

A MECHANISM OF BURST ERROR OCCURRENCE DUE TO MULTIPATH PROPAGATION IN DIGITAL MOBILE RADIO

Susumu YOSHIDA, Fumio IKEGAMI and Tsutomu TAKEUCHI
 Department of Electronics, Kyoto University, Kyoto 606, JAPAN

1. INTRODUCTION

It is well-known that bit error rate (BER) deteriorates heavily in mobile digital signal transmission due to multipath interference [1]. Especially a BER floor at high SNR, sometimes called "irreducible error", is often observed in urban areas, as shown in Fig.1. It is by all means necessary to "reduce" such errors in order to make mobile digital signal transmission feasible. In parallel with the multipath propagation analysis, the measurement system for microscopic BER, together with corresponding fading waveforms, has been developed to clarify the mechanism of bit error occurrence for instantaneous variations of multipath parameters. This paper describes the measurement system and the measured results, from which error occurrence mechanism will be analyzed.

2. MICROSCOPIC BER MEASUREMENT SYSTEM [2][3]

We showed theoretically that there existed no BER floor for BPSK if we choose the appropriate sampling timing adaptively [4]. According to our laboratory measurement, however, we found the BER floor actually existed. This discrepancy was the initial motive of the present research.

Block diagram of microscopic BER measurement system is shown in Fig.2. A Rayleigh-distributed two-ray multipath propagation model has been assumed as an approximation of the urban propagation with large delay difference. The Rayleigh fading simulator produces Rayleigh-faded signal by first dividing the input signal to two signals in quadrature, each modulated with independent Gaussian distributed signal and then combining the two signals, where Gaussian signal is obtained by spectrally shaping the M-sequence with an FIR digital filter. Thus the fading signal as well as the instantaneous amplitude ratio and phase difference of multipath signals can be completely reproducible and predictable by counting the number of clock pulses applied, if the initial state of M-sequence generating shift register is fixed.

The microcomputer controls the whole measurement system. It distributes clock pulses, yielding Rayleigh-fading signal and at the same time measures BER using error bit counter through IEEE-488 bus.

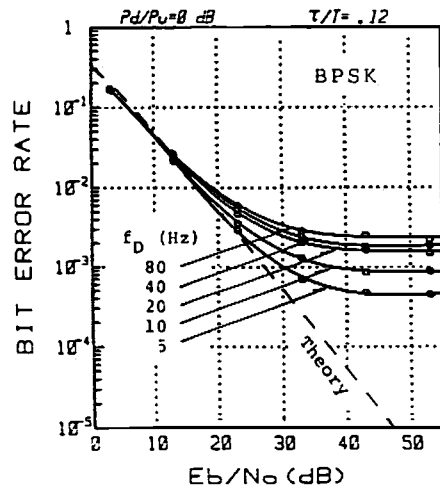


Fig.1 Typical BER curves in multipath fading.

BPSK signal of 1.544 Mbps ($f_c = 280$ MHz) is transmitted and coherently demodulated, followed by the sampler whose timing is phase locked to eye pattern movement through PLL.

BER's are measured every 2.5 msec for maximum Doppler frequencies $f_D = 10$ and 20 Hz. Phase difference between recovered clock and transmitter clock is measured by a vector voltmeter to detect the timing jitter of sampling pulse at the receiver.

Microscopic BER's are measured under the condition of average E_b/N_0 of D-wave = 50 dB, average D/U = 0 dB and normalized multipath delay $\tau/T = 0.12, 0.38$ and 0.67 .

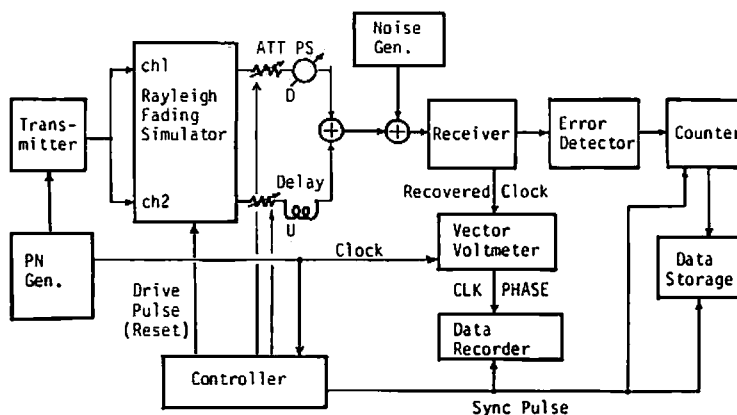


Fig.2 Block diagram of microscopic BER measurement system.

