DEVELOPMENT OF AN INDOOR MOBILE RADIO PROPAGATION MEASUREMENT SYSTEM WITH A FUNCTION OF MEASURING ITS OWN POSITION AND DIRECTION

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Introduction

Indoor mobile radios, such as low bit-rate data transmission and paging, are being increasingly used in offices and factories. In the future, more functional systems, which include a high speed radio LAN and mobile radio message communication, will surely be introduced. The indoor radio multipath propagation environment is a limiting factor in designing these systems. Indoor radio propagation measurements have been carried out to clarify the physical mechanism of propagation and to develop the solutions for the problems caused by radio propagation 1)2). The authors have developed an indoor measurement system to investigate the indoor radio propagation characteristics efficiently. This system was able to simultaneously record both the position/direction of a mobile measuring vehicle and the RF test signal strength, and to measure more exactly the differences in the propagation characteristics depending on the transmitting conditions. This paper describes this measurement system and some test measurement results.

Indoor Mobile Radio Propagation Measurement System(Figs.1 and 2)

(1)Mobile measuring vehicle

Table 1 shows the specification of the vehicle. An electromotive vehicle was used to travel with even speed if necessary. Rotary encoders connected to the front wheels of the vehicle generate distance pulses. A large battery and DC-AC inverters were used for an electric power source for the on-board measuring instruments. Continued measurement for 3 hours was possible without changing the battery.

(2)Position and direction measuring unit(Fig.3)

A gas rate sensor (azimuth angle velocity sensor) was used to measure the direction of the vehicle. The error of angle sensing is warranted to be within 0.5 degrees per 90 degree azimuthal change. The position and direction of the vehicle are calculated using the sensed angle and the distance pulses and are transmitted both to data processing/recording unit and to position/direction indicator. The measured errors of the position indicator were within 5 cm after 15 m travel along a straight course, and within 2 m when the vehicle returned to the starting point after the vehicle covered approx. 200 m along the test course in Figure 8. The errors were partly due to the occasional lack of the wheels' contact with an uneven floor and partly due to the above-mentioned error of angle sensing.

(3)Synchronous signal transmitter(Fig.4) and receiver(Fig.5)

These instruments are used to investigate the differences in the propagation characteristics depending on the transmitting conditions (transmitting antenna type, antenna location and so on). The transmitting condition are changed faster than the propagation environment changes while the memory areas for gathering data at the receiver are simultaneously changed, and then the data in the memory areas are compared. The transmission and reception of a synchronous signal enable us to know the timing of the change in the transmitting condition at the receiving point.

Figure 6 shows the method to measure the differences in propagation characteristics depending on two transmitting antennas. A 1kHz synchronous signal is generated with an oven-controlled crystal oscillator at the transmission side. One of two antennas which transmits RF test signal is selected using this signal. A carrier modulated with a sinusoidal wave, which have the same frequency and phase as the synchronous signal, is transmitted. At the reception side, the carrier is received and the signal which has the same frequency and phase is regenerated with a PLL whose VCO is also oven-controlled and which has a loop filter with a long time constant. The data from the RF test signal receiver are selected using this regenerated signal, and the data for each antenna are separated. This method is also applicable when diversity reception is used.

When the level of the received carrier becomes less than a threshold level by fading, the control voltage for an OCVCXO is fixed at the value just before leveling down. The phase error between the regenerated signal and the synchronous signal at the transmission side is kept small by the high stability of the oscillators and a long time constant of the PLL. The measured phase error was within 3 degrees when the carrier diminished for 10 minutes, and the error became within 1 degree after recovery of reception, which were acceptable for the purpose.

(4)Data processing/recording unit

The position/direction of the vehicle, synchronous signal and the strength of the RF test signal are all gathered into the data processing/recording unit. A personal computer was used for processing and recording. Position/direction of the vehicle and the received signal strength in dB is able to be monitored on a CRT in real time during travel. As soon as a measurement is carried out, some processed results from the measurement can be monitored, such as level variation, cumulative distribution of the recieved signal strength and so on. These monitored results can be immediately reflected on the selection of the condition for the following measurement. The measured data and processing result can be recorded on magnetic media. These records directly constructed the propagation database, since they are clearly related to the receiving position/direction of the vehicle.

Preliminary Test Results

In order to investigate the performances of this measurement system, a mobile measurement test was carried out in an office(Fig.7), which had a large number of desks and metal lockers, which are not all shown in Figure 7. A 1.2 GHz band CW was transmitted from a 160cm high fixed antenna (9.4 dBi,vertical polarized). The received signal strength of two antennas (190 cm high) and the position/direction of the vehicle were sampled every 2.5 ms. The two antennas were separated 55 cm (2.4λ) perpendicular to the travelling course, and the signal from each antenna was sampled and switched in the 2.5ms. Measurement course was divided into 9 courses.

Figure 8 shows the spatial distribution of the signal strength averaged among 1001 sampling points. During the measurement, the signal strengths of the two antennas and the position/direction of the vehicle were stored in the memory of the computer every 2.5 ms. If this data in the memory is recorded into magnetic media, a propagation database may be constructed which will enable us to examine the effect of the configuration of the room and the arrangement of furniture.

