti Scheme

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ABSTRACT
In helicopter satellite communications, the periodic blockage of the received signal and the carrier frequency fluctuation are the most important problems. This paper proposes a space signal processing with time diversity combining scheme for helicopter satellite communications. In the proposed scheme, a space signal processing combining with time diversity tracks the carrier frequency fluctuations due to Doppler shift . Results of computer simulation show that the proposed scheme improves the BER performance of the previous conventional scheme.

General Terms
Communications, Digital signal processing, Software

Keywords
Space signal processing using Alamouti scheme , AFC (Automatic Frequency Control) and Tapped delay line or Transversal filter.

1. INTRODUCTION
Emergency rescue and disaster relief are important applications of helicopters. To establish reliable communications in these applications, helicopter satellite communications are attractive.

One of the most important problems in helicopter satellite communications is periodic blockage of the signal due to rotor blades. This causes BER performance degradation and cycle-slip of the recovered carrier , to overcome the problem, proposing the space signal processing with time diversity combining scheme. the scheme achieves good BER performance [4]. Also proposing transversal filter which also cancels Doppler offset of the received signal caused by helicopter maneuvers , as a result BER performance is improved .In this paper, to improve the BER performance Two approaches are used , 1st using two transmit and one receiving antennas , 2nd using two transmit and two receiving antennas such that the BER performance is more improved , space-time processing radio operates simultaneously on multiple antennas by processing both in space and time.

The paper is organized as follows. The communication system model is illustrated in section 2. The proposed scheme is described in section 3. In section 4 , show results of the computer simulation of the space time characteristics and the BER performance. Finally, conclusion the paper in section 5.

2. COMMUNICATION SYSTEM MODEL
As mentioned previously, one of the most important problems in helicopter satellite communications is the periodic blockage of the signal due to rotor blades. Fig. 1 shows the periodic blockage model.

The blockage period Tp and the blockage duration Td are constant dependent on the type of helicopter, respectively.

$$T_p: blockage\ period$$
$$T_d: blockage\ duration$$

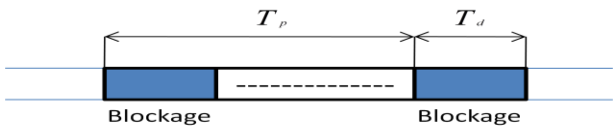


Fig. 1. Periodic blockage model

Fig. 2 shows the communication system model employing pre-detection combining. In Fig. 2, a binary information data sequence {ui} is encoded by convolutional encoder with coding rate 1/2, and binary encoded data sequences {pi} and {qi} are produced. Then, a fixed delay mT_b is given to the encoded data sequence {qi}, where m is a positive integer and T_b is the bit duration of the information data. This is the first time diversity processing. Choose the nearest integer of $T_p/(4T_b)$ as m because it is the delay achieving the best BER performance after Viterbi decoding in the receiver. After parallel-to-serial conversion of the encoded data sequences, the second time diversity processing is performed. That is, the encoded data sequence after parallel-to-serial conversion is duplicated, and a fixed delay $2mT_b$ is given to the duplicated sequence. These two sequences are multiplexed to a binary transmitted data sequence {ai} by parallel-to-serial conversion. The encoded sequences {pi}, {qi} and the transmitted data sequence {ai} have the following relations:

$$\left.\begin{aligned} a_{4i} &= p_i \\ a_{4i+1} &= p_{i-2m} \\ a_{4i+2} &= q_{i-m} \\ a_{4i+3} &= q_{i-3m} \end{aligned}\right\} \quad (1)$$

