THE SPREAD-SPECTRUM MULTIPLEXING TELEMETRY SYSTEM USING PARALLEL MOVE EQUIVALENT SEQUENCE

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ABSTRACT

In this paper, based on the parallel move equivalent sequence of *m* sequence ,one type of CDM telemetry system is issued. Also the method for anti multi-path interference(MPI) of the system is proposed and its performance is analyzed. We proved that this system not only holds the merits which are inherent in common spread-spectrum communication system, but also has better transmission efficiency.

KEYWORDS

Spread-Spectrum Communication, CDM Telemetry System, *m* Sequence, Parallel Move Equivalent Sequence.

INTRODUCTION

It is known that, in many multiplexing telemetry systems, the multiplexing telemetry data have to be simultaneously transmitted, thus the multiplexing communication technology should be adopted in these systems[1~4]. FDMA, TDMA and CDMA are these commonly used multiplexing technology, in which CDMA is the best multiple access mode. In CDMA, orthogonal codes are used to realize multiple access. Since *m* sequence has good pseudo-random nature, it is commonly adopted in spread-spectrum communication system. The common spread-spectrum communication system has better characteristics than other communication systems such as FDMA and TDMA communication systems. It has good merits such as good anti-interference ability, low signal trapped rate, good anti multi-path ability, easily realized, sharing the bandwidth with the traditional modulation mode and etc. Therefore, more and more attention has been paid to the development of the spread-spectrum communication technology. In this paper, we proposed one type of spread-spectrum CDM system used in multiple telemetry system whose error probability is lower than the common spread-spectrum communication system.

THE SYSTEM MODEL

As is known, *m* sequence has good pseudo-random nature, especially has periodic autocorrelation nature: $\rho(\tau)=\begin{cases}1\ , & \tau=0\\ 1/N\ , & \tau=others\end{cases}$ where N is the *m* sequence's cyclic. The parallel move equivalent sequence of *m* sequence is adopted as the orthogonal codes for the CDM system. This not only makes this type of multiplexing system own the inherent merits of common spread-spectrum communication system, but also can enhance the data transmission rate. But unfortunately, since the parallel move sequences of *m* sequence are quasi-orthogonal, there exists multiplexing interference when they are used as the orthogonal codes for the CDM system. In order to counteract the multiplexing interference, one method is proposed in this paper. This method makes the CDM system in this paper different from the common CDM system. The difference is described as follows: for one path data, it is modulated not only by the parallel move equivalent sequence of one *m* sequence, but its negative signal is modulated by another parallel move equivalent sequence. With the same way, other paths' data are pseudo modulated. If the synchronization for the codes is strictly accurate, it can be proved that such CDM system constructed by the parallel move equivalent sequence of *m* sequence can subtract out the multiplexing interference completely, also the channel has higher output *SNR* than the common CDM system which adopts the common spread-spectrum modulation mode. Its block diagrams are shown follows as Figure.1 and Figure.2.

As is shown in Figure.1, there are *M*-path data that will be transmitted, in which $PN_{11}, PN_{12}, PN_{21}, PN_{22}, \ldots, PN_{M1}, PN_{M2}$ are the same *m* sequence's parallel move equivalent sequences, for example, $PN_{11}=a_n$,PN_{12}=a_{n-2},…, PN_{M1}=$a_{n-4(M-1)}$,PN_{M2}=$a_{n-4(M-1)-2}$.(a_n is a *m* sequence, a_{n-2} is a_n's left shift two bits parallel move equivalent sequence, the other sequences are expressed with the same way.) According to different synchronization methods, we can also select other respective parallel move equivalent sequences which have different phases. At the source end, PN_{11} is used to modulate the first path data $d_1(t)$, PN_{12} is used to modulate the first path's negative signal $-d_1(t)$, the others are dealt with the same way. For example, the M^{th} path data $d_M(t)$ is modulated with PN_{M1}, its negative signal $-d_M(t)$ is modulated with PN_{M2}. After modulation, the multiplexing data is linearly accumulated firstly, then is multiplied with signal carrier and transferred by the antennas.

