DEVELOPMENT OF MULTIPATH MEASUREMENT EQUIPMENT FOR MICRO-CELLULAR SYSTEMS

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Abstract An equipment for micro-cellular multipath measurement is described. To obtain both high resolution time and small transmitter peak power, a spread spectrum signal is used for channel sounding. Real-time coherent averaging is employed to enhance the S/N ratio. Correlation to obtain the delay profile is performed by off-line data processing to avoid the difficulty of real time correlation.

1. Introduction

So far, research into micro-cellular systems has concentrated only on the development of high-capacity communication systems with low power consumption. In micro-cellular systems, the cells are several times smaller than in conventional systems. Thus, the propagation distance from the base station to the cell's boundary is decreased. Consequently, the delay spread will also be decreased. Therefore, one advantage of micro-cellular systems is their smaller delay spread which makes possible implementation of high-speed digital land mobile communications [1]. In view of this we developed a multipath measurement system to measure the multipath in the micro-cellular environment.

2. The multipath measurement equipment

The system parameters of the multipath measurement equipment are shown in Table I. The transmitter output signal for channel sounding is a 2.598 GHz carrier which is BPSK modulated by a 511 bit length pseudo random binary sequences (PRBS) at a clock rate of 25 Mbps. The development of real-time delay profile calculation equipment is very difficult because extremely high-speed digital signal processing is required. For instance, number of multiplication required to obtain a complex delay profile is (511x2x2)x(511x2)/profile. Thus calculation speed necessary for real time processing is $(511\times2\times2)\times(511\times2)/(40\times10^{-9}\times511)= 10^{11}$/sec. To avoid this difficulty, the micro-cellular multipath measurement equipment stores the signals for off-line processing. However, this makes it impossible to monitor the multipath in real time which is inconvenient for field measurement. We thus added a delay profile monitoring capability. For this purpose, correlation is performed between the received signal and a replica signal stored in the equipment. Correlation is implemented using several MACs (multiplying accumulators) and DSPs (digital signal processors). Since these devices are too slow for real-time delay profile calculation using all the received signal, correlation could only be performed intermittently. Nevertheless this is a very useful capability for measurements.

The delay spread calculated from the average power delay profile is susceptible to noise [2]. To combat this a noise reduction operation of averaging by coherent addition was performed in real-time by the equipment. Unlike correlation, averaging requires no multiplication. The addition rate for an N frame PRBS is $N\times511\times2\times2/(40\times10^{-9}\times511\times N)=10^{8}$/sec. This speed is easily obtained by current technologies. The division associated with the averaging operation is realized by simple bit shift operation.

The a sampling rate of A/D is about 50 Msamples/sec which requires that very high speed memory be used for data storage. To avoid this, a four way interleave scheme is employed. However the frame length of transmitted PRBS is not a multiple of 4. The easiest way to make the frame length of the PRBS a multiple of 4 is to insert a dummy bit in both of Tx and Rx PRBS's.

Figure 1 shows the autocorrelation function with dummy for insertion. Inserted dummy data is 1 for DC balance. Figure 1 has many spurious peaks and thus it is not suitable for channel sounding. This phenomenon obstructs use of a power-of-two FFT for frequency domain correlation.

Another way to make the frame length a multiple of 4 is to use a slightly faster sampling rate, i.e. 50x512/511 Msamples/sec. Number of digitized samples per PRBS frame is 1024 at the receiver for a Tx PRBS of 511 bits. For this method to be valid the reference PRBS for off-line correlation must be matched to the transmitted PRBS signal. This reference PRBS'(t) can be obtained by sampling a transmitted PRBS(t) waveform at 50x512/511 Msamples/sec. For this purpose we can use sampling theory;

$$PRBS'(t)=\sum_{n=-\infty}^{\infty} PRBS(n/2W)\,\frac{\sin 2\pi W(t-n/2W)}{2\pi W(t-n/2W)}$$

Where W is bandwidth and 2W is the Nyquist rate. For our example, t=ks {k=1,2,,,1024} and s=511/1024.

Figure 2 shows the autocorrelation function obtained for a sampling speed changed PRBS. The inherent excellent correlation property of the PRBS and a digitized frame length of 1024 are combined by this technique. The correlation noise floor shown in Figure 4, of about -54 dB corresponds to the inverse of the PRBS length $1/(2^9-1)$.