3. RESULT FOR FREQUENCY FLAT FADING

The measurement was made first for a frequency-flat faded signal (i.e. without U-wave). In most of the time, no errors were observed because of large noise margin. Only within very short periods, errors occurred instantaneously in a burst manner. To the deep fade of the signal envelope, rapid carrier phase change by about 180 deg corresponds. It is there that burst errors were observed. From these facts, the errors seem to be caused by imperfect operation of carrier recovery circuit due to random FM effect, i.e., rapid and abrupt phase change. These burst errors limit the lower bound of BER curves, thus resulting in a BER floor. However, the floor level is much lower than that for frequency selective fading, discussed in the following section, because the frequency of burst error occurrence has been proven much fewer as compared with the selective fading.

4. RESULT FOR FREQUENCY SELECTIVE FADING

Examples of measured result for frequency selective two-ray multipath fading are shown in Fig.3. From the top, the envelope, DU ratio, and phase difference between D and U carriers are shown, where the abscissa is time axis proportionate to Doppler frequency. The next two show microscopic BER's and the following three the recovered clock phases relative to transmitter clock, calculated position of eye pattern, and the sample timing of eye for $\tau/T = 0.12$. The rest five figures are those for the multipath delay $\tau/T = 0.38$.

At a glance, we notice that the occurrence frequency of burst errors increases as the multipath delay τ/T increases and error occurring points are reproducible regardless of maximum Doppler frequency. Those points for smaller τ/T are included in those for larger τ/T . By closely looking at the figures, good correspondence between points of burst error and abrupt phase changes of recovered clock can be noticeable. By analyzing these kinds of experimental data in detail, we found that most of burst errors are not caused by additive random noise at deep fade, but caused by imperfect

