Proposal of High Capacity 2Mbps/ 8Mcps Phase Continuous Portable diffCDMA and Its System Capability

位相連続化 QPSK を用いた大容量 2M ビット/秒 8M チップ/秒 携帯 diffCDMA の提案と そのシステム容量

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Abstract: From the frequency usage efficiency points of view, the novel CDMA with phase continuity QPSK is proposed in this paper to achieve such high reliability as shown in free space propagation, and is also discussed in system capability to get significant scheme for system design.

Phase continuity is facilitated by substituting smoothing function over adjacent symbol fringes, in which the function touches current and next frame phase values with 0th order contact and varies with the steepest gradient just at the center.

Simulations are verified to be error free to transmit 2 Mbps over 7.282 MHz bandwidth by employing diffCDMA with phase continuous QPSK without any compensations. The system configuration is also optimized through simulations to be defined by 11.651 MHz bandwidth, where the necessary Eb/No is -11.5 dB for error free in 2-ray Rayleigh fading environment of DUR= 10 dB with 1 micro second delay over 2 GHz domain.

1. INTRODUCTION

It is important to improve high capacity and high speed transmission of such CDMA featured with low power transmission, high reliability, and system flexibility.

This CDMA is strongly eager to be developed as IMT2000 in serving high speed links among pedestrians walking through urban multi-ray propagation environment. CDMA being given by the direct product of primary modulating PSK and spread spectrum code, the CDMA transmission capacity is defined by the product of QPSK transmission speed and spread spectrum code number. The frequency bandwidth of the CDMA is, therefore, also defined by the convolution of QPSK and the spread spectrum code bandwidth. Because of such Walsh function being adopted to span the code space, the CDMA inherits robustness from QPSK genius in fading propagation.

BER vs. Eb/No is shown in fig.1 for QPSK measured after propagation through such two-ray Rayleigh fading environment as 10 dB DUR with 1 micro second delay spread. As clearly shown in fig.1, the transmission quality is degraded in proportion to narrowing bandwidth to get so high frequency efficient as up to 2 bit/Hz owing to remarkable expansion of fading bandwidth through the multi-ray propagation environment. The multi-ray fading robustness is catastrophically improved in BER meanings by expanding frequency occupancy from Nyquist limit to doubled and quadrupled bandwidth.

Being depended on symbol speed, QPSK

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bandwidth is especially extended beyond the Nyquist limit by switching its phase value at every symbol fringe. In fact, even if it loses transmission capability, QPSK vanishes bandwidth to zero to match CDMA with spreading spectrum code in bandwidth in the case of QPSK phase being set to be unique in every symbol.

However, it is possible to reduce QPSK bandwidth close to Nyquist limit with decreasing phase gradient by introducing phase continuity into QPSK at every symbol fringe.

Only if the phase continuous QPSK is employed as the primary modulation of CDMA over a given limited frequency bandwidth, this CDMA with phase continuity is expected to transmit in such high reliability shown in fig.1 as the case of being quadrupled with expanding bandwidth beyond the Nyquist limit.

From the frequency usage efficiency points of view, the novel CDMA with phase continuity QPSK is proposed in this paper to achieve such high reliability as shown in free space propagation, and is also discussed in system capability to get significant scheme for system design.

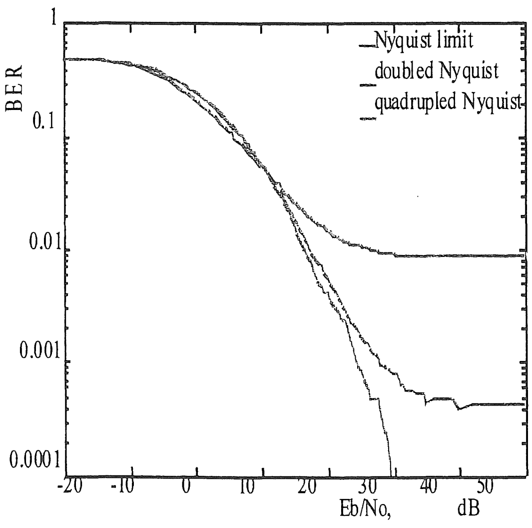

Fig.1 BER vs. Eb/No of QPSK, limited within the Nyquist limit, doubled, or quadrupled bandwidth, through 2-ray Rayleigh fading environment of DUR= 10 dB with 1 micro second delay.

