2014 3rd International Conference on Informatics, Environment, Energy and Applications
IPCBEE vol.66 (2014) © (2014) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2014. V66. 29

A Method of PCMA based on Subsection Weighting Process for the Helicopter Satellite Communication System

Shi Zijian+, Wang Yuhan, Ma Zhengxin and Wei Zhang

Department of Electronic Engineering, Tsinghua University, Beijing 100084, China

Abstract. A self interference cancellation method based on subsection weighting process is proposed in this paper for the issue that the frequency and amplitude in return signal is unsteadiness when applying paired carrier multiple access technology (PCMA) in helicopter satellite communications. The estimator which have been contributed for estimated the self interference signal when the helicopter blades covered the antenna beam in the first phase, and using the asymmetric PCMA algorithms to estimate the self interference signal when the beam is unobstructed in the second phase, then weighted the two part of the result to equilibrate the estimator and finish the cancellation. Computer simulation results show that the method can reduces the random error of the PCMA estimate algorithms effectively, and the Eb/N0 lost of desire signal is always less than 0.2dB in the asymmetric systems.

Keywords: helicopter satellite communication, paired carrier multiple access, subsection weighting, self interference cancellation.

1. Introduction

PCMA was proposed by ViaSat in 1998, according to the theory of echo cancellation, a relayed two-part full duplex communication can use the same frequency, time slot or the same spreading code [1]. The satellite communication system was applied firstly. A transparen transponder is needed to composite the signals and to conversion the frequency from uplink to downlink. Because of the own sequence which had been transmitted was copied by the local modulator, a process of channel parameter estimation and a process of self signal rebuilder will eliminate the interference signal from the compounded signals. With a little *Eb/N0* lost of desire signal we can obtain a double satellite bandwidth. When this technology is used in the helicopter satellite communication system, the data secrecy is acquired and the bandwidth can be saved.

There still a little different from the nominal VSAT system, the helicopter has to rely on the rotating blades to lift it selves. The position of the antenna has to assembling below the blades, and then the problem of interruption and microwave reflect occurred. To solve those problems, the effective way is resort to a burst transmission mode named blade-synchronized transmission technique in the backward link, and a time diversity transmission used in the forward link [2]. The difference of the two-part transmitting power level impels the system has to worked at the asymmetric mode, so the more accuracy of estimate is needed. As for the host site, the asymmetric PCMA algorithm by using cross correlation calculation is proposed to estimate all the parameters in modern systems.

After the estimate, the own sequence has to be rebuild with a carrier adjustment, include the time delay, frequency drifting, phase rotation and an adaption of amplitude. A fast initializing based on the training sequence has been proposed by Dankberg earlier [3], but synchronization has to deal with a mutual recognition arrangement between the two sites by protocol. It makes the system more complicated.

Shao adopt a kind of correlator that can capture the time delay in a loop and use a delay lock loop (DLL) to keep tracking, the tracking result nearby the time $0.01\mu s$ [4] can meet the needs in engineering. Liang introduced an algorithm to estimate the frequency and phase based on the adaptive way for single signal [5].

+ Corresponding author. Tel.: +86013811485206; fax: +8601062986020.
E-mail address: morphlingszj@hotmaill.com.

Gong proposed an algorithm in order to estimate the frequency offset, and created an estimation curve for correlation function based on least mean square error, the computer simulation shows that absolute value of estimation error is less than 100Hz [6]. As for the amplitude of single signal estimator, Pan gives an algorithm base on the maximum likelihood estimator (MLE) [7], and the result is always attain the attain the Cramer-Rao bound with the original data aided. Cai is proposed a new amplitude estimation algorithm based on the numerical fitting in PCMA system [8], it can offset the error which caused by the non-zero cross correlation calculations without introducing phase noise.

This paper is organized as follows. The structure and algorithm of the self interference cancellation are proposed in section 2. The new processing of state transition is first being established in section 3. In section 4, computer simulation showed that the result is brightly improved by application the method of subsection weighting process than the existing algorithm and some kind of device's quality index. The paper is summarized in section 5.

2. System Model

This paper contributed an appropriative system model for the intermittent communications. The helicopter is a typical example, and it is a mobile station with fast moving and no fixed track, thus the Doppler shift and the signal quality unsteadiness happened, so it is difficult to estimate the parameters of own signal. In addition, through a credible link budget, the airborne antenna can not receive the self interference signal in the receiver noise, the cancellation is not necessary in the helicopter allocation. The other side, the capacity of host station is much higher than the helicopter's, so the residual error of cancellation will affects the desire signal demodulation directly. How to increase the accuracy of the parameters estimate is the key for this system. The self interference cancellation block diagram as shows in figure 1.

