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WIDE BAND CHANNEL MODEL FOR THE ANALYSIS OF NEAR-FAR PROBLEM IN CDMA MOBILE RADIO

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1. Introduction

As a multiple access system in future mobile communications, the usefulness of adopting CDMA (Code Division Multiple Access) has been vigorously disputed in the past few years[1]. Compared to the FDMA or TDMA currently used, CDMA has many advantages in security, resistance to interference, flexibility in constructing networks and so on[2], however it also has an inherent disadvantage in the near-far problem. Overcoming this problem is said to be the key technology for realization of CDMA mobile communication systems.

In considering countermeasures against the near-far problem, a grasp of propagation phenomena becomes important. This paper presents a simulation method for wide band fading channel which enables us to analyze near-far problems in CDMA mobile radio systems, and gives an example of the analysis.

2. Theory

2.1 Assumption

In mobile radio environments, the variation of signal strength is roughly classified into three parts[3], that is, (1) median transmission loss proportional to distance between base and mobile stations, (2) variation of local sector median signal strength depending on location variability, (3) fast fading typified by Rayleigh fading. When we assume 1km as a cell radius, the sum of the first two parts may amount to 100dB. Because the processing gain of CDMA in mobile applications is at most 30dB or so, power control in the mobile stations is indispensable. Because fluctuations due to these two parts are relatively slow and have little frequency dependance compared with fast fading, power control of this part may be possible by open-loop control in a simple configuration. On the other hand, the fast fading varies quickly in millisecond order and has a large and complicated frequency dependance, so the effect of this fading on temporal signal variation must be made clear in order to construct stable mobile communications systems.

The analysis method proposed here, based on the assumption that the former two temporal variations are perfectly suppressed by power control, is a wide band propagation model whereby the effects of fast fading on variation of C/I ratio can be estimated by means of computer simulations.

2.2 C/I Estimation Method

Suppose that there are M mobile stations in a zone. The effective carrier to noise ratio of a mobile station (channel 1) without considering interference from other zones can be expressed as :

$$\left(\frac{C}{N}\right)(t) = \frac{G_p P_C(t)}{\sum_{m=2}^{M} P_{Im}(t) + N_o B_c} \approx \frac{G_p P_C(t)}{\sum_{m=2}^{M} P_{Im}(t)} \qquad (M>>2) \qquad (1)$$

where G_p is processing gain of CDMA, P_c is desired signal power, P_{Im} is interference signal power of channel m (m : 2-M) and N_oB_c represents system noise. Because the case where the number of mobile stations becomes closer to zone capacity is usually assumed when a near-far problem is discussed, the influence of system noise can be neglected. Each interference signal power P_{Im} in Eq.(1) is a total power arriving from mobile station m given by

$$P_{Im}(t) = \int_{-\infty}^{\infty} |S_m(f)F_t(f)T_m(f,t)F_r(f)|^2 df \tag{2}$$

where $F_t(f)$ and $F_r(f)$ are the frequency responses of the transmitting and receiving filter which have a bandwidth proportional to the spreading sequence rate. $S_m(f)$ is given as modulated signal spectrum of information bits by a spreading sequence (repeated PN code). To evaluate P_I, $S_m(f)$ can be regarded as the following continuous spectrum.

$$S_m(f) = \frac{1}{\sqrt{f_{PN}}} \frac{\sin(\pi(f-f_C)/f_{PN})}{\pi(f-f_C)/f_{PN}} \tag{3}$$

where f_{PN} is a spreading sequence rate and f_C is the carrier frequency. In the last analysis, if the actual transfer function T_m of each transmission path is given, the value of denominator of Eq.(1) can be obtained.

We then estimate the temporal variation of the desired signal $P_C(t)$. The behavior of the desired signal variation depends on the configuration of the CDMA receiver, that is to say, depends on which wave in the many arriving waves with different time delays is synchronized, or whether path diversity which combines some delayed waves like a RAKE receiver is adopted or not. Here we suppose the case where the receiver keeps synchronization with the wave whose delay is τ_k (k=1,2, , ,G_p) in several delayed waves. Let the received power be P_{Ck}. In this case P_{Ck} is represented as :