2. PHASE CONTINUOUS PSK

2.1 Concept of Phase Continuity

Reducing CDMA bandwidth is not only effective for finite frequency resources but also promising solution for realizing such high reliability in given bandwidth as free space with base of prevention both from fading bandwidth expansion and spectrum distortion through multi-ray propagation. CDMA being defined by convolution of the primary PSK modulation and spreading code spectrum, reduction of the primary modulation bandwidth is discussed here as an important problem.

PSK phase is illustrated in fig.2. As shown by dotted lines, the existing PSK is given by square topped waves to maintain an unique value within every symbol to cause a jump at every fringe in proportion to the phase difference among the adjacent frames. If there exists no jumps around all symbol fringes, PSK modulated waves obviously vanish frequency bandwidth to zero with victim of losing transmission ability.

It is, therefore, necessary to maintain individual phase value at every frame center, but is sufficient to keep the same value in neighbors at the center in order to transmit information with phase difference among the adjacent frames. It becomes to be possible to reduce the occupied bandwidth where the

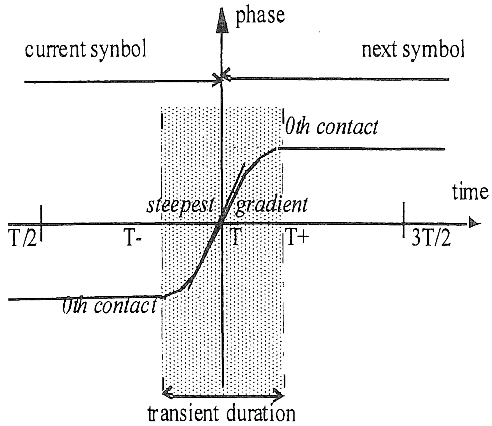

Fig.2 Illustrative time response of continuous phase

rapid variation is suppressed to yield smooth continuous phase in PSK.

Phase continuity is facilitated as shown in fig.2 as solid curve by substituting smoothing function over newly introducing transient duration spanning over adjacent symbol fringes. The former is the current and the later is the next symbol. The function touches current and next symbol phase values at the front and tail ends with 0th order contact, respectively, and varies with the steepest gradient just at the center of the transient duration, i.e. at the fringe. For example, given by following eq.1 is matched to the above phase smoothing function.

$$\theta(t) = \theta c + \Delta\theta(t) S(t) \qquad (1)$$

here, $\theta(t)$ *is the current frame phase value,* $\Delta\theta = \theta c - \theta n$, θn *is the next frame phase value,*

S(t) is such a function given by

$$S(t) = \begin{cases} \frac{1}{2}\left\{1 + \sin\frac{\pi tm}{\tau}\right\}, & \text{if } |tm| < \tau \\ 0 & , \text{else} \end{cases} \qquad (2)$$

where, $tm = t\,|_{\mathrm{mod}T}$ (3)

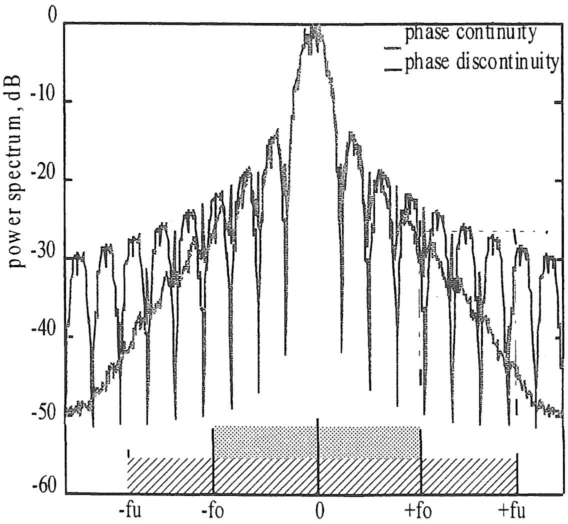

Fig.3 Frequency response comparison between phase continuous and discontinuous PSK power spectrum

2.2 Bandwidth Reduction Effect of Phase Continuous PSK

Both lower and upper eight side lobes are shown in fig.3 as averaged instantaneous spectrum at plural frame fringes. The solid and dotted curves show the ensemble averaged spectrum of phase continuous and phase discontinuous existing PSK, respectively. If the transient duration is set to be a quarter of symbol length, it is observed by 3.87 and 19.36 dB at the force and eighth harmonics to reduce the side lobe amplitude.

