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# Link Budget Design and Analysis for UWB Indoor Wireless Communications

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**ABSTRACT**

Ultra-wideband impulse radio (UWB-IR) technology is an ideal candidate for wireless networks that can be widely used for short-range, high-speed, low power, and low costindoor applications. In these applications transmit and receiveantennas are placed very close to each other and the far-fieldcondition assumed in most of the link budget models may not besatisfied. In near field conditions, variations in the link budgetand pulse shape compared to the far-field can be observed. Inthis paper, near field condition is taken and transmitter andreceiver are placed considering different scenarios such as line of sight (LOS) and non line of sight (NLOS). Path loss for leasttime of arrival (TOA) and highest power is calculated between transmitter and receiver that are placed at a reference distanceof 1m. Simulation is carried out in different environments such as small office, house considering both LOS and NLOSconditions. With the calculated path loss, designed antenna gain, input transmitter power received power is calculated.

***Keywords:*** Ultra-Wide band, Link budget, Path loss, Received Power, Least TOA, Highest Power, NLOS.

## 1. INTRODUCTION

The FCC allocated the 3.1-10.6 GHz frequency band to ultra-wideband (UWB) in 2002[1]. Other regulatory regimes, including Japan and the European Union, made similar spectrum allocation to UWB. This state-of-the-art technology presents itself as one of the most innovative and promising wireless technologies to enable high-speed data transmission, with applications including integrated home digital network, etc [2]. The assiduous efforts from the industry developers have led to recent product release of UWB devices on the market [3]. Most of these devices employ the WiMedia UWB technology that is based on multi-band orthogonal frequency division multiplexing (MB-OFDM) [4]. The WiMedia specification divides the whole 7.5 GHz frequency range into 5 band groups with 14 sub-bands [5]. In this model, near field condition is taken by placing transmitter and receiver considering different scenarios such as line of sight (LOS) and non line of sight (NLOS) at a reference distance of 1m [6]. Different paths taken between transmitter and receiver are observed that undergo various reflections, refractions and diffractions. Out of these, paths that take least time of arrival and highest power are observed and path loss is calculated. Simulation is carried out in different environments such as small office, house considering both LOS and NLOS conditions. Comparison is done between narrow band communications and ultra wide band communications. The rest of the paper is organized as followed. Section II presents path loss and link budget. In Section III, measurement procedure and environments in both office and home environments are presented. In Section IV, measurements and simulations are given. Finally, Section V, concludes the paper.

## 2. PATH LOSS (PL) AND LINK BUDGET

Path loss is defined as the dB reduction in power from the transmitter to the receiver location, where the received power is spatially averaged around the location [7]. Specifically it is averaged over an area

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whose radius is several wavelengths, with the wavelength being that at the center frequency of the transmission [8].

For the characterization of UWB path loss behavior, we use the widely known log-distance path loss formula.

$$PL\,(d) = PL\,(d_0) + 10.n.\,\log(d/d_0) + X_\sigma(dB) \tag{1}$$

The formula is given in (1) where PL ($d_0$) means path loss at the reference distance $d_0 = 1m$, $d$ is separation between the transmitter and receiver, $n$ is the path loss exponent and $X_\sigma$, is the standard deviation of shadowing factor. A link budget is accounting of all the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system [9]. It accounts for the attenuation of the transmitted signal due to propagation, as well as the antenna gains, feed line and miscellaneous losses [10]. A simple link budget equation is shown in (2).

$$R_P(dB_m) = T_P(dB_m) + \text{Gain}\,(dB) - \text{Losses}\,(dB) \tag{2}$$

In equation (2) $R_P$ is received power, $T_P$ is the transmitted power. Gains and losses are respected gains and losses of propagation paths.

## 3. INDOOR ENVIRONMENT AND MEASUREMENT PROCEDURE

The ultra-wide band communications has a unique character that it don't use carrier wave for its propagation, instead it uses pulses as input. For present scenario, a simple office room and floor design of a college building is taken as shown in fig.1 and fig. 3. While designing a room, the height of walls is taken as 3m, the materials used for walls and floor is layered dry wall. Layered dry wall permittivity is 2.800, conductivity is 0.00100 and thickness is 0.127m. For windows, material used is glass whose permittivity is 2.400, conductivity is 0.00 and thickness is 0.0030m. In the floor design, corridor which is narrow is considered, with the transmitter kept at the entrance and receivers are placed with 0.5 m spacing. The transmitter and receivers used omnidirectional antennas placed at a height of 1.5m from ground level. Assuming the gain of antenna to be 0dB, the transmitted power given is -41.3dBm. The input for transmitter given is Gaussian derivative pulse with a pulse width of 1 ns.