From equation (1) express the time diversity process in Fig. 3

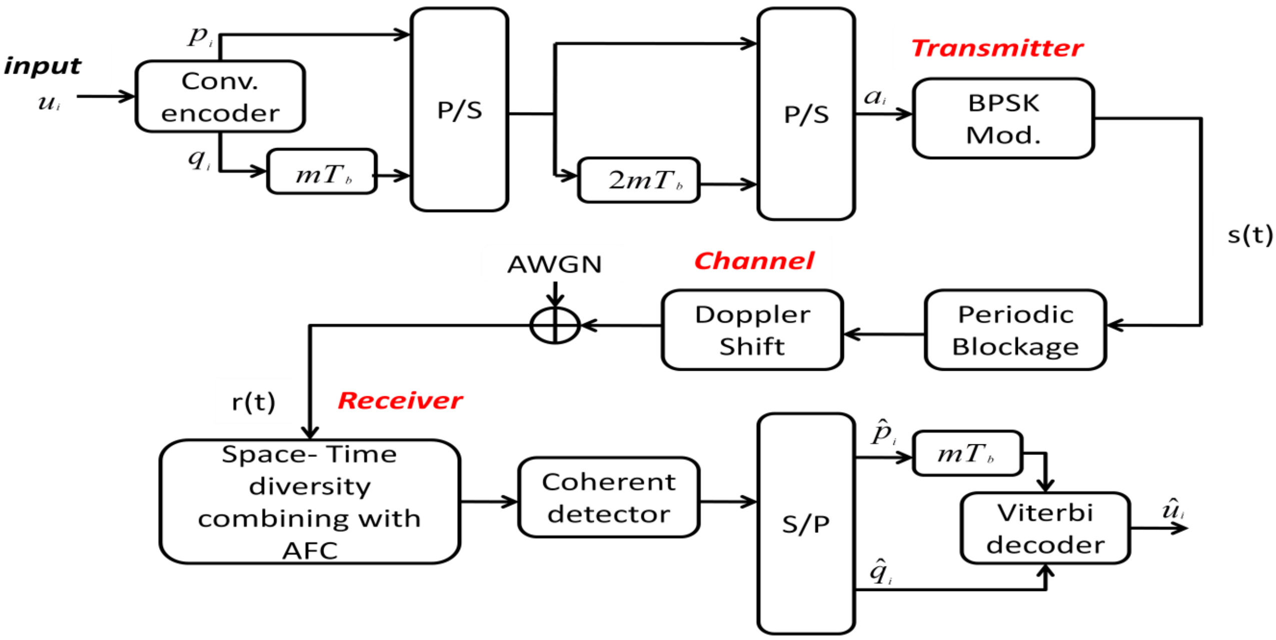


Fig.4 Configuration of conventional scheme

In the receiver, Doppler shift of the receiver signal is firstly

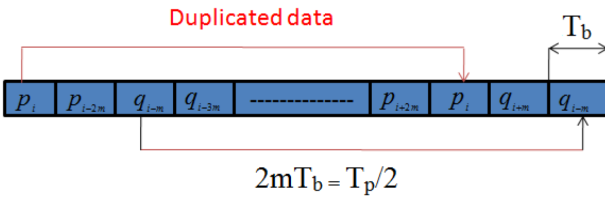
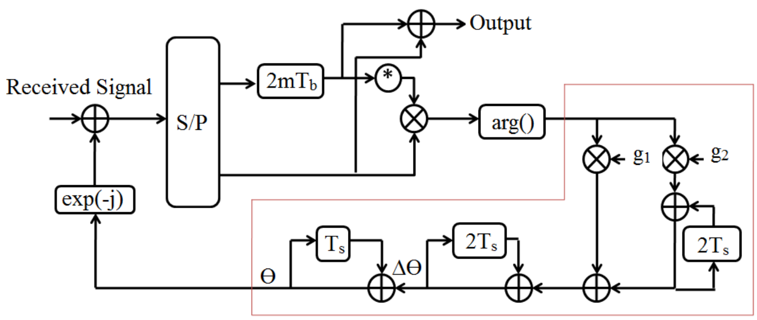