It is adequate to the assumption to define all the spectrum except main lobe are interference rather than unnecessary component in communication system, because of the alias being leaked into inside from the outside and of remarkable distortion being occurred at band edges if frequency bandwidth being limited. It requires so widely expanded bandwidth up to 2fu as shown in fig.3 in order to suppress the interference energy of the phase discontinuous PSK to the equal level of the force harmonic.

In paradoxically speaking for phase discontinuous existing PSK and/or CDMA which employs existing PSK as the primary modulation, the newly proposing phase continuous PSK is able to get frequency margin by fu-fo to improve fading or frequency selective fading robustness by this margin amount in the multi-ray propagation environment.

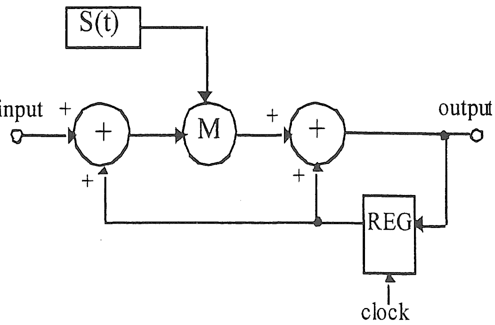

Fig.4 Block Diagram of phase continuity circuit

2.3 Circuitry Configuration of Phase Continuity

The phase continuous PSK is realized by merely prefixing the phase continuity circuit shown in fig.4 to the existing PSK modulator. In fig.4, S(t) means a ROM stored into the smoothing function of eq.2 and read out by modulus T time base, the register REG latches the output at the tail-end of the transient duration and keeps the holding value within the following duration T, and the mark M or + means a multiplier or an adder, respectively.

3. CDMA WITH PHASE CONTINUOUS QPSK

3.1 System Configuration

The system configuration of the CDMA with phase continuous QPSK is illustrated in fig. 5 as significant functional block diagrams.

In fig. 5a showing the transmission module of the CDMA with phase continuity QPSK, the circuitry skeleton is almost the same to the existing CDMA transmission module only with exception of the phase continuity circuit CP being interpolated between phase information input terminal and the primary modulator MOD for every transmission channel. Here, mark SS, CG, or BPF means the secondary modulator of spread spectrum, spread spectrum code generator, or band-pass filter, respectively. And, the total number of transmission channels is m. The circuit topology of the receiving module of the CDMA with phase continuous QPSK is as shown in fig. 5b the same to the existing CDMA receiving module. Mark RX, SYN, CNT, deSS, CG, or DEC means the receiving unit, synchronization detector, control signal recovery circuit, the primary demodulator, de-spread spectrum circuit, spread spectrum code generator, or decision circuit, respectively. Here, the total receiving speech channel is m'. In general speaking, the transmission channel number m is required to be larger than receiving speech channel m', even if the maximum transmission capacity is achieved in the case of m being equal to m'.

In fact, control and synchronization signals are carried through the redundant m-m' channels in cdamOne and WcdmaOne, or carried by redundant time slot shared by time compression to yield equivalent redundancy