It took only 40 minutes to cover the 9 courses. Only one person was required for this measurement. This measurement system notably reduced the time and the number of operators required for measurement compared with conventional methods, which required either measuring the position of specific points on the travelling course with a scale and a compass, or recording distance pulses, point markers or anouncements into a track of a data recorder.

Figure 9 shows the instantaneous variation of the received signal strength of the two receiving antennas in the vicinity of point A in Figure 7. Figure 9(b) is an enlarged portion of (a). From Figure 9(b), it can be seen that the received signal varied with a very short and definite period with a considerable width of 3 dB. This variation was observed at several

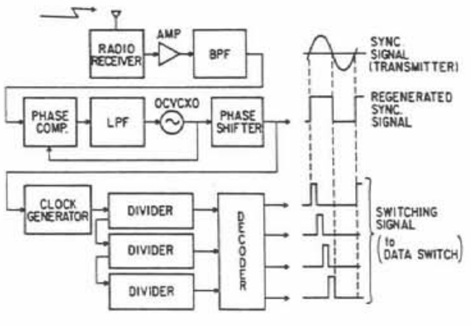

Fig.5 SYNCHRONOUS SIGNAL RECEIVER

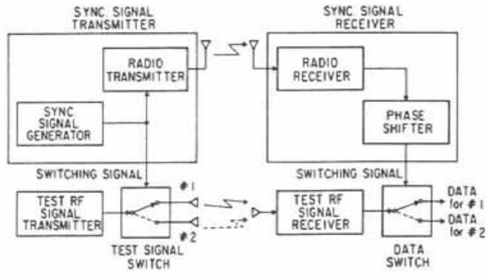

Fig.6 MEASURING THE DIFFERENCE OF TWO SIGNALS FROM TWO TRANSMITTING ANTENNAS

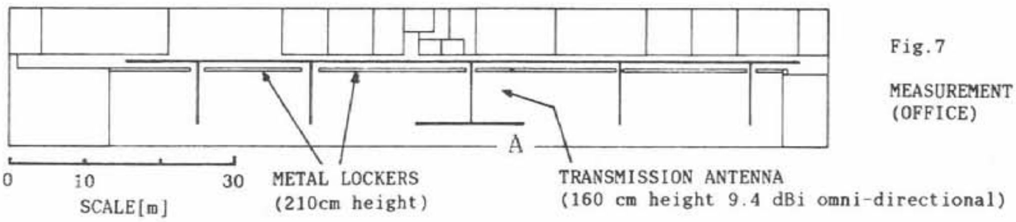

Fig.7

MEASUREMENT SITE (OFFICE)