Fig. 3. Time Diversity Process



Then, the transmitted data sequence$\{a_i\}$is modulated in the BPSK modulator, and the transmitted signal s(t) is generated. The transmitted signal is represented by

$$\left.\begin{aligned} s(iT_b) &= \sqrt{E_s}\exp(-jp_i\pi) \\ s(iT_b+T_s) &= \sqrt{E_s}\exp(-jp_{i-2m}\pi) \\ s(iT_b+2T_s) &= \sqrt{E_s}\exp(-jq_{i-m}\pi) \\ s(iT_b+3T_s) &= \sqrt{E_s}\exp(-jq_{i-3m}\pi) \end{aligned}\right\} \quad (2)$$

Where $E_s = E_b/4$, E_b is the signal energy per bit of the information data sequence $\{u_i\}$ and $T_s= T_b/4$. In the transmission channel, the transmitted signal s(t) is periodically blocked and Doppler shifted. Furthermore, the additive white Gaussian noise (AWGN) with single-sided noise power spectral density N_o is added to the signal, resulting in the received signal r(t). If constant Doppler shift f is assumed, the received signal r(t) is represented by

$$r(t) = \sum_{-\infty}^{\infty} h(t-nT_p)\, s(t)\exp(-j2\pi f t) + n(t) \quad (3)$$

$$h(t) = \begin{cases} 1 & (T_d \le t < T_p) \\ 0 & (else) \end{cases} \quad (4)$$

removed by AFC, and in-phase combining corresponding to the second time diversity processing in the transmitter is performed. After coherent detection of the combined received signal, the serial-to-parallel converter produces binary sequences $\{\hat{p}_i\}$ and $\{\hat{q}_i\}$ corresponding to the encoded sequence {pi} and {qi}, respectively. In addition, a fixed delay mT_b is given to the sequence {pi}. It corresponds to the first time diversity processing in the transmitter, and gives time diversity effect to the branch metric calculation in the Viterbi decoder.

3. CONVENTIONAL SCHEME

Fig. 4 shows the configuration of the conventional AFC scheme, achieving pre-detection combining in the environment of helicopter satellite communications. In Fig.4, the conventional frequency error detector is described in red line. Let denote ri the discrete received signal. That is , ri = r(iTs). Hereafter, assuming that no signal blockage, no AWGN and constant Doppler shift f for simplicity. On the assumption, the following relations are held:

$$\left.\begin{aligned} r_{4i} &= r(iT_b) \\ &= \sqrt{E_s}\exp[-j\pi(p_i + 2f_iT_b)] \\ r_{4i+1} &= r(iT_b+T_s) \\ &= \sqrt{E_s}\exp\{-j\pi[p_{i-2m} + 2f(iT_b+T_s)]\} \\ r_{4i+2} &= r(iT_b+2T_s) \end{aligned}\right\} \quad (5)$$

$$= \sqrt{E_s}\ \exp\{-j\pi[q_{i-m} + 2f(iT_b + 2T_s)]\}$$

$$r_{4i+3} = r(iT_b + 3T_s)$$
$$= \sqrt{E_s}\ \exp\{-j\pi[q_{i-3m} + 2f(iT_b + 3T_s)]\}$$

In Fig. 4, the phase rotation of the discrete received signal ri is performed for Doppler shift removal firstly. Then, serial- to-parallel converter produces two signal sequences {αi} and {βi}. In the initial state (i.e. no phase rotation), these signals can be represented by

$$\left.\begin{aligned} \alpha_{2i} &= r_{4i} \\ \beta_{2i} &= r_{4i+1} \\ \alpha_{2i+1} &= r_{4i+2} \\ \beta_{2i+1} &= r_{4i+3} \end{aligned}\right\} \quad (6)$$

Next, the fixed delay 2mTb is given to the signal sequence {αi}. The delayed sequence {αi} is added to the other sequence {βi}, resulting in the combined output signal. When Doppler shift is exactly removed, the in-phase combining, maximizing signal-to-noise power ratio of the combined signal, is achieved. On the other hand, the complex conjugate of the delayed sequence {αi}is multiplied by the other sequence {βi}, resulting in the phase difference sequence {ei}. From Eq. (5) and (6), have

$$\left.\begin{aligned} e_{2i} &= \alpha^*_{2i-2m}\beta_{2i} \\ &= r^*_{4i-2m} r_{4i+1} \\ &= E_s \exp[-j2\pi f(2mT_b + T_s)] \\ e_{2i+1} &= \alpha^*_{2i-2m+1}\beta_{2i+1} \\ &= r^*_{4i-2m-2} r_{4i+3} \\ &= E_s \exp[-j2\pi f(2mT_b + T_s)] \end{aligned}\right\} (7)$$