3. Configuration of multipath measurement equipment

Figure 3 shows the schematic diagram of the equipment. The multipath measurement receiver consists of two blocks, an RF block and a signal processing block. In the RF block, the 2.598 GHz RF signal with a bandwidth of 50 MHz, is amplified and converted to a 140 MHz IF signal.

In the signal processing section, AGC was implemented at IF using a PIN diode attenuator whose phase characteristics do not change over the AGC range. This allowed accurate delay-Doppler spectra to be obtained regardless of any amplitude change during the mobile measurement. The AGC dynamic range exceeded 70 dB which is sufficient for land mobile measurements. In the signal processing block, the 140 MHz IF signal is down converted to baseband. This signal is digitized and stored in memory for averaging to enhance the S/N ratio.

Once a trigger pulse to start a measurement is generated, averaged data corresponding to one delay profile is transferred to the personal computer. This data transfer rate restricts the vehicle speed during delay-Doppler measurement. Using a block transfer capability of the personal computer, a data transfer rate of 200 profiles/s was obtained. The personal computer could accommodate about 8000 delay profiles.Once the signals for one course had been recorded on the personal computer, the measurement vehicle was stopped and the data was transferred to a 512 MByte MO (magneto-optical) disk for off-line processing. Measurements for the next course could then be started.

In both stations all clock and carrier frequencies are controlled by Rubidium vapor atomic clock master oscillators. The frequency stability of 10^{-11} ensured synchronization during measurements. To avoid the influence of a phase noise on the delay-Doppler scattering function, PLL technology was not employed for generating the Tx carrier frequency. For the Rx local oscillator a commercially available frequency synthesizer with low phase noise was used.

4. Delay profiles

Figure 4 shows a delay profile for direct Tx RX connection. The instantaneous dynamic range, determined by the peak-to-spurious correlation ratio, is about 40 dB.

Figure 5 shows the delay profiles for Tx Rx connection with 2^5 times averaging by coherent addition. The peak level proportionally increases as input level increases from -110 dBm to -20 dBm. Averaging reduces noise floor to about -135 dBm. This consistent with estimation from the system parameters and the S/N improvement factor of 2^5.

Figure 6 shows an example of delay Doppler scattering function measured in a residential area using 64 successive complex delay profiles. Components coming from back of the measurement vehicle having a normalized Doppler frequency of -1 are clearly resolved. This result demonstrates the excellent phase noise performance of the measurement system [3].

5. Conclusions

A multipath measurement equipment for micro-cellular communication system has been developed. The major advantages realized by this equipment are as follows:

(1) Enhancement of S/N by coherent addition.
(2) Measurement of each delayed path amplitude and phase with high accuracy.
(3) Time resolution of 40 ns.
(4) Measurement throughput greater than 200 profile/sec.
(5) Instantaneous dynamic range of about 40 dB.

6. Acknowledgment

The authors wish to acknowledge to Mr. Hitoshi Matsui for his efforts in designing and developing this equipment.

7. Reference

[1] E. Moriyama, et al., "2.6 GHz band multipath characteristics for micro-cellular telecom munication systems", IEEE International symposium on Personal, Indoor and mobile radio communications. 1991. London.
[2] E. Moriyama, et al., "Development of multipath measurement and simulation equipment for wideband mobile radio", IEEE VTC'92, Denver, Colorado
[3] J.D.Parsons, et al., "Sounding techniques for wideband mobile radio channels: a review", IEE Proceedings-I, Vol.138, No.5, October 1991.

Table I : Multipath measurement system parameters

Modulation	BPSK
Code length	511
Time resolution	40 ns
RF frequency	2.598 GHz
Frequency stability	10^{-11}
Tx. power	37 dBm
Noise figure	5 dB
IF frequency	140 MHz
Sampling frequency	50 MHz
Quantization	8 bits

