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DEVELOPMENT OF A 60-GHz INDOOR PROPAGATION EXPERIMENTAL SYSTEM WITH A FINE DELAY-TIME RESOLUTION

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1 Introduction

There is a growing need for high-speed wireless indoor communication systems. The millimeter-wave band is considered to be promising for this application field because of its vast frequency spectrum, compactness and lightness of equipment, and ease of interference-free system configuration. Study programs to explore this new application field are being conducted in North America and Europe [1][2].

In Japan, the Communications Research Laboratory (CRL) of the Ministry of Posts and Telecommunications (MTP) recently started a research project in this area. This project includes studies on indoor propagation, anti-multipath CODEC and equalization techniques, and integrated antenna technologies in the millimeter-wave band. For the first step, propagation measurements in indoor multipath environments are planned. An experimental 60-GHz system, with a delay-time resolution in the order of one nanosecond, based on the frequency sweep technique[3], has already been developed by CRL in collaboration with the Institute for Posts and Telecommunications Policy (IPTP) of the MTP.

In this paper, we will describe the configuration and major electrical characteristics of the developed 60-GHz experimental system. The spatial scanning capability of the experimental system is also introduced. Finally, the results of measured delay-time resolution are presented to demonstrate the fine delay-time resolution of the system in the order of one nanosecond.

2 Experimental System

2.1 System Configuration and Delay Profiling Technique

Figure 1 shows a block diagram of the 60-GHz indoor propagation experimental system. This system consists of a vector network analyzer, a 60-GHz band transmitter, and a 60-GHz band receiver. Major system characteristics are listed in Table I. To achieve delay-time resolution, this system uses the frequency sweep technique[3].

A signal synthesizer, which is contained in the network analyzer, generates transmitting IF signals at a frequency range of 2 to 3 GHz. The IF frequency is varied in a stepwise manner over the 1-GHz bandwidth. The IF signal is mixed with a local 55-GHz signal, thereby upconverted to an RF signal of 57 to 58 GHz. The received multipath signal is mixed with a local signal, which is phase-locked to the local signal of the transmitter, thereby downconverted to an IF signal keeping a coherency with the transmitting IF signal. The phase-lock between the transmitter and receiver local signals is maintained by the common use of a 98.21-MHz crystal oscillator signal distributed through a coaxial cable from transmitter to receiver.

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The vector network analyzer measures the amplitude and phase of the received IF signal with respect to the transmitting IF signal. This provides a complex channel transfer function for the indoor multipath over 1 GHz bandwidth. The inverse discrete Fourier transform of the channel transfer function corresponds to a band-limited impulse response for the indoor multipath environment[4]. Since the used bandwidth is 1 GHz, the minimum time resolution is 1.2 ns when a rectangular frequency window is used for the inverse Fourier transform. Since the rectangular frequency window results in a high range (time) sidelobe level of -13.5 dB, different frequency windows, which enable faster roll-off of range sidelobe levels, are applied at the expense of time resolution.

2.2 Antennas, Polarization, and Spatial Scanning

(a) *Antennas*

In this system, scalar horn antennas, with half-power beamwidths of about 49°, are used for both signal transmission and reception. A scalar lens horn antenna, with a half-power beamwidth of 5°, is also used for the receiver when we measure the distribution of angles of arrival of multipath components.

(b) *Polarization*

The transmitter antenna feed circuit consists of an electrical waveguide switch and an orthomode transducer. Transmitting polarization is, therefore, switchable between horizontal and vertical.

The receiver consists of an orthomode transducer and dual-channel downconversion circuits. Therefore, horizontal and vertical polarization components are received at the same time. This dual-channel configuration enables the concurrent measurement of copolar and cross polar multipath delay profiles.

Additional use of circular polarizers, both for transmitting and receiving antenna feed circuits, is also available. This enables data collection of multipath propagation characteristics for circular polarization as well. Such measurements may be useful for determining the most suitable polarization in terms of the received multipath delay characteristics in the millimeter-wave region.

(c) *Spatial Scanning Capability*

Detailed knowledge of indoor multipath structures is required for efficient implementation of various anti-multipath techniques, such as antenna directivity diversity, space diversity, adaptive antenna, adaptive equalization, and so on. To measure detailed indoor multipath structures, the multipath probe must be scanned in various directions; in the horizontal and vertical directions, and also in the azimuth and elevation angles.

A movable pedestal to enable this is prepared. The pedestal is capable of precisely scanning the receiver equipment along the horizontal and vertical directions, and also in the azimuth and elevation angles. The major scanning characteristics are summarized in Table II.

3 Measured Time Resolution Characteristic

Figure 2 shows an example of band-limited impulse responses as measured by the developed propagation experimental system. In this experiment, a multipath environment was artificially created by two corner reflectors as shown in Fig. 3. This measurement was conducted to determine the delay-time resolution of the experimental system. In this case, the time domain function, built into the vector network analyzer, was used, and a frequency window corresponding to the first range sidelobe level of -44 dB was applied. It was found that a time resolution of about 2 ns (−6 dB width) is attained. The floor level due to the range sidelobe is less than −40 dB relative to the pulse peak level. The pulse width at the −40 dB level (relative to the pulse peak level) is about 6 ns. This delay-time resolution can be used to examine detailed indoor multipath structures.

4 Summary

A 60-GHz indoor propagation experimental system, developed at the CRL in collaboration with the IPTP, was introduced. A fine delay-time resolution in the order of one nanosecond was demonstrated by measuring a simple multipath environment created by corner reflectors. This experimental system will be useful for measuring and characterizing indoor multipath radio channels whose knowledge is indispensable in the development of millimeter-wave high-speed indoor communication systems.