It is clear that the argument of the phase difference sequence {ei} is proportional to Doppler shift f. That is

$$\arg(e_i) = 2\pi f(2mT_b + T_s) \qquad (8)$$

Where arg(·) denotes the argument of the complex signal, can thus estimate Doppler shift exactly. Based on the argument, the second order feedback loop tracks and removes Doppler shift. Then, as mentioned above, the in-phase combining is achieved.

4. PROPOSED SCHEME

Proposing a space time diversity combining scheme with accurate tapped delay line , achieving pre-detection combining in the environment of helicopter satellite communications. Fig. 5 shows the proposed scheme. In the scheme, the tapped delay line tracks and removes Doppler shift accuracy and the space time (ST) processing can increase array gain and improve diversity compared to the other two systems.

$$\hat{\theta} = \sum_{k=0}^{5} C_k\, x[n-k] \qquad (9)$$

Such that From analysis of the AFC , have the tapped delay line coefficients

$$\left.\begin{aligned} C_0 = C_1 &= g_1 + g_2 \\ C_2 = C_3 &= g_1 + 2g_2 \\ C_4 = C_5 &= g_2 \end{aligned}\right\} (10)$$

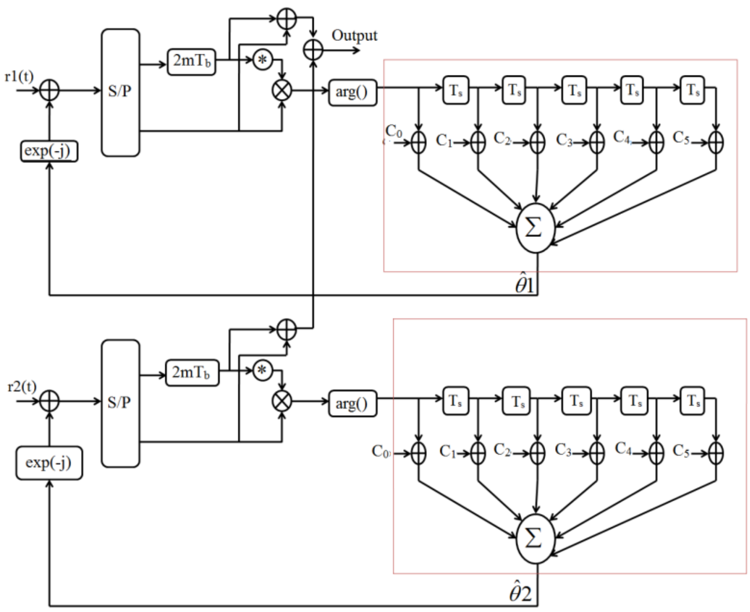


Fig.5 Configuration of proposed scheme

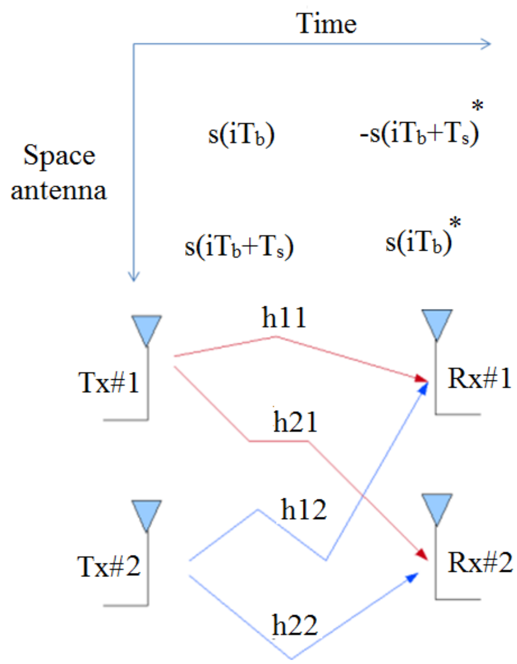


Fig.6 Configuration of 2x2 Alamouti scheme

The received signal in the first time slot is :