The block diagram of the system's reception end is presented with Figure 2: First, the carrier is demodulated, then the received signal is multiplied with $PN_{11}, PN_{21}, \ldots, PN_{M1}$ through correlation calculation. Thus every path data is separated from its carrier(Here

$PN_{12}, PN_{22}, \ldots, PN_{M2}$ don't need to be dealt with correspondingly).Since the fixed phase is ensured between $PN_{11}, PN_{12}, PN_{21}, PN_{22}, \ldots, PN_{M1}, PN_{M2}$, after reception , one path signal is synchronously dealt with correlation calculation, the interference from others is only $+1/N$ or $-1/N$, N is the m sequence' s period, which is determined by the *m* sequences' self-correlation nature. As well as for any path signal, it and its negative signal are modulated with two different parallel move equivalent sequence of a *m* sequence. So after dealt with correlation calculation, the residual interference is just $(+1/N)+(-1/N)=0$, thus it can be seen that the multiplexing interference is completely removed. It is not difficult to prove that the demodulated signals consist of $PN_1(t)d(t)$ and $-PN_1(t)d(t)$. After being demodulated, the output *SNR* and the anti-interference ability are enhanced corresponding.

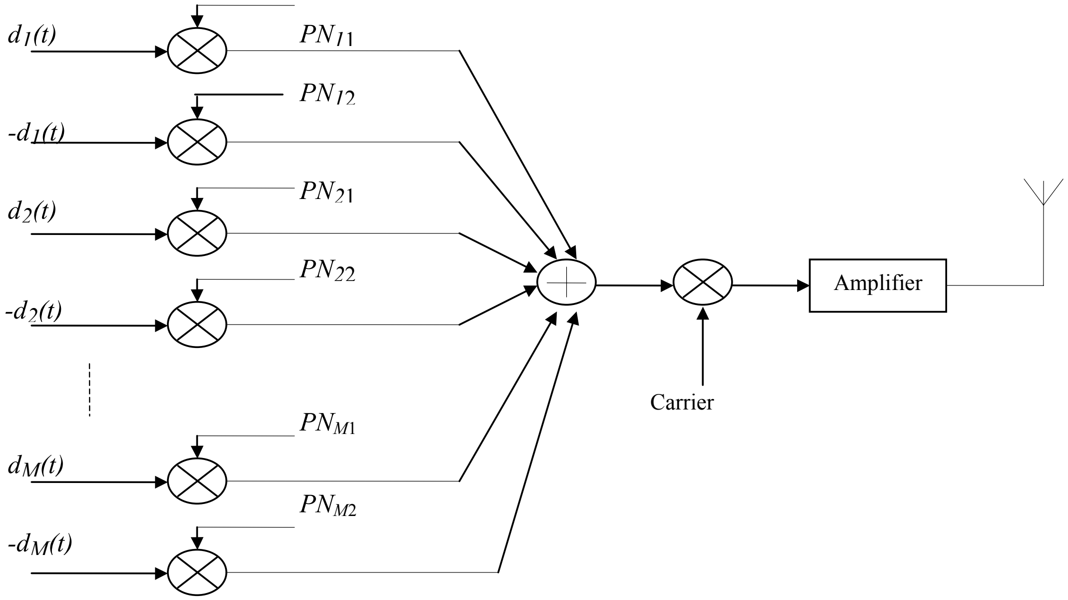

Figure 1 The source end's schematic diagram of the CDM system

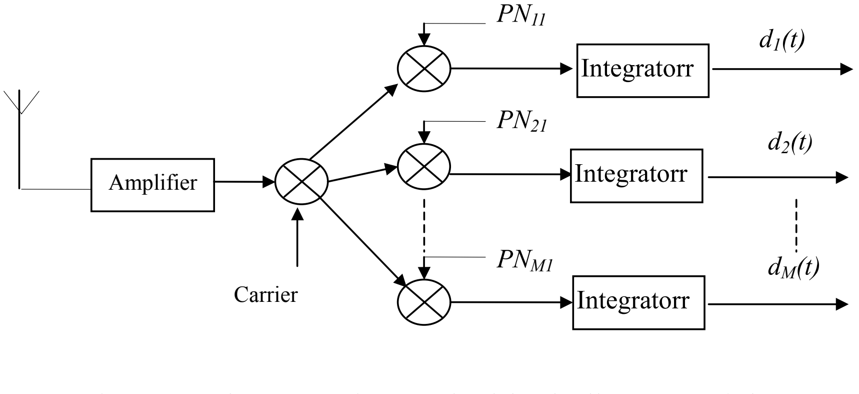

Figure 2 The reception end's block diagram of the CDM system

THE PERFORMANCE OF THE SYSTEM

1.The data transmission rate of the system

In common spread-spectrum communication system, a PN sequence is used to fulfill the modulation by adding it to the data with modulus 2. After reception, two phases “+” and ”-” can be demodulated, so at any transmission time, the information quantity is $\log_2 2^1 = 1(bit)$.