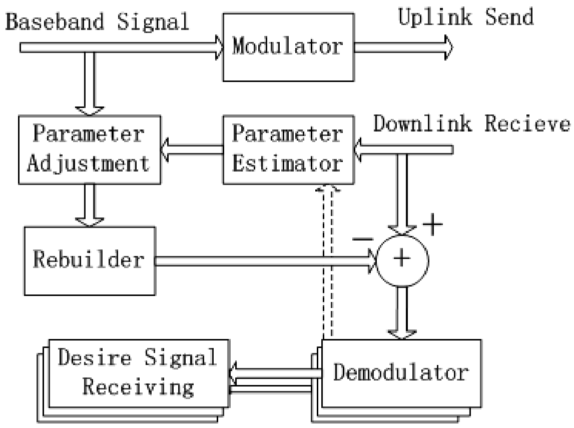

Fig. 1: Self interference cancellation block diagram.

We discussed the every When the blades covered the path between the antenna and the satellite, the helicopter will not to transmitting carriers. The only one signal to consist of a single complex sinusoid is the self interference signal with a white Gaussian noise in the host receiving system, the signal expression as shown in(1).

$$r_1(t) = A_1 s_A(t-\tau_{A1}) e^{j(2\pi\Delta f_{A1}t+\phi_{A1})} + n_1(t) \tag{1}$$

The self interference signal S_A contains several indeterminate parameters, like link delay τ_{A1}, amplitude alter A_1, frequency drift Δf_{A1} and initial phase ϕ_{A1}. The noise, $n_1(t)$, is assumed to be a zero mean complex white Gaussian signal, σ^2 is the variance of $n_1(t)$. Frequency auto-tracking adaptive frequency estimator will be applied in the frequency estimate [5], it will attain the Cramer-Rao bound in a high signal to noise ratio (SNR) as $Var_{CRLB}(\hat{\omega}) = \frac{6}{rN(N^2-1)}$. N is the sequence length, and r is SNR.

The MLE is used to estimate the real received signal amplitude by (2).

$$\hat{A}_1 = \frac{1}{M}\sum_{k=1}^{M} r_{1k}s_{1k} \tag{2}$$

The result will also attain the Cramer-Rao bound in a high SNR as $CRB(A_1) = N_0 / NT$ [7].

Once the path goes free, the backward signal is on, so the received compound signals expression as (3).

$$r_2(t) = A_2 s_A(t-\tau_{A1}) e^{j(2\pi\Delta f_{A1}t+\phi_{A1})} + B_2 s_2(t-\tau_{B2}) e^{j(2\pi\Delta f_{B2}t+\phi_{B2})} + n_2(t) \tag{3}$$

Due to the introduction of the backward signal B, the error wills inevitably increasing based on single signal parameters estimate. After compensate the result of cross correlation calculation based on the known sequence, an asymmetric PCMA algorithm has been proposed as (4).

$$R \approx f_s N t_b \frac{\sin\left[2\pi\left(\Delta f_{A2} - \Delta\hat{f}_{A2}\right) N t_b\right]}{2\pi\left(\Delta f_{A2} - \Delta\hat{f}_{A2}\right) N t_b} \tag{4}$$

The maximum value is obtained when $\Delta f_{A2} = \Delta\hat{f}_{A2}$ [6]. As for the amplitude estimator, an algorithm based on numerical fitting will be use in asymmetric PCMA estimator [8].

3. Implementation Process

We can inform that the duty ratio is a range from 10% to 30%, so there is more than 10% idle time to inhibit the backward signal per cycle. Then the Stage 1 is created for a single signal estimating, and Stage 2 created for an asymmetric PCMA estimation, so a state transition diagram is proposed as shown in fig 2.