$$\begin{bmatrix}\alpha^1_{2i}\\ \beta^1_{2i}\end{bmatrix} = \begin{bmatrix}h_{11} & h_{12}\\ h_{21} & h_{22}\end{bmatrix}\begin{bmatrix} s(iT_b).\,e^{-j2\pi f_d iT_b} \\ s(iT_b+T_s).\,e^{-j2\pi f_d(iT_b+T_s)}\end{bmatrix} + \begin{bmatrix}n^1_1\\ n^1_2\end{bmatrix} \qquad (11)$$

Assuming that the channel remains constant for the second time slot , the received signal will be:

$$\begin{bmatrix}\alpha_{2i}^2\\ \beta_{2i}^2\end{bmatrix}=\begin{bmatrix}h_{11} & h_{12}\\ h_{21} & h_{22}\end{bmatrix}\begin{bmatrix}-s^*(iT_b+T_s).\,e^{-j2\pi f_d(iT_b+T_s)}\\ s^*(iT_b).\,e^{-j2\pi f_d iT_b}\end{bmatrix}+\begin{bmatrix}n_1^2\\ n_2^2\end{bmatrix}$$

(12)

$\begin{bmatrix}\alpha_{2i}^1\\ \beta_{2i}^1\end{bmatrix}$ are the received information at time slot 1 on receive antenna 1,2 respectively.

$\begin{bmatrix}\alpha_{2i}^2\\ \beta_{2i}^2\end{bmatrix}$ are the received information at time slot 2 on receive antenna 1,2 respectively.

h_{ij} is the channel from i^{th} receive antenna to j^{th} transmit antenna .

$s(iT_b)$, $s(iT_b+T_s)$ are the transmitted symbols.

$\begin{bmatrix}n_1^1\\ n_2^1\end{bmatrix}$ are the noise at time slot 1 on receive antenna 1 , 2 respectively.

$\begin{bmatrix}n_1^2\\ n_2^2\end{bmatrix}$ are the noise at time slot 2 on receive antenna 1 , 2 respectively.

Combining the two equations at time slot 1 and 2

$$\begin{bmatrix}\alpha_{2i}^1\\ \beta_{2i}^1\\ \alpha_{2i}^{2*}\\ \beta_{2i}^{2*}\end{bmatrix}=\begin{bmatrix}h_{11} & h_{12}\\ h_{21} & h_{22}\\ h_{12}^* & -h_{11}^*\\ h_{22}^* & -h_{21}^*\end{bmatrix}\begin{bmatrix}s(iT_b)e^{-j2\pi f_d iT_b}\\ s(iT_b+T_s)e^{-j2\pi f_d(iT_b+T_s)}\end{bmatrix}+\begin{bmatrix}n_1^1\\ n_2^1\\ n_1^{2*}\\ n_2^{2*}\end{bmatrix} \quad (13)$$

Let define

$$H=\begin{bmatrix}h_{11} & h_{12}\\ h_{21} & h_{22}\\ h_{12}^* & -h_{11}^*\\ h_{22}^* & -h_{21}^*\end{bmatrix} \quad (14)$$