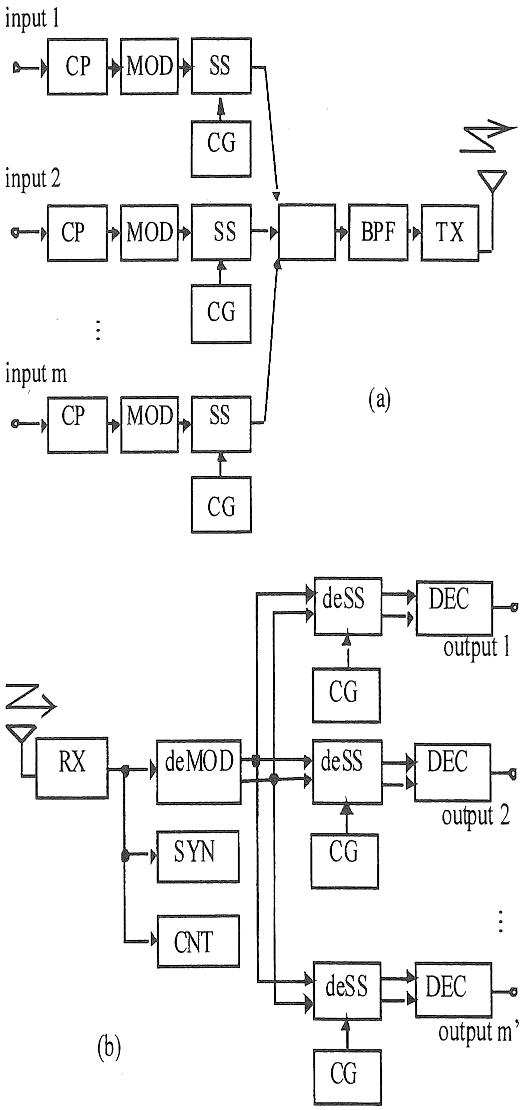

Fig.5 Block diagram of CDMA with phase continuous QPSK, m speech channel transmission module (a), and m' speech channel receiving module (b)

both on time and frequency space in W-CDMA at which a glance shows m being nearly equal to m'.

Fortunately, a novel CDMA system, named by diffCDMA, has been already developed by the same author to perfectly exclude redundancy of the channel or time slot. From transmission and signaling points of views, this diffCDMA which is categorized into an enhanced system of WcdmaOne , and is also based on such technologies as differential coding and post de-spreading spectrum analytic receiving to be verified 2 Mbps transmission ability within up to 5 MHz bandwidth even through multi-ray fading environment.

3.2 Signal Scheme

The maximum 2 Mbps transmission capacity is possible to be performed through 32 simultaneous speech channels by employing 32 kHz frame QPSK as the primary modulation. So long as the diffCDMA being facilitated in CDMA with phase continuous QPSK to exclude any redundancy, the spread spectrum code length is enough to be 32, because of transmission m being equal to receiving channel number m', and of receiving channel number m' being sufficiently 32.

Figure 6 shows the signal scheme in order to transmits 2 Mbps in the diffCDMA with phase continuous QPSK, in which every symbol is consists of 8 segments, and these segments are themselves consist of 32 chips. Here, eight segments are employed within every symbol to verify the effect of phase continuity though 4 segments are sufficient for QPSK.

The chip rate is given by

$$32ksymbol/sec \times 8seg/symbol \times 32chip/seg$$

$$= 8.192\ Mcps.$$

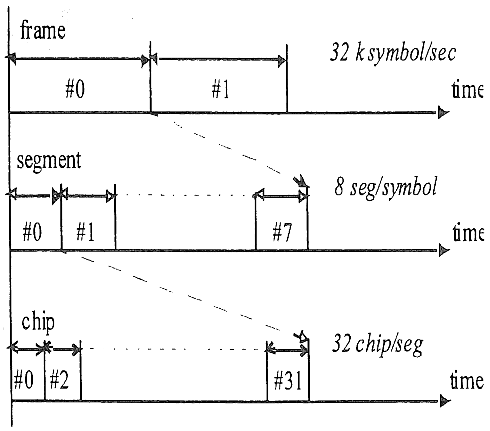

Fig.6 Signal scheme of 2 Mbps defCDMA with phase continuous QPSK

3.3 BER Improvement Effect

The diffCDMA with phase continuous QPSK is verified as shown in fig.7 for BER vs. Eb/No through simulations under the following conditions. High capacity 2.048 Mbps signals are carried by using 7.282 MHz bandwidth on the 2 GHz domain from 10 km/h walking pedestrians passing through such urban environment as two-ray fading propagation of DUR=10dB with 1 micro second delay spread. All the codes of 32 length Walsh sequence are employed to perform 2.048 Mbps rate, signal scheme is given as shown in fig.6, chip rate is 8.192 Mcps, the transient duration is a quarter symbol. Therefore, fdT is set to be 0.0005

