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Variance of Errors between Users in DS/CDMA Communication

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1. Introduction

This subject is to investigate the inequality in errors between individual DS/CDMA users under the various conditions such as chip codes, chip rates and the number of users. The average error due to the interference noise in the DS/CDMA communication is considered to be the same to all users as long as each transmits the same power. However, the recent preliminary simulation study by the current authors using the analysis of variance (ANOVA) has shown that the variance of errors between users exists [1]. It is addressed that, in addition to the frequency of errors, the variance of errors among individual users must be considered in the quality of wireless broadband communication in perspective of the progress of high speed and large content like video. Especially in the advent of new systems such as the cell sectorization and the non-LOS systems including the mesh network (Air Head /Air Hoods) and the smart base-station antenna, where the influence of interference aggravates the quality of communication as the number of sectors, hops and unintended lobes respectively increase, it will be of great importance to assure the equity of errors between users.

In this paper, the average error and the variance of errors among users are presented, which have been derived by the simulation with parameters such as the number of sectors and the combination pattern of pseudorandom codes.

2. Theory

DS/CDMA, direct sequence / code-division multiple access, is a system which aims at multiple access by assigning each user a unique spread code, pseudorandom sequence and/or orthogonal code (Hadamard Walsh). In CDMA, the interference signals from other uses are suppressed by the reverse spreading. As an example in this study, a sector under a single base station is divided into three subsectors, and each user in a subsector is assigned a unique spread code. The user's code is an orthogonal code and the subsector's code is a maximal length pseudorandom sequence, M-sequence code. The length of the subsector code is four times as long as that of user's code.

M-sequence code PN1 is generated by the linear feedback shift register circuitry shown in Fig.1. The codes up to PN31 are generated by shifting every "1" from PN2. Under this scheme, the following relationship holds.

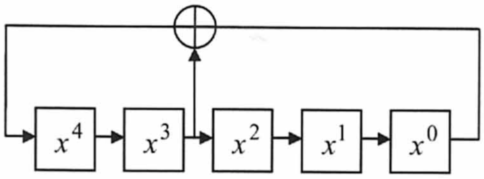

Fig. 1 Linear feedback shift register.

$$PN_1 \oplus PN_2 = PN_{15} \quad (1)$$

This relationship is considered the best combination from the point of the cross correlation [2].

3. Simulation

(1) Setup parameters

The simulation model with a single base station is set up by the references [2][3]. The parameters are as follows. A sector is divided into three subsectors as shown in Fig. 2. One subsector has eight users, each of which is assigned the Hadamard Walsh code with the length of 8. Each subsector is assigned M-sequence code with the length of 31. Each user emits the same power at the same frequency.

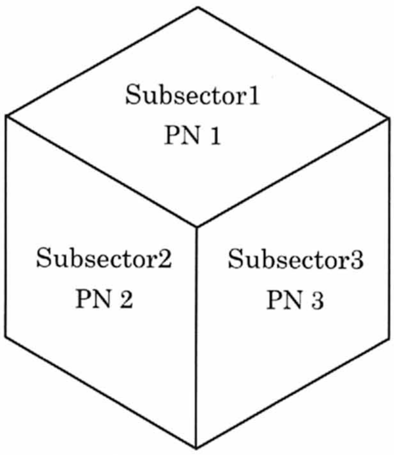

Fig. 2 Sectorization for single DS/CDMA base station.

(2) Case-1: number of subsectors

The average error and the variance of errors among users are studied by changing the number of subsectors from 1 to 3. M-sequence code assigned to each subsector is PN1, PN2 and PN15 as indicated in (1).

(3) Case-2: pn pattern of subsectors

The average error and the variance of errors are studied by changing the pn code pattern for three subsectors, as PN1, PN2, and PNn, where n is varied from 3 to 31.

(4) Evaluation of the variance of error

ANOVA is used to evaluate the variance of errors with the number of sampling as much as 30 times [4]. ANOVA is a method of testing whether groups to be sampled differ significantly with respect to some property. In this simulation, the difference of errors between users, which is the measure of equity among users, is evaluated by the variance of errors, F. The lower the value of F, the smaller the variance of error among users.

4. Result

4.1 Result of Case-1

The results are shown in Table1, Fig. 3 and Fig. 4. As the number of subsectors increases, the average error also increases. As to the variance of errors among users, there is no difference in the case of one-subsector, meaning that the equity is assured to all users. But as the number of subsectors increases, the variance of errors increases and the equity is collapsed.

Table1 Average error and variance of errors for sector model

Model	Average errors (%)	Variance of errors (F)
Sector 1	0.00	0.00
Sector (1+2)	18.49	0.79
Sector (1+2+3)	24.70	1.29

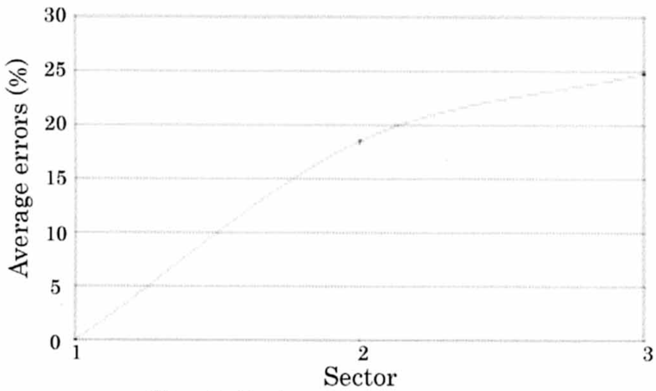

Fig. 3 Sector - average errors.