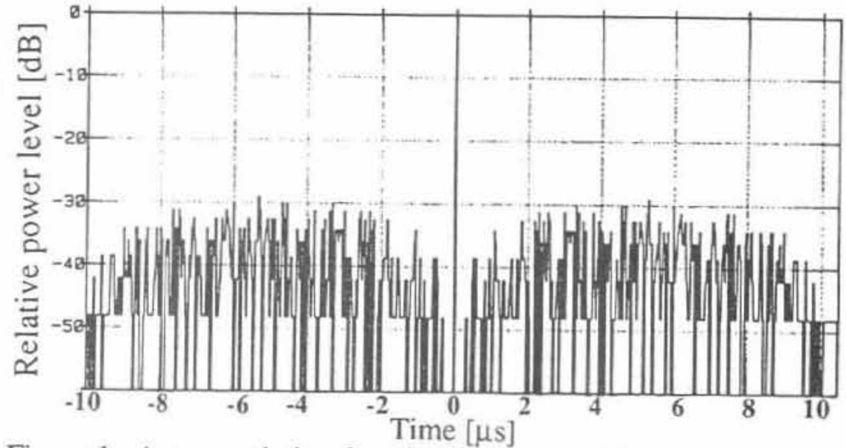

Figure 1 Autocorrelation function for dummy bit insertion.

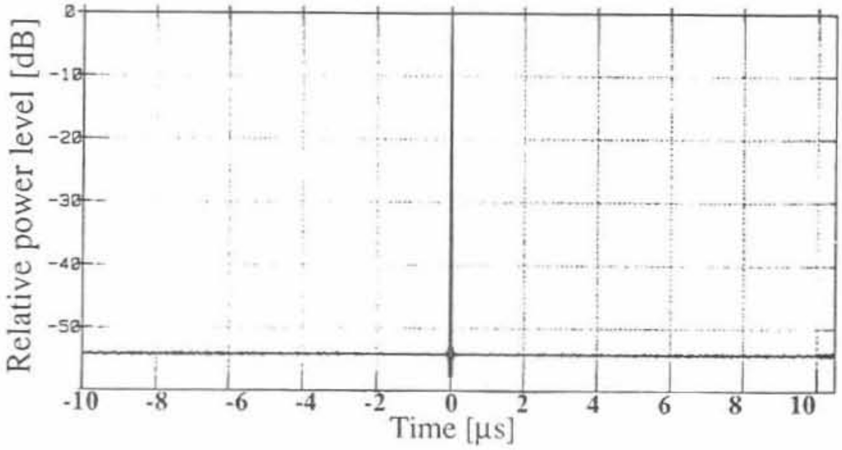

Figure 2 Autocorrelation function for sampling speed changed PRBS.

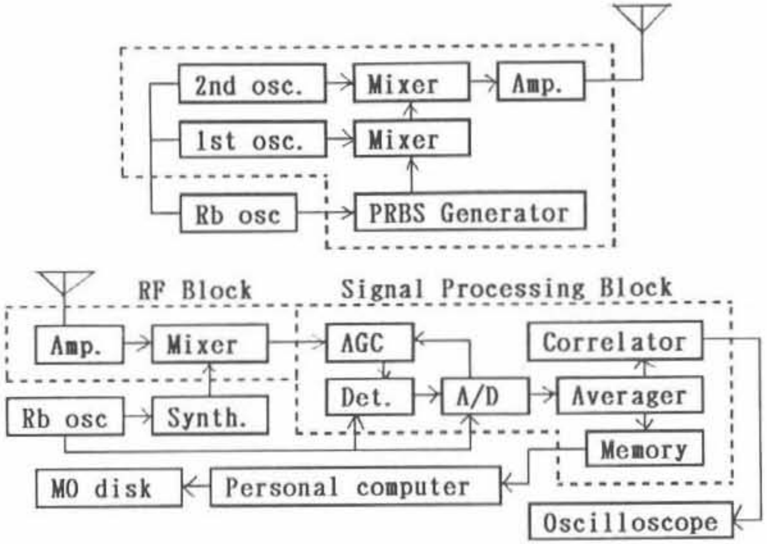

Figure 3 Schematic diagram of the multipath measurement equipment.

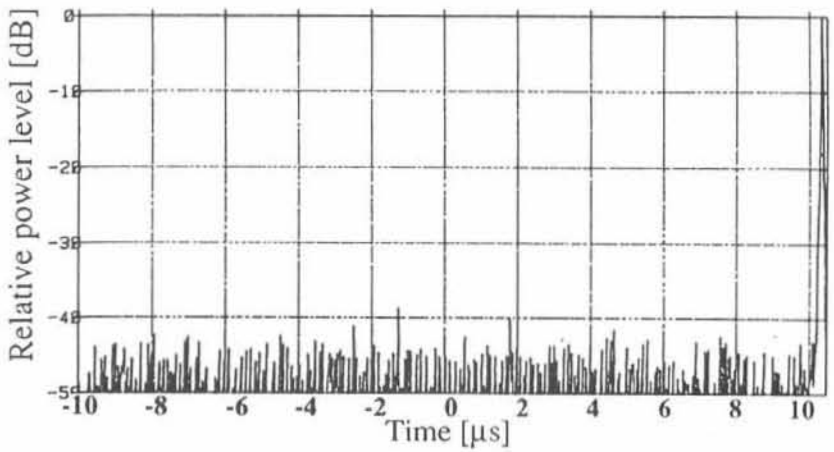

Figure 4 Delay profile for direct Tx Rx connection.