With the given input the propogation paths are observed between transmitter and recievers. It can be observed that they are multiple paths for a single reciver from transmitter. This is due to various reflections, refractions and diffractions that has undergone during propagation. For an analysis propagation paths between tranmitter and first reciever are taken for both office room and floor design and are shown in figure (3) and figure (4). Transportation. Even though, they had not provided any mechanism where data owner authenticates privacy orupdate security of data.

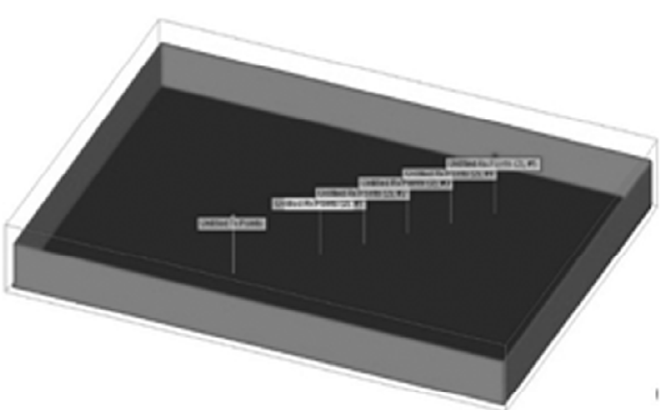

**Figure 1: Office room setup with transmitter and receivers**

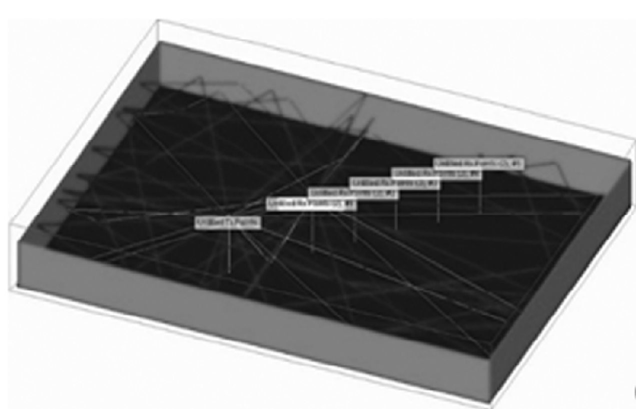

**Figure 2: Propagation paths between transmitter and first reciever**

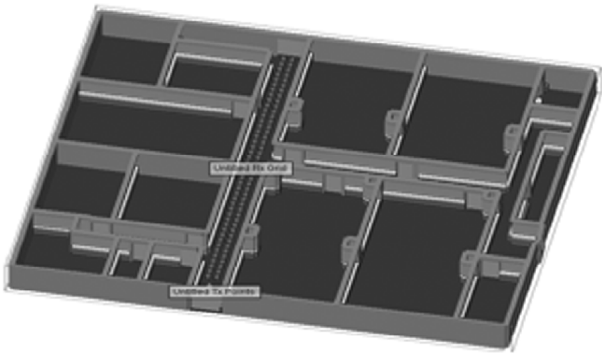

**Figure 3: Floor design of a building with transmtter and receivers**

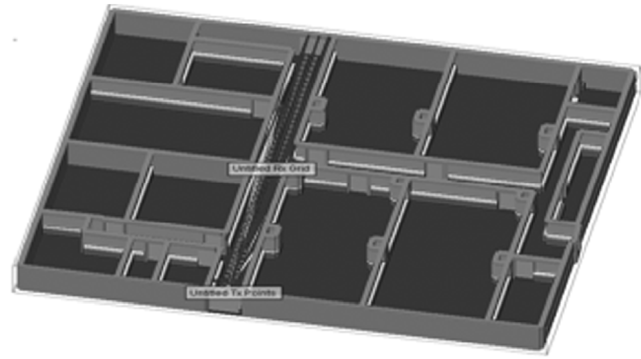

**Figure 4: Propagation paths between transmitter and first receiver**

The materials used for floor design and their properties are as shown in table (1).