$$P_{Ck}(t) = \rho_C(t,\tau_k)\rho_C^*(t,\tau_k)P_r(t) \tag{4}$$

$$P_r(t) = P_{I1}(t) \tag{5}$$

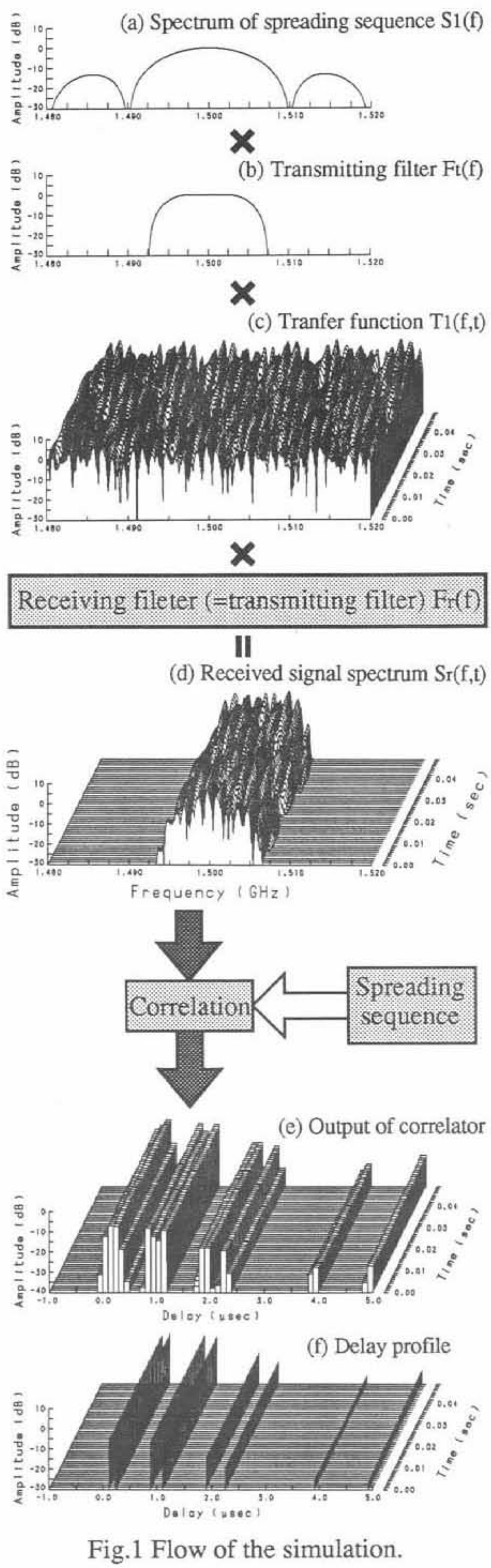

Fig.1 Flow of the simulation.

$$\rho_C(t,\tau_k) = \frac{\int_{-\infty}^{\infty} S_1(f)F_t(f)T_1(f,t)F_r(f)S_1^*(f)\, e^{j2\pi f\tau_k} df}{\sqrt{\int_{-\infty}^{\infty} |S_1(f)F_t(f)T_1(f,t)F_r(f)|^2 df \int_{-\infty}^{\infty} |S_1(f)|^2 df}} \quad (6)$$

$$\tau_k = (k-1)T_c. \quad (7)$$

where T_c is the tip period of the spreading sequence.

The application of a path diversity technique will be indispensable in land mobile CDMA systems where no major wave exists. The RAKE receiver or PDI (Post Detection Integrator) are classified in this diversity. Typical diversity methods, maximum-level selection and maximum-ratio combination can be expressed as

maximum-level selection

$$P_C(t) = \mathrm{Max}\{P_{Ck}(t)\ ;\ k=1,2,,,,\} \quad (8)$$

maximum-ratio combination

$$P_C(t) = \sum_k P_{Ck}(t) \quad (9)$$

2.3 Propagation Model for Wide Band Transmission

In a mobile radio environment, an ensemble average of a delay profile with temporal variation can be well approximated by an exponential function. Until now, for the sake of evaluating digital transmission characteristics in a frequency selective fading environment, the delay profile has been simply modeled by an aggregate of several Rayleigh waves, or by only two Rayleigh waves, because BER characteristics under frequency selective fading conditions mainly depend on the delay spread of the transmission path, and even a two-Rayleigh-wave-model is sufficient for estimating transmission characteristics if only the delay spread is properly set.