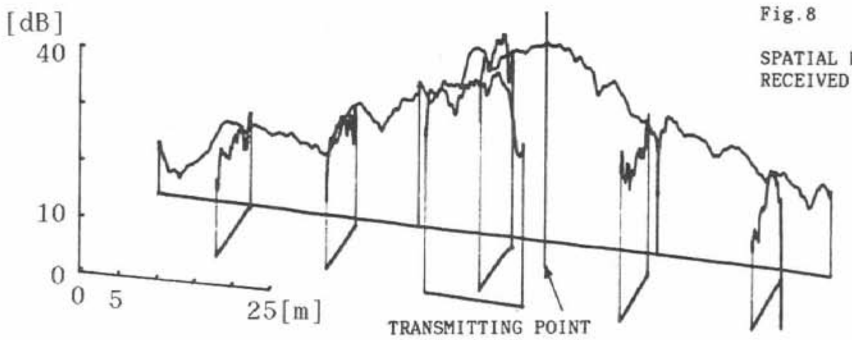

Fig.8

SPATIAL DISTRIBUTION OF RECEIVED SIGNAL STRENGTH

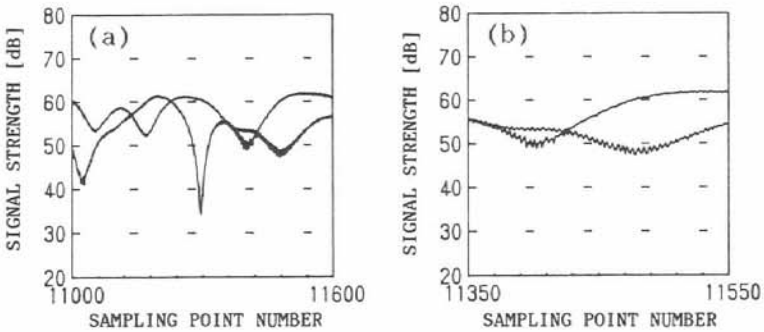

Fig.9

INSTANTANEOUS VARIATION OF SIGNAL STRENGTH

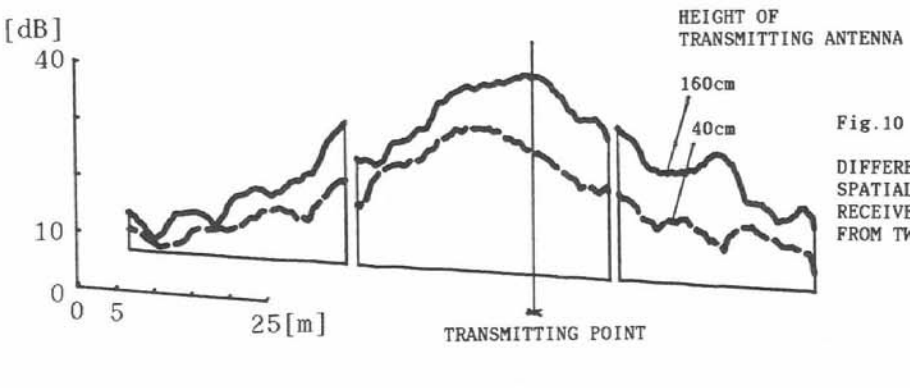

Fig.10

DIFFERENCE OF SPATIAL DISTRIBUTION OF RECEIVED SIGNAL STRENGTH FROM TWO TRANSMITTING ANTENNAS other points, both when standing still and in motion, and when fluorescence lights were turned off, and the width of the variation became small. Thus, fluorescence light was verified as causing this variation, as reported in 3).

The difference in the spatial distribution of the signal strength from two transmitting antennas having a different height (160 cm and 40 cm) was also measured, using the synchronous signal transmitter and receiver (Fig.10). The figure shows that the difference tended to be smaller the farther from the transmitting point.

Conclusion

A new indoor mobile measurement system was developed to investigate the indoor radio propagation characteristics efficiently. Using this system, data clearly related to the receiving position/direction of the vehicle were measured, and the time and number of the operators were reduced. The applicapability of antennas, diversity techniques, radio port locations and modulation techniques for indoor mobile communication can be efficiently studied by this system.

Reference

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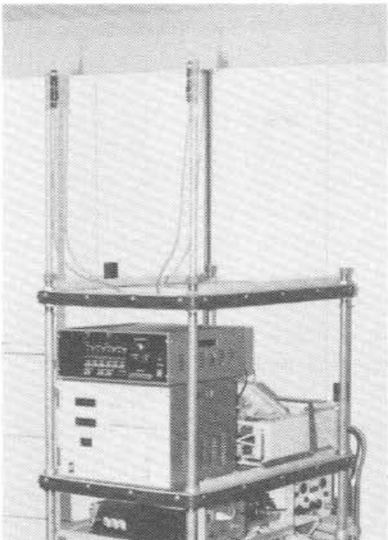

Fig.1

INDOOR MOBILE RADIO PROPAGATION MEASUREMENT SYSTEM

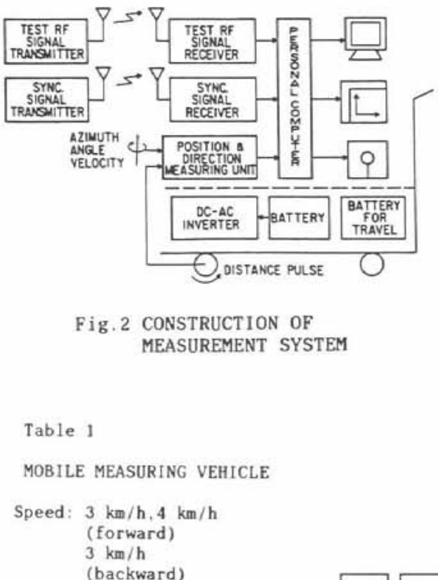

Fig.2 CONSTRUCTION OF MEASUREMENT SYSTEM

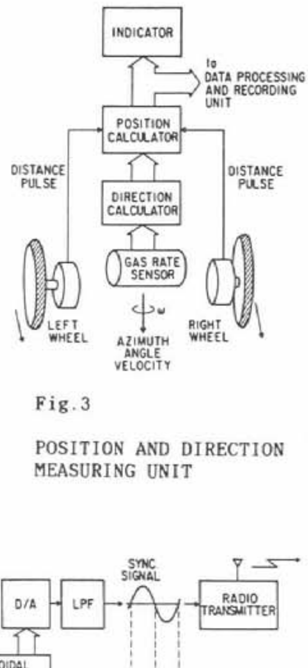

Fig.3

POSITION AND DIRECTION MEASURING UNIT

Table 1

MOBILE MEASURING VEHICLE

Speed: 3 km/h, 4 km/h (forward)
3 km/h (backward)

Distance Pulse : 1.6 mm interval (x2)
(one leads (forward) or lags (backward) another by 90 deg.)

Battery: 12 V, 50 Ah (for electromotive travel)
12 V, 200 Ah (for measuring instruments)

Height: 110 cm-176 cm
Width : 110 cm
Length: 60 cm

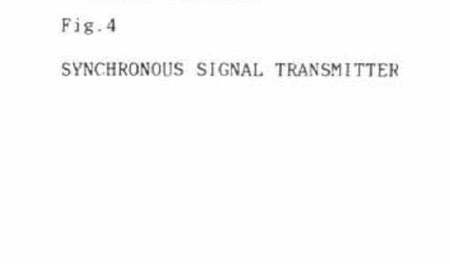

Fig.4

SYNCHRONOUS SIGNAL TRANSMITTER