**Table 1**
**Materials used and their properties**

| *Materials Used* | *Properties* | | |
|---|---|---|---|
| | *Permittivity* | *Conductivity* | *Thickness(m)* |
| Porcelain Tiles (Floor) | 3.0 | 0.00 | 0.02 |
| Glass (Doors & Window) | 2.4 | 0.00 | 0.003 |
| Wood (Door & Window Partitions) | 5.0 | 0.00 | 0.31 |
| Gypsum Board (ceiling) | 3.0 | 0.00 | 0.02 |

## 4. RESULTS AND DISCUSSION

The propagation of pulses is observed between transmitter and receivers. For office room setup a pulse width of 1 nsis given as input and for that path loss versus distance is plotted as shown in Fig. 5.

From the path loss value obtained, the received power is calculated. Thus for receiver placed at different positions received power is calculated and link budget investigation is done. In this scenario, the transmitter and receivers are considered to be in line of sight.

Similarly, floor design is taken and the propagation of pulses is observed and path loss versus distance is plotted for receivers placed at different positions as shown in fig. 6. Received power is also calculated. A

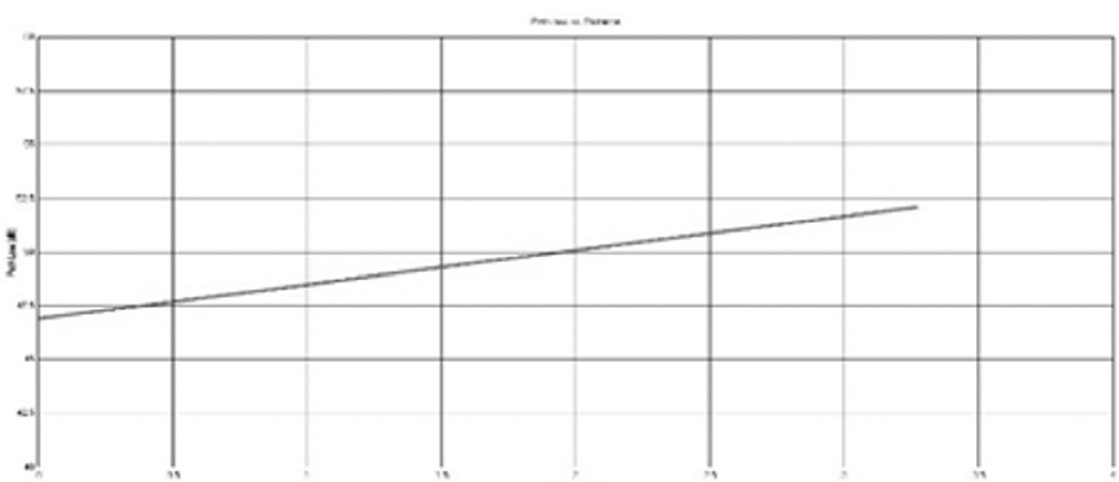

**Figure 5: Path loss versus distance for office room setup**

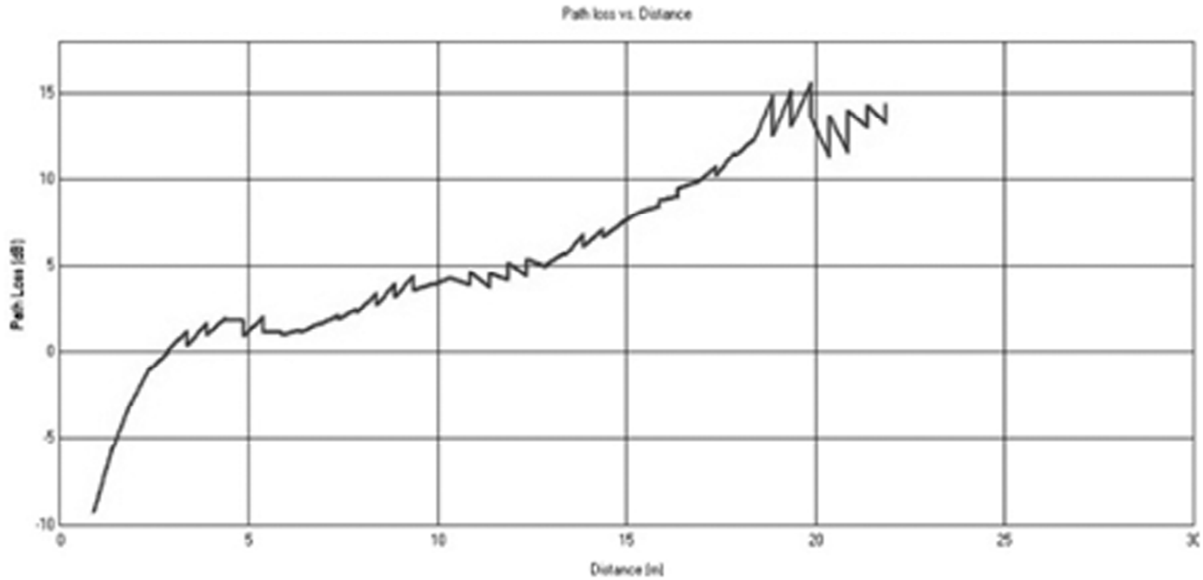


**Figure 6: Path loss versus distance**

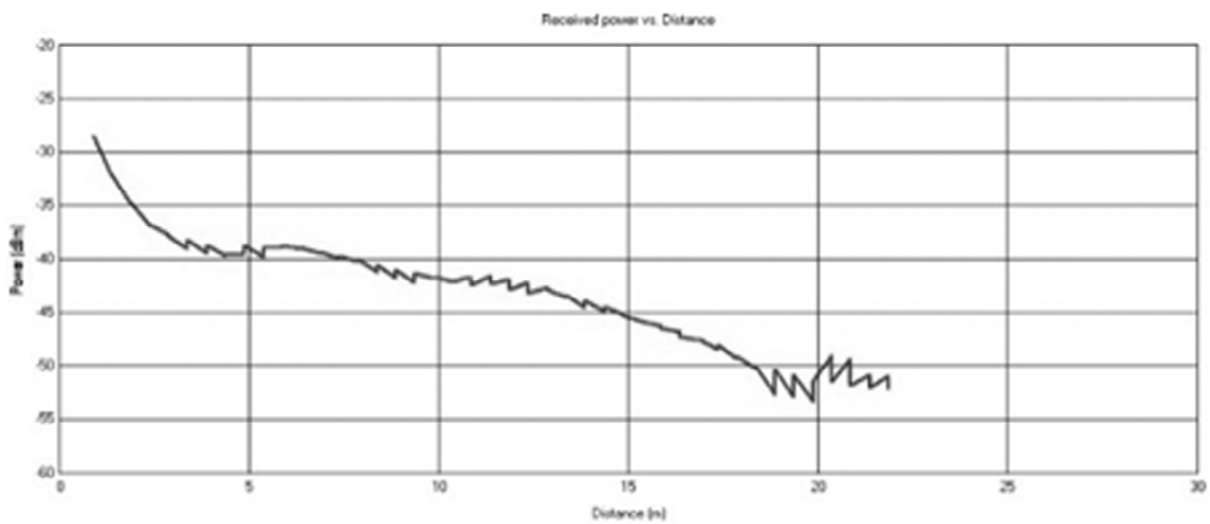


**Figure 7: Received Power versus distance**

graph is plotted between received power and distance as shown in fig. 7. Link budget investigation is done, for different receivers placed at different positions.

For the floor design path gain is maximum at receiver 1 placed at a distance of 0.9022m. The maximum path gain is 9.252dB and path loss at this distance is -9.252dB with a delay spread of 5.347e$^{-010}$. The path gain is minimum at a distance of 21.8708m at receiver 86 with a value of -14.391dB, a path loss of 14.392dB with a delay spread of 5.500e$^{-010}$.

## 5. CONCLUSION

Due to the limitations in narrowband communications such as multipath fading, insecurity, poor range resolution and limited data rate, ultra-wide band is promising for its wide bandwidth. In this paper, path loss for ultra-wideband channels in indoor communications is calculated for different environments considering LOS and NLOS conditions. Simulation results are taken for different layouts such as office room and floor design and path loss is calculated when transmitter and receiver are placed at different positions and paths are observed and plot is made between distance and path loss. From path loss power received is calculated and from that an analysis can be made for which paths maximum power can be obtained at the receiver.

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