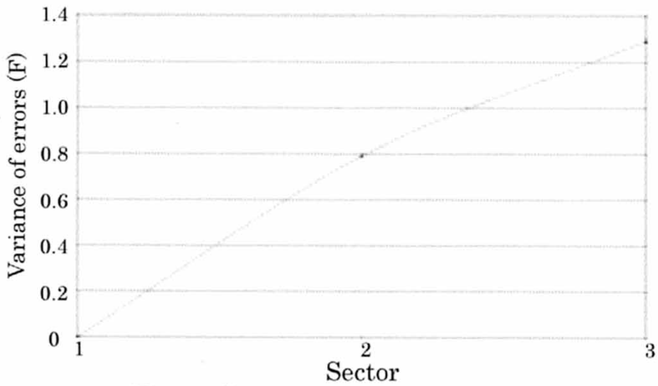

Fig. 4 Sector - variance of errors.

4.2 Result of Case-2

The result is shown in Table 2, Fig. 5 and Fig. 6. Whereas the pattern combination by (1) is considered the best, namely, PN1, PN2 and PN15, there exist better combinations. In term of the average error, there are six cases having the error between 22.00 and 24.66, compared to 24.70 in the case of PN15. Also in term of the variance of errors, there are 26 cases having better results as 0.42 to 1.26, compared to 1.29 with PN15.

Furthermore, it is noted that, when the error is more emphasized than the equity among users, PN7 is the appropriate choice where the average error and the variance of errors are 22.00 and 0.64, respectively. On the other hand, when the equity is more important than the error, PN24 is the appropriate choice where the average error and the variance of errors are 24.65 and 0.42, respectively.

Table 2 Average error and variance of errors for PN model

PN n	Average errors (%)	Variance of errors (F)
PN3	24.85	1.02
PN4	24.77	0.82
PN5	24.54	0.80
PN6	25.06	0.55
PN7	22.00	0.64
PN8	25.05	0.99
PN9	25.02	1.16
PN10	24.93	3.47
PN11	24.90	0.58
PN12	24.66	1.26
PN13	24.85	0.56
PN14	25.13	0.75
PN15	**24.70**	**1.29**
PN16	24.91	1.36
PN17	24.63	0.81
PN18	24.86	1.04
PN19	24.84	1.17
PN20	24.98	0.52
PN21	24.76	1.09
PN22	24.72	0.76
PN23	24.73	1.06
PN24	24.65	0.42
PN25	25.07	0.72
PN26	25.13	1.04
PN27	24.66	1.17
PN28	24.85	0.70
PN29	24.82	0.99
PN30	24.91	0.97
PN31	25.23	1.10

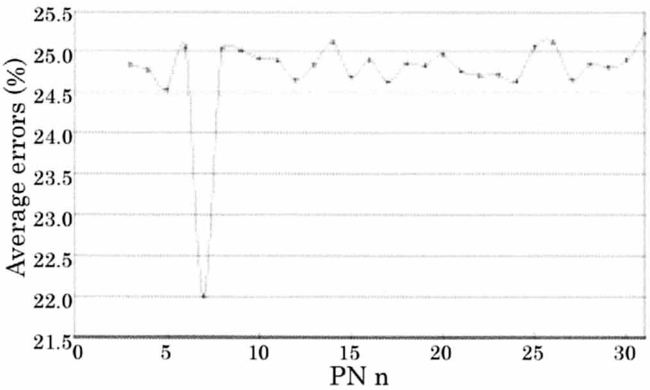

Fig. 5 PN n - average errors.

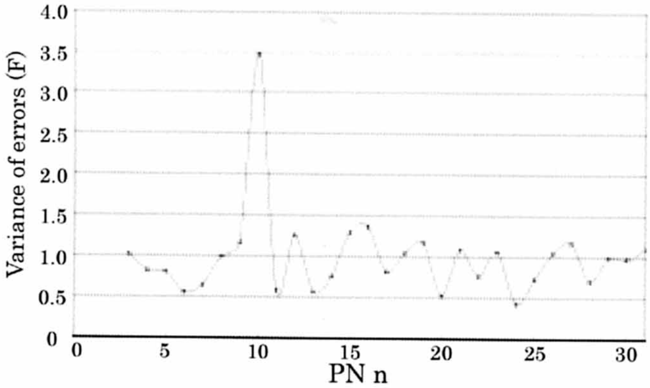

Fig. 6 PN n - variance of errors.

5. Conclusion

It is derived by simulation that there exists better combinations of pn codes than the predicted, and the variance of errors among users becomes apparent depending upon the choice of pn codes. Further study has been conducted for parameters such as the type of spread code, chip rates and the number of users.

References

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