References

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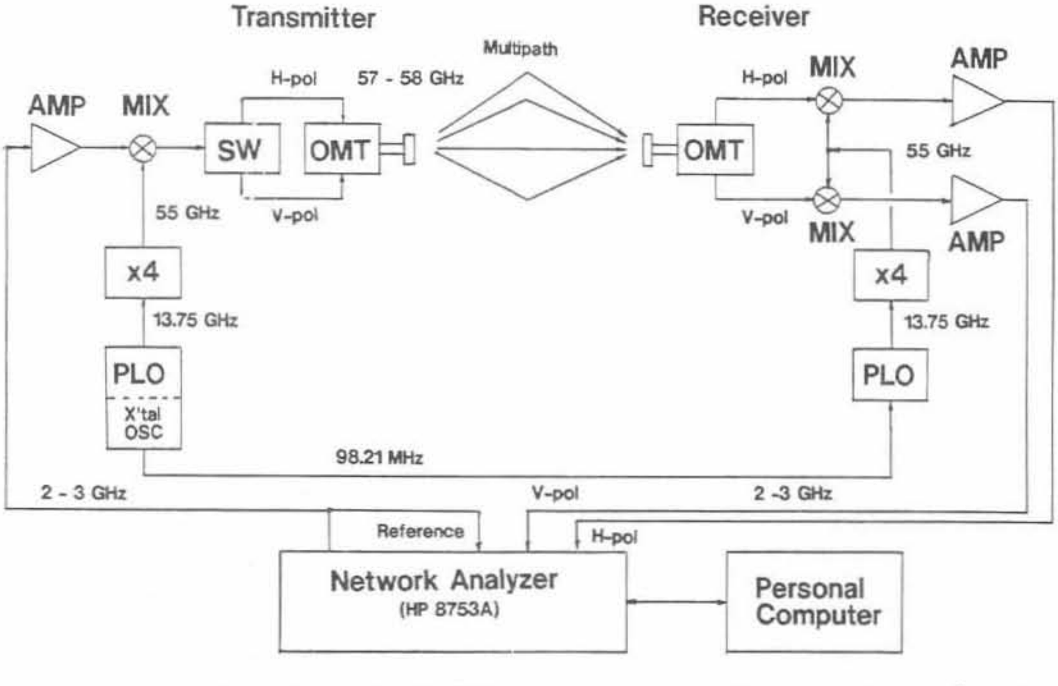

Figure 1: Configuration of a 60-GHz indoor propagation experimental system

Table I: Major system characteristics

Frequency	57 – 58 GHz
Transmitting Power	0 dBm
Transmitting Antenna	Scalar Horn (Beamwidth 49°)
Receiving Antenna	Scalar Horn (Beamwidth 49°) or Scalar Lens Horn (Beamwidth 5°)
Transmitting Polarization	H-pol, V-pol, RHC-pol, or LHC-pol (Switchable)
Receiving Polarization	H-pol and V-pol, or RHC-pol and LHC-pol (Dual-channel capability)
Receiver Noise Figure	12 dB
IF Frequency	2 – 3 GHz
Time Resolution	1 ns (Rectangular Window)

Table II: Spatial scanning capability of receiver

Pedestal Height	
Coarse Change	1 to 2 m
Fine Change	0 to 0.2 m (error: < 0.1 mm)
Horizontal Position	
Coarse Change	Continuous
Fine Change	0 to 0.2 m (error: < 0.1 mm)
Azimuth Angle	0 to 360° (error: < 0.5°)
Elevation Angle	−45° to 95° (error: < 0.5°)

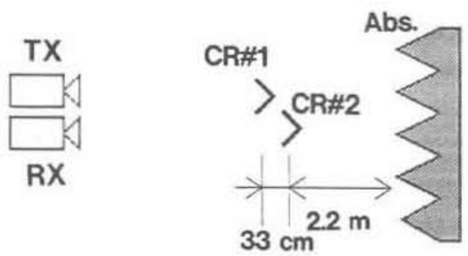

Figure 3: Exprimental setup (CR: corner reflector, Abs.: absorber)

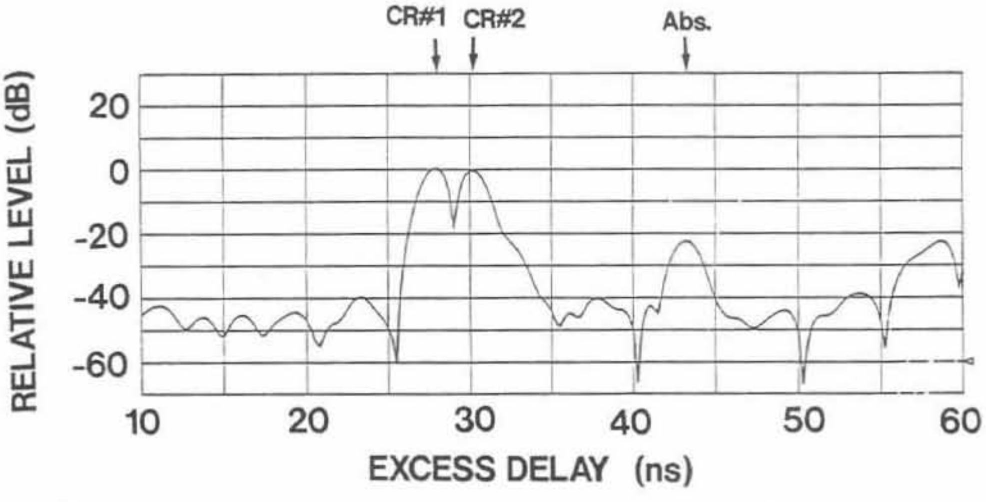

Figure 2: An example of measured band-limited impulse response for the experimental setup shown in Fig. 3.