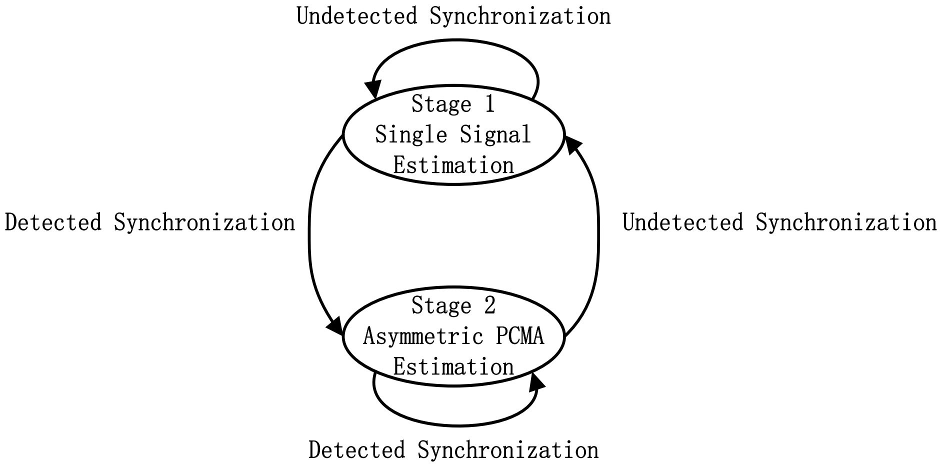

Fig. 2: State transition diagram.

A code of synchronous inspection mechanism is needed. Whenever a synchronization code of packet header has not been detected on time, the Stage 1 will be started in the estimator. In this Time, the estimate result is considered valid, and update on time. On the contrary, the synchronization code has been detected, Stage 2 in the estimator goes to started, the result of asymmetric PCMA algorithm will be equalize with the lasted result of Stage 1, though the different weight from formula (5) to adjustment the critical parameters to rebuild the local sequence to a carrier, and modulation carrier to get ready to the cancellation.

$$\begin{aligned} w_f\,\omega_1 + (1-w_f)\omega_2 &= \omega \\ w_\phi \phi_1 + (1-w_\phi)\phi_2 &= \phi \qquad\qquad w_f, w_\phi, w_A \in [0,1] \\ w_A A_1 + (1-w_A)A_2 &= A \end{aligned} \tag{5}$$

If the stability of transmission of forward signal is credible, the weight of w_f, w_ϕ, w_A should be increased. Even so the amplitude will considering the rain fade of Ku-band transmitting and the peaking accuracy of the airborne satellite antenna, and the frequency drifting of local oscillator should be balanced through the selection of weight.

4. Computer Simulations

A computer simulation was performed to compare and compound the result of the two stage estimators given in (1)-(5). Based on the actual satellite link, BPSK modulation, the symbol rate is 2.5Mbps and simulation time is 0.002sec., the critical parameters is 1 for initial phase, 5KHz for frequency shifting per 0.0625sec., the self interference *Eb/N0* is 14dB, and the desire *Eb/N0* is a range of [0, 0.01, 14]. Assuming that the time delay estimator using DLL loop tracking, no error will be considered, so the residue signal after filter as shown in figure 3(a),(b) and figure 4.

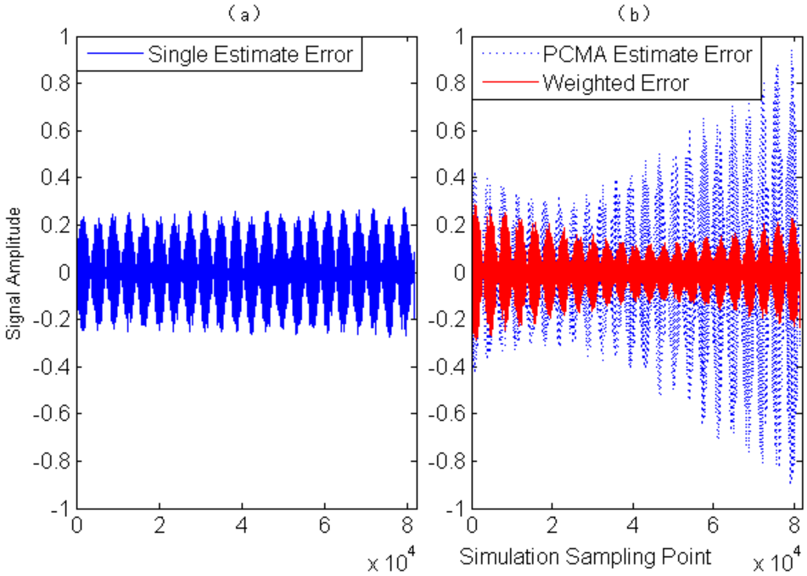

Fig. 3: Self interference cancellation residual signal.