By similarity , the combining received signal of the second two time slots is :

$$\begin{bmatrix}\alpha_{2i+1}^1\\ \beta_{2i+1}^1\\ \alpha_{2i+1}^{2*}\\ \beta_{2i+1}^{2*}\end{bmatrix}=\begin{bmatrix}h_{11} & h_{12}\\ h_{21} & h_{22}\\ h_{12}^* & -h_{11}^*\\ h_{22}^* & -h_{21}^*\end{bmatrix}\begin{bmatrix}s(iT_b+2T_s)e^{-j2\pi f_d(iT_b+2T_s)}\\ s(iT_b+3T_s)e^{-j2\pi f_d(iT_b+3T_s)}\end{bmatrix}+\begin{bmatrix}n_1^1\\ n_2^1\\ n_1^{2*}\\ n_2^{2*}\end{bmatrix} \quad (15)$$

The estimation of the first transmitted two symbol is:

$$\begin{bmatrix}s\widehat{((\imath T_b))}\\ s(\imath T_b+T_s)\end{bmatrix}=(H^H H)^{-1}H^H\begin{bmatrix}\alpha_{2i}^1\\ \beta_{2i}^1\\ \alpha_{2i}^{2*}\\ \beta_{2i}^{2*}\end{bmatrix} \quad (16)$$

The estimation of the second transmitted two symbol is:

$$\begin{bmatrix}s\widehat{((\imath T_b+2T_s))}\\ s(\imath T_b+3T_s)\end{bmatrix}=(H^H H)^{-1}H^H\begin{bmatrix}\alpha_{2i+1}^1\\ \beta_{2i+1}^1\\ \alpha_{2i+1}^{2*}\\ \beta_{2i+1}^{2*}\end{bmatrix} \quad (17)$$

Such that the Doppler is canceled by a tapped delay line which is proposed, also the effect of noise is decreased. The same method is applied for the estimation of other two symbols and so on. In the proposed scheme, the space-time diversity combining is performed before coherent detection. The time diversity effect contributes to carrier recovery in the coherent detector consequently, and the space diversity increase gain and mitigate interference which improve BER performance of the previous two systems.

Table 1 Simulation Conditions

Helicopter	
Maximum speed	V=68.4 m/s
Maximum acceleration	A=3.09 m/s^2
Modem	
Modulation	BPSK
Information data rate	3600 bit/s
Carrier frequency	12.5 GHz
Demodulation	Coherent detection
Forward error correction	
Code	Convolutional
Rate	R=1/2
Constraint length	K=7
g1	2*10^-3
g2	5*10^-5

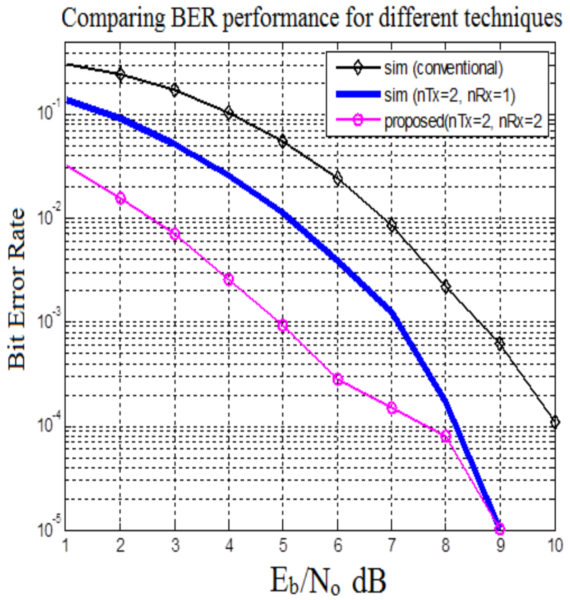


Fig.7 BER performance

Fig. 7 shows the BER performance. It is shown that the BER performance of the proposed scheme (nTx=2 , nRx=2) is better than that of the conventional and alamouti (nTx=2 , nRx=1) schemes.

5. CONCLUSIONS

In this paper, proposing a space time diversity combining scheme with accurate tapped delay line for helicopter satellite communications. Results of computer simulation show that the proposed tapped delay line tracks and removes time-varying Doppler shift exactly. It is also shown that the proposed scheme improves the BER performance better than of the previous conventional system combining scheme, and also that of (2x1) Alamouti scheme which achieves the excellent BER performance .

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