The M-path CDM system which is constituted with the parallel move equivalent sequence of m sequence can encode M paths data, which has M states, thus at any transmission time, the information quantity is $\log_2 2^M = M(bit)$. This shows that the M-path CDM system which is constituted with the parallel move equivalent sequence of m sequence has M times data transmission rate and effectivity than common spread-spectrum communication system, which is obtained just through transmitting *2M PN* code sequence synchronously.

2.The error probability of the system

We assume that the transmitted signal of the M-path CDM system which is constituted with the parallel move equivalent sequence of m sequence is:

$$s(t)=\sqrt{2P}\left[d_1(t)PN_{11}(t)-d_1(t)PN_{12}(t)+\ldots+d_M(t)PN_{M1}(t)-d_M(t)PN_{M2}(t)\right]Cos(\omega_0 t+\varphi) \tag{1}$$

and it can be rewritten as such forms:

$$s(t)=\sqrt{2P}\sum_{i=1}^{M}\left[d_i(t)PN_{i1}(t)-d_i(t)PN_{i2}(t)\right]Cos(\omega_0 t+\varphi) \tag{2}$$

Where P is the signal’s power, $d_i(t)$ is the i^{th} path’s data, PN_{i1}、PN_{i2} are the i^{th} parallel move equivalent sequences of m sequence. Without loss of generality, considering the noise added on the channel when the signal is transmitted, the received signal can be written as:

$$u(t)=s(t)+n(t) \tag{3}$$

Where $n(t)$ is the noise added to the channel. In order to encode the k^{th} path data, the carrier is demodulated first, then PN_{k1} is used to process the correlation calculation, thus the encoded signal is:

$$\begin{aligned}V_k(t)=&\int_0^T\sqrt{2P}\left\{\sum_{i=1}^{M}\left[d_i(t)PN_{i1}(t)-d_i(t)PN_{i2}(t)\right]Cos(\omega_0 t+\varphi)\right\}\\&\times\sqrt{2P}PN_{k1}(t-\tau)Cos\left(\omega^n t+\varphi^n\right)dt+\int_0^T n(t)\sqrt{2P}PN_{k1}(t-\tau)Cos\left(\omega^n t+\varphi^n\right)dt\end{aligned} \tag{4}$$

When the local PN code is not accurately synchronized with the received signal, then

$\tau = 0, \omega^n = \omega_0, \varphi^n = \varphi$.After being filtered by a LPF, the encoded signal can be expressed as follows:

$$V_k(t) = P\int_0^T \left\{ \sum_{i=1}^{M} \left[d_i(t)PN_{i1}(t) - d_i(t)PN_{i2}(t) \right] \right\} PN_{k1}(t)dt + \sqrt{2P}\int_0^T n(t)PN_{k1}(t)Cos\left(\omega_0 t + \varphi\right)dt \quad (5)$$

The first term of the right-hand side（RHS）of formula (5) is:

$$V_{k1}\left(t\right) = P\int_0^T \left\{ \sum_{i=1}^{M} \left[d_i\left(t\right)PN_{i1}\left(t\right) - d_i\left(t\right)PN_{i2}\left(t\right) \right] \right\} PN_{k1}\left(t\right)dt \qquad (6)$$

When $k \neq i$, the cross correlation coefficients between $PN_{k1}(t)$ and $PN_{i1}(t)$ 、 $PN_{i2}(t)$ 、 $PN_{k2}(t)$ are -1/*N*， *N* is the circle of *m* sequence. But the cross correlation coefficients between $PN_{k1}(t)$ and $PN_{k1}(t)$ is 1, then (6) can be rewritten as:

$$V_{k1}\left(t\right) = PT\left\{ d_k\left(t\right)\left(1 + 1/N\right) + \sum_{i=1, i\neq k}^{M} \left[d_i\left(t\right)\left(-1/N\right) - d_i\left(t\right)\left(-1/N\right) \right] \right\} = PT\left(1 + 1/N\right)d_k\left(t\right) \qquad (7)$$