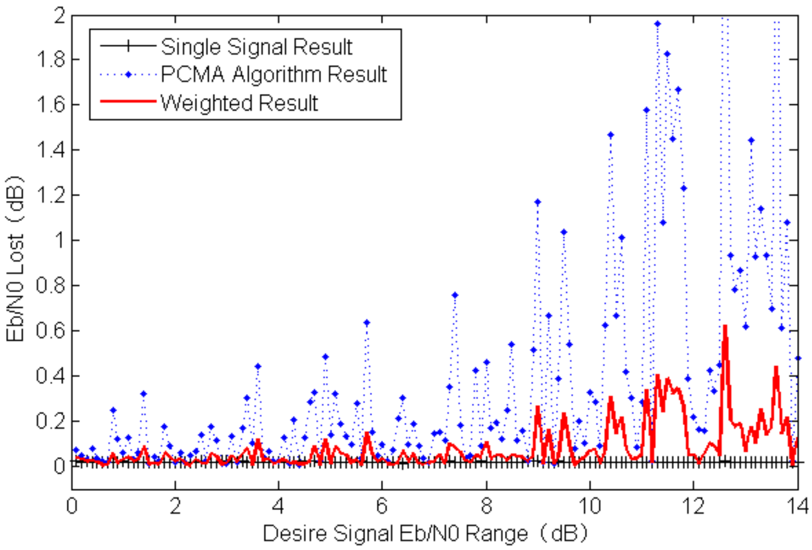

Fig. 4: The desired signal *Eb/N0* lost.

Figure 3(a) shows that the residual signal amplitude via single signal estimated is less than 0.2dB, so the average power is no more than 0.1dB, and no extra phase shift error had been accumulated. It is obvious in the figure 3(b) that the weighted estimate error is much lower than the asymmetric PCMA estimate error from the residual signal where the *Eb/N0* of backward signal is 5dB, because of the phase shift has been accumulated by time.

Experiment result indicate that the self interference cancellation of Stage 1 single signal estimate is much stability from the figure 4, and it can be learnt that the accuracy of asymmetric PCMA estimator will reducing gradually by the increasing power of the backward signal. The cross correlation calculate will never be zero because of the length of random sequence is finite. The weighting process counteracted the random error when the critical parameters are relatively stable in a cycle of rotating blades (0.0625sec.).

The *Eb/N0* of backward signal is always less than the forward signal for 5-10dB, it is less than 9dB. So the self interference cancellation error is stable for about 0.1dB and meet requirements for a week signal recovery. So a link budget is easier to make for a power limited system.

5. Conclusion

This paper proposed an appropriative system model and a subsection weighting method of self interference cancellation which applied to helicopter satellite communication PCMA system. By analyzing the trajectory of helicopter's blades, it can be learnt that backward signal is in the burst mode. The estimation of the state transition diagram is proposed for adaptability the helicopter system. The estimated result of critical parameters in asymmetric PCMA mode will be equilibrating with the result which in single signal mode. So the residual error will reduce when running a two-part related calculation between the two signals obviously, and the method can balance the amplitude jitter and frequency drift like the rain fade and an unstable transmission. The computer simulation shows that the lost *Eb/N0* of desire signal is inappreciably in helicopter satellite communication system and an interval satellite communication system for example most of kinds of TDMA systems when using PCMA mode.

6. References

[1] Mark Dankberg Mark D.. "Paired Carrier Multiple Access (PCMA) for Satellite Communications". *Proceedings of Pacific Telecommunications Conference*. Honolulu, Hawaii: IEEE, 1998:322-329.

[2] LI H B, et al. "Ku-Band Helicopter Satellite Communications for on Scene Disaster Information Transmission". *15th IEEE International Symposium on Personal Indoor and Mobile Radio Communications*. Barcelona, Spain: IEEE, 2004:2792-2976.

[3] Dankberg Mark D., Miller Mark J, and Mulligan Michael G. "Self-interference cancellation for two-party relayed communication": *US Patent No.5,596,439*. Jan.21, 1997.

[4] Shao Shuyuan, Zhang Yang. "Estimation of Interference Delay in PCMA System". *Information and electronic engineering*. 2006,4(1):49-52.

[5] Liang Guolong, Yang Chun, and Wang Dejun. "Research on Properties of Frequency Auto-Tracking Adaptive Frequency Estimator". *ACTA ELECTRONICA SINICA*. 2005,33(7):1204-1208.

[6] Gong Bo, Guo Qing. "A Novel Self-Interference Frequency Estimation Algorithm in PCMA Systems". *Communications Technology*. 2010,43(11).37-38.

[7] Pan Shenfu, Li Zhendong, and Liang Qinglin. "Decision-Directed Feedback Amplitude Estimate for BPSK/PQPSK Signal". *Acta Scientiarum Naturalism*. 2004.40(5).830-834.

[8] Cai Yuncheng, Wang Yuhan, and Ma Zhengxin. "Amplitude Estimation Based on Numerical Fitting of Interference Signal in PCMA Systems". *Telecommunication Engineering*. 2013,53(6):730-734.