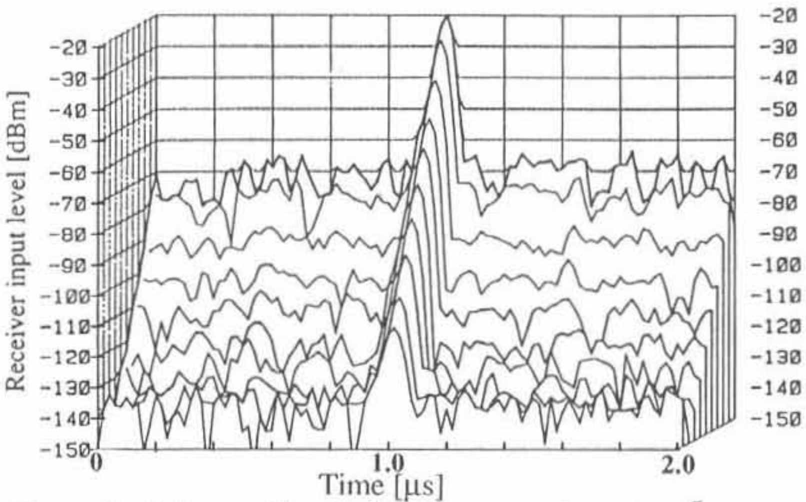

Figure 5 Delay profiles for Tx Rx connection with 2^5 times averaging by coherent addition for receiver inputs from -110 dBm to -20 dBm.

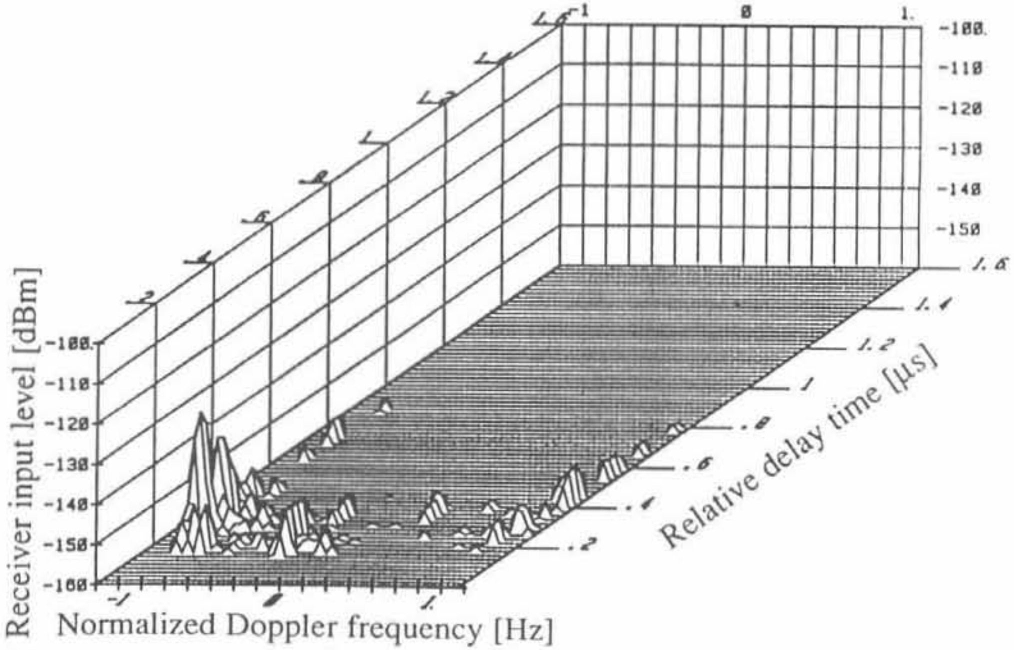

Figure 6 An example of delay Doppler scattering function measured in a residential area.