This shows that the branch signal $d_k(t)PN_{k2}(t)$ has enhanced the useful signal. The second item of formula (5) is:

$$N\left(t\right) = \sqrt{2P}\int_0^T n\left(t\right)PN_{k1}\left(t\right)Cos\left(\omega_0 t + \varphi\right)dt \qquad (8)$$

According to [1], we know that: The mean of $N(t)$ is $E\left[N(t)\right] = 0$, the variance of $N(t)$ is $\sigma^2{}_{N(t)} = PT\frac{N_0}{2}$,in which $\frac{N_0}{2}$ is the two sided power spectrum density of $N(t)$.So the *SNR* of the system's reception end can be deduced as follows:

$$(S/N)_{out} = \frac{\left[PT(1 + 1/N)\right]^2}{PT\frac{N_0}{2}} = \frac{2PT(1 + 1/N)^2}{N_0} \qquad (9)$$

According to reference [1], we can know that the error probability is:

$$P_e = Q\left(\sqrt{\frac{2PT(1 + 1/N)^2}{N_0}}\right) \qquad (10)$$

Where $Q(\square)$ is the error function. Using this result, we can derive that the error probability of the common spread-spectrum communication system is:

$$P_e^{'} = Q\left(\sqrt{\frac{2PT}{N_0}}\right) \qquad (11)$$

3. Multiplexing interference

From formula (7), we can know that the multiplexing interference of this CDM system is:

$$R_M(t) = PT \sum_{i=1,i\neq k}^{M} \left[d_i(t)(-1/N) - d_i(t)(-1/N) \right] = 0 \qquad (12)$$

Thus it can be seen that, in this system the multiplexing interference is removed completely. The increasing of the transmission paths does not affect the anti-interference ability of this system.

THE NUMBERIC RESULT AND CONCLUSION

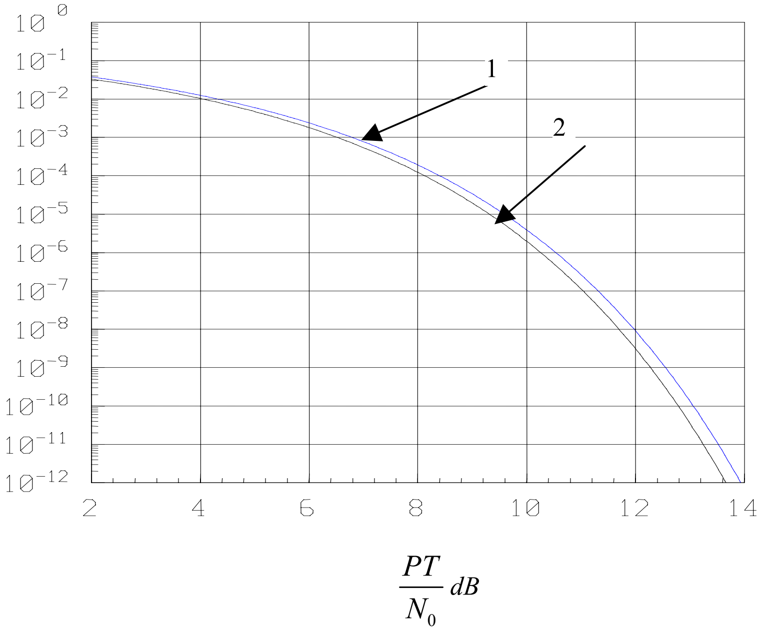

Figure 3 The error rate probability curves of the proposed CDM system and the common spread-spectrum communication system

In order to compare with the common spread-spectrum communication system, through the computer simulation we give the curve of the system's error probability performance versus PT/N_0(dB). It was given in Figure 3.

In Figure 3 , the circle of the *m* sequence is *N* which is equal to 127, the curve 1 is the error probability for the common spread-spectrum communication system, the curve 2 is the error probability of the parallel moves equivalent sequence of the m sequence. It is obvious that the CDM system constituted with the parallel moves equivalent sequence of *m* sequence has less error probability than the common spread-spectrum communication system. Simulation results also show that the system's reliability is enhanced through the method we have proposed.

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