On the other hand, when transmission bandwidth increases and the delay spread of the transmission path is far larger than the tip period of the spreading sequence Tc, scattered waves can be detected every T_c period reflecting each delay. As is clear from Eq.(6) variation of the correlation depends not only on delay spread but also on delay profile, therefore to evaluate wide band transmission characteristics, a two-(or several)Rayleigh-wave-model is apparently insufficient. We have thus proposed a propagation model to contribute to the evaluation of wide band transmission characteristics via a computer simulation[4]. The model implements path model where paths are generated and disappear repeatedly, keeping consistency with the statistical property of current mobile propagation theory.

3. Simulation Results

Fig.1 shows a simulation flow to evaluate the desired signal power using the method presented here. The parameters used in the simulation are listed in Table 1. Nyquist filters are assumed as transmitting and receiving filters (b). Part (c) is a temporal variation of the transfer function of transmission path 1 [$T_1(f,t)$] obtained by the propagation model mentioned above. Part (d) shows the received spectrum $S_r(f,t)$ [$=S_1(f)F_t(f)T_1(f,t)F_r(f)$]. By integrating spectrum (d), the total received power can be obtained. Fig.2 shows the temporal variation of this power with changing signal band width B_c. The figure shows that the magnitude of temporal variation decreases as B_c increases. By calculating the correlation between the original spectrum (a) and received spectrum (d) according to Eq.(6), the output of each tip (e) can be obtained. Comparing (e) with the delay profile (f), it is seen that outputs of tips corresponding to delayed waves increase. Fig.3 shows the temporal variation of the simulated desired signal in the cases where (i) maximum-level selection, (ii) maximum-ratio combination of the top three tip outputs, (iii) maximum-ratio combination of all tip outputs, are used as path diversity, where the spreading sequence rate is 2MHz. The variation behavior of the desired signal can be estimated in this way.

When C/I is evaluated in actual systems, because the interference power I is represented as the sum of sufficiently large number of interfering signals and their fluctuations seem to be independent, the relative magnitude of variation of I becomes small due to an averaging effect. The deterioration of C/I therefore depends almost only on the decrease of the desired signal.

4. Conclusion

In this paper, we have presented a method for evaluating the effect of fast fading on C/I. This method enables us to analyze the subject in a mobile radio environment as stated below :

- (i) Quantitative study of dependance of C/I variation (within or beyond zone) on system and environmental parameters.
- (ii) Performance evaluation of path diversity methods.
- (iii) Examination of temporal response characteristics necessary for power control.

Using this propagation model, we intend to investigate various subjects related to CDMA mobile radio communications.

[References]

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(3) Y. Okumura *et al.* : Rev. Elec. Commun. Lab, vol.16, pp.825-873, 1968.

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Mobile velocity	10.0 m/s
Delay spread	1 μs
Average path number	10
Average path life length	30 m
Spread sequence rate	10 MHz
RF Frequency	1.5 GHz

Table 1 Parameters used in a computer simulation.

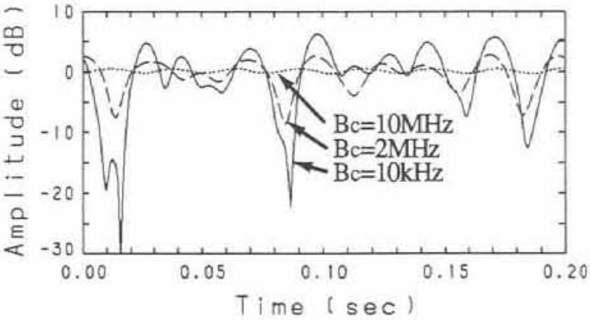

Fig.2 Temporal variation of the simulated signal with changing signal bandwidth.

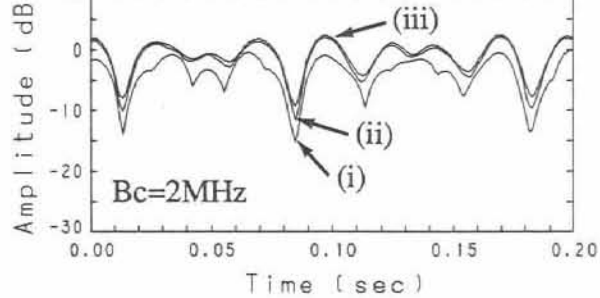

Fig.3 Temporal variation of the simulated signal using path diversities.