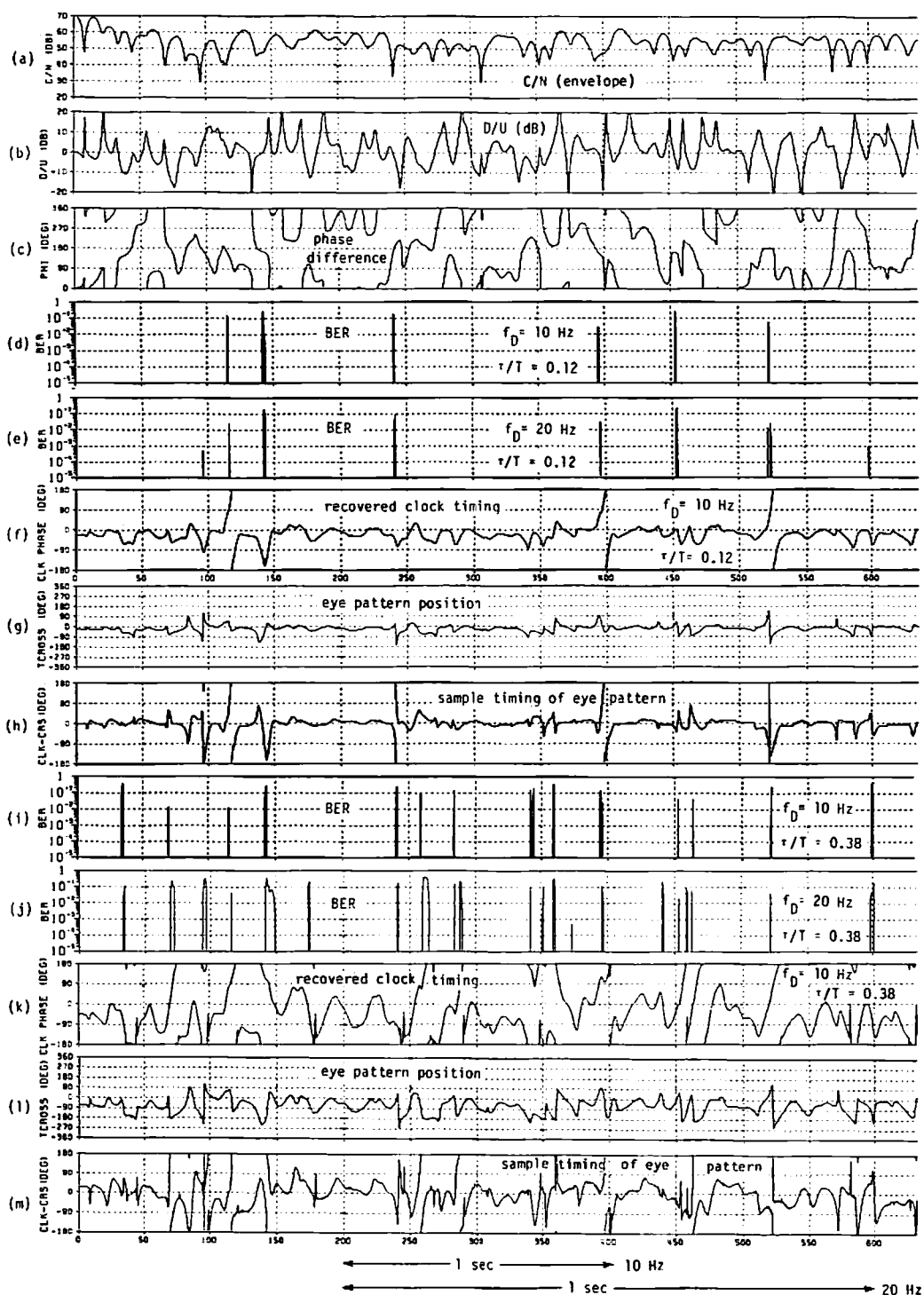


Fig.3 Correspondence between various fading waveforms and microscopic BER's.

operation of clock recovery circuit, i.e., tracking delay or loss of bit-synch of PLL.

To confirm it, the eye patterns are calculated for each multipath condition and the optimum sampling timings are computed. These timings are then compared with those timings of measured recovered clock, as shown in Fig.3 (h) and (m) where 0 deg corresponds to optimum sampling and 180 deg to out-of-phase sampling. The results verified that more than 90 % burst errors correspond with inadequate sampling timing of eye pattern.

At the same time, we computed the best achievable BER by averaging microscopic BER over the same Rayleigh-distributed two-ray multipath signal used in the experiment, provided that clock recovery circuit works ideally and samples the eye pattern at its center. This result agreed well with theoretically predicted BER [4] and there appeared no BER floor.

5. CONCLUDING REMARKS

Through the microscopic BER measurement in the frequency selective fading which is encountered in urban mobile radio, we could show that major source of burst errors is the tracking delay or loss of bit-synchronization in the clock recovery circuit. Random FM should also be taken into account. However, it is rather minor source judging from the results for flat fading, and its effect on carrier recovery circuit, for instance, is reflected on the behavior of the clock recovery circuit. Even if the loop bandwidth in clock synch circuit is broadened, the problem cannot be solved completely. In addition, the rapid eye pattern movement due to severe delay distortion is usually unavoidable in most of the conventional modulation techniques. To overcome this annoying phenomenon, we have proposed a new modulation technique named DSK which is resistant to severe delay distortion associated with multipath fading [5], which will be reported elsewhere in more detail.

ACKNOWLEDGMENT

The authors wish to express their thanks to graduate students Messrs. K.Yamazaki, H.Takai and others who cooperated with them in the measurements. This work is supported in part by Grant-in-Aid for Scientific Research of the Ministry of Education, Science and Culture of Japan.

REFERENCES

- [1] W.C.Jakes, Jr. (ed.) Microwave Mobile Communications, Chapter 4, John Wiley & Sons, 1974.
- [2] K.Yamazaki, S.Yoshida, F.Ikegami et al., "Instantaneous BER Characteristics in Rayleigh-Distributed Two-Ray Model", Papers of Technical Group on Communication Systems, CS82-125, IECE Japan (in Japanese), Feb. 1983.
- [3] H.Takai, S.Yoshida, F.Ikegami and T.Takeuchi, "Analysis of Error Occurring Mechanism by Observing Instantaneous BER and Bit-Synchronization System under Multipath Propagation, *ibid.* CS83-158 (in Japanese), Jan. 1984.
- [4] S.Yoshida, F.Ikegami and S.Onoe, "Performance Comparison Among Digital Modulation Schemes Subjected to Rayleigh-Distributed Two-Ray Multipath Fading", Proceedings of IEEE GLOBECOM'84, 44.3, Atlanta, Nov. 1984.
- [5] S.Ariyavisitakul, S.Yoshida, F.Ikegami and T.Takeuchi, "A Modulation Technique Suffering from Less Timing Fluctuation of Eye Patterns in Multipath Fading", Papers of Technical Group on Communication Systems, CS84-67, Aug. 1984.