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Radio Propagation Inside Office Buildings

1. Introduction

This document presents a summary of results of radio propagation measurements taken inside office buildings of various types. In particular, the buildings can be classified into steel reinforced, open plan structures and older style, solid partition wall structures. Measurements were conducted for line of sight, non line of sight, between floors, open plan design, and through outside walls. The effect of furniture was determined by before and after placement measurements. Multipath and frequency selective fading characteristics for two mobile environments were determined.

2. Proposal

It is proposed that the text provided in the Annex be included in section 5.5.1.2 of Report M/8. A more detailed description of the measurements on which these comments are based is included for reference purposes (see Attachment)

All propagation data should be brought to the attention of SG 5.

3. Reference

Bultitude, R.J.C "Data Pertaining to Radio Propagation Inside Buildings", attached report.

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ANNEX

Add to section 5.5.1.2:

"Indoor radio channel characteristics will serve two primary requirements;

1) to provide voice and non voice communication to portable hand held units which may be in motion, and

2) to provide communication to fixed desk top terminals where the primary cause of fading is due to movement of intervening people or equipment.

Because of the different fading characteristics of these two environments, frequency selective phenomena also behave differently and have different effects on digital communications.

Radio Signal Attenuation on Indoor Channels

In-building radio attenuation data was measured in steel reinforced concrete office buildings using simultaneous transmissions at 433, 861, and 1,705 MHz. The following conclusions were obtained.

* Line of Sight Propagation

When transmit and receive antenna are located in the same corridor, the average signal level varies in an inverse power law of the line of sight separation (between r^-1 to r^-3 at 433 and 861 MHz, approximately r^-1 at 1,705 MHz). Attenuation in corridors can be less than free space attenuation due to guiding effects of the corridor walls.

* Non Line of Sight Propagation

In a building with concrete block partition walls, the loss suffered by a signal penetrating a single partition was 5dB. With the transmitter located at the end of the corridor, attenuation to locations within offices off the corridor ranged between 12 and 20dB relative to free space loss.

* Between Floor Propagation

Measurements between floors in a open office environment at the three test frequencies indicate that unrestricted frequency re-use every third floor would be possible at the higher frequency,

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but that, at the lower frequencies, additional cell coordination may be required. The problem may be less severe in a building with solid internal walls.

Frequency (MHz)	Interference Power (dBm)
433	-86
861	-93
1,705	-113

assumptions:
- floors 3 m apart,
- transmit power 5dBm,
- no additional fading or shadowing of the interfering signal,
- interference received from above and below.

* Open Plan Office Propagation

Attenuation in an open office environment was found to vary about free space loss by approximately +4, -3, and -5 dB respectively at the three test frequencies. Multipath propagation via the ceiling introduces a distance dependant loss of 4 dB for ranges less than a few metres and -4 dB for ranges greater than 20 metres.

* Attenuation due to Furniture

Measurements before and after placement of furniture in an open office environment indicated a loss increase of 5 to 7 dB when line of sight was maintained and 12 to 17 dB when the furniture blocked line of sight. Where there were building structures obstructing line of sight, the addition of furniture reduced the atttenuation due to multipath filling. Furniture had no effect on the mean values of the fine structure characteristics.

* Propagation Through Outside Walls

The minimum attenuation due to transmission through an outside wall (normal incidence at transmitter elevation, adjacent to windows) ranges from 17 dB at the lower frequencies to 24 dB at the higher frequency. This loss increases with oblique incidence and elevation separation.

* Multipath Characteristics

Multipath propagation on indoor radio channels leads to frequency selective phenomena which result in non uniform transmission characteristics across the band. On fixed links (type 2 environment), the average transfer function is quasi-static, once a disturbance passes conditions return to the background state.

On mobile links (type 1 environment), there is no steady background state. Based on measurements at 910 and 1700 MHz with monopole antenna, the average delay spread on static channels ranges from about 10 to 150 nsec. with an average of approximately 30 nsec. A larger standard deviation at the higher frequency implies that coverage may be less uniform. Delay spreads are lower when there is line of sight between transmitter and receiver. In non line of sight situations, the delay spread increases as the range increases.

* Temporal Characteristics of Indoor Channels

Closed form distributions which best fit experimentally determined envelope fading distributions of measurements made at 910 and 1,700 MHz tended to be Rician with random to specular power ratios (K) between -1dB and -16dB. A few links subject to shadowing exhibited Rayleigh fading. In line of sight situations, the maximum depth of fade at both frequencies was about -30dB with enhancements of +2dB at 910 MHz and +6dB at 1,700 MHz respectively. In non line of sight situations, the maximum fade ranges between -30 and +10 dB at 910 MHz and -38 to +12 dB at 1,700 MHz."