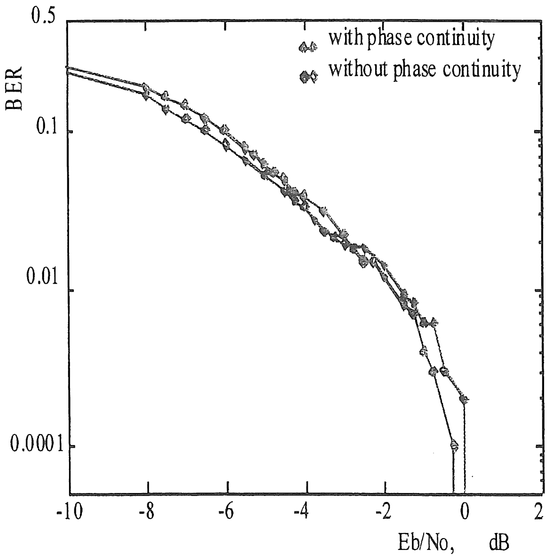

Fig.7 BER vs. Eb/No comparison between phase continuous and discontinuous QPSK of 2 Mbps/ 7.282 MHz pedestrian difCDMA

and Doppler shift is 0.01 ppm, respectively. Such compensations as RAKE receiving, error correction, and power control, are easily facilitated in the diffCDMA with phase continuous QPSK, which are all excluded from simulations to make the phase continuity effect clear. BER is measured on the worst condition channel spanned by the alternative code of the second Walsh sequence when all the 32 length Walsh sequences are devoted to span the simultaneous 32 channels.

4. SYSTEM CAPABILITY of diffCDMA WITH PHASE CONTINUOUS QPSK

4.1 Transmission Characteristics

The diffCDMA with phase continuous QPSK is simulated under the same conditions to the previous section in order to plot fig.8 error free Eb/No by taking transmission bandwidth as parameters. As shown in this figure, error free 2Mbps transmission is achieved at Eb/No = 1.0 dB through 7.282 MHz, at Eb/No = -5.25 dB through 8.322 MHz, Eb/No = -10.5 dB through 10.485 MHz bandwidth without employing any compensations, respectively. That is, the necessary receiving level for error free 2 Mbps transmission in the newly proposing diffCDMA system is in proportion to the reciprocal number of the bandwidth on the domain from 7 to 13 MHz, and is gradually saturated with -14 dB beyond the 15 MHz.

4.2 Concept of the System Capacity

It is strongly eager in promising high efficiency for finite frequency resources especially for developing large system. It is easily improved frequency efficient by narrowing the bandwidth if the transmission power being kept to be constant. Nevertheless, the necessary power is keenly sensitive to the transmission bandwidth as shown in the diffCDMA with phase continuous QPSK.

The area covered by low power with broad bandwidth is not always coincident with that of high power with narrow bandwidth as shown in fig.9. Transmission power P being given in free space by a Gauss integral on a spherical surface of radius R,

$$P = k_1 E R^3 \tag{4}$$

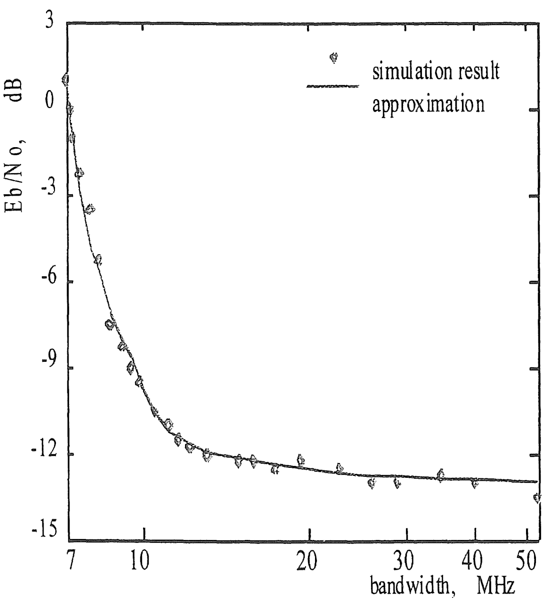

Fig.8 Eb/No bandwidth response of error free 2 Mbps pedestrian difCDMA with phase continuous QPSK

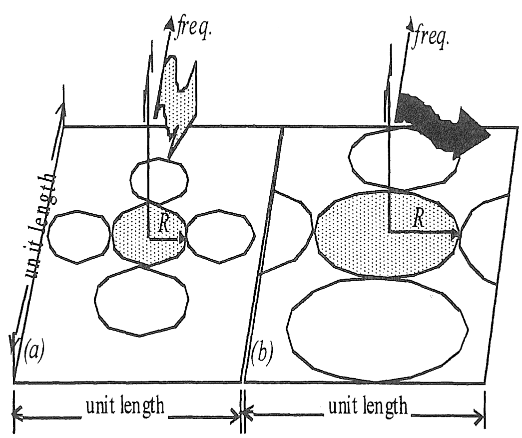

Fig.9 Dimensional comparison between typical CDMA system areas, covered by low-power wide-bandwidth (a) and high-power narrow-bandwidth transmission radio waves (b)

Here, k_1 *is constant,*

E is absolute of receiving field.

the radius R of the covering area is in proportion to the cube root of power P, and the cross section S of the area is in proportion to a square of radius R. Here,

$$S = \pi R^2 \tag{5}$$

Because the subscriber distribution density is generally considered to be uniform on whole the subjective domain, the proposing system transmission capacity η is adequately evaluated both by per unit frequency and per unit section for significant criteria of system design as follows.

$$\eta = k_2 \frac{1}{W} \frac{1}{S} \tag{6}$$

Here, k_2 *is proportional constant.*

Substituting eqs.4 and 5 into eq.6, it gives an other notation for η described by P and W.

$$\eta = k_2 \frac{1}{W} P^{-\frac{2}{3}} \tag{7}$$

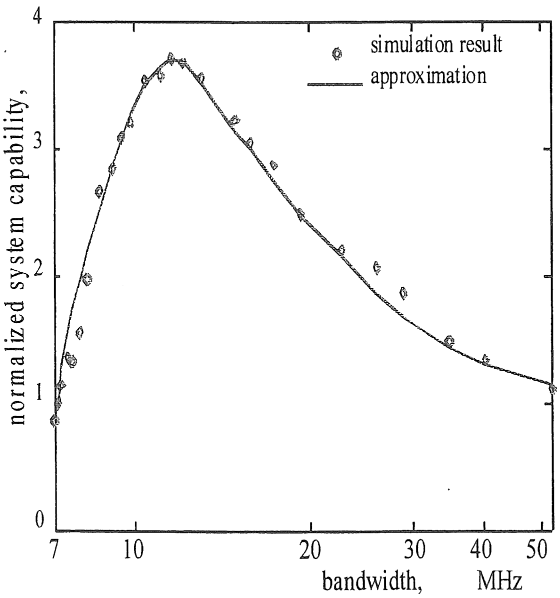

Fig.10 Normalized system capability vs. bandwidth, measured for error free 2Mbps pedestrian diffCDA transmit through two ray Rayleigh fading of DUR= 10dB with 1 micro sec. delay

4.3 Optimization of the System Capability

System capability vs. bandwidth is shown in fig.10 for 2 Mbps diffCDMA with phase continuous QPSK after normalizing with the system capability of 7.384 MHz bandwidth whose necessary receiving level being Eb/No=0 dB for error free transmission. The normalized system capability is vanished to zero owing to appearance of the so-called floor at BER = 0.02, if the bandwidth is narrowed to below 7.085 MHz.

As the bandwidth is expanded from 7.085 to 11.651 MHz, the normalized system capability varies dynamically from 0.256 to 3.704 with 14.5 times improvement, while the necessary Eb/No for error free transmission changes from 9.16 to -11.5 dB. This peaking point means the optimum system for the diffCDMA with phase continuous QPSK in the meaning of system capability. Beyond 11.651 MHz, the normalized system capability is monotonically decreased from the maximum value of 3.704 to unity because of the Eb/No being saturated in improvement.

CONCLUSION

The newly proposing diffCDMA with phase continuous QPSK has been successfully discussed in this paper with emphasis both on realizing pedestrian 2 Mbps CDMA system and optimizing the transmission bandwidth. The system configuration is optimized through simulations to be defined by 11.651 MHz bandwidth, where the necessary Eb/No is -11.5 dB for error free in 2-ray Rayleigh fading environment of DUR= 10 dB with 1 sec delay over 2 GHz domain.

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