Radio Propagation Characteristics in Subway Tunnel at 2.65GHz

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1. Introduction

Recently, the DMB (Digital Multimedia Broadcasting) services are researched by many countries. The environments for DMB are expected to get extended into underground areas that would include underground shopping mall, subway, and so on. For implementing that service, radio propagation characteristics should be clarified since the path-loss and fading characteristics affect the coverage and quality of the transmission[1][2]. Also the wave propagation in an underground area, a subway tunnel, is not sufficiently investigated[3]-[6]. Thus, this paper deals with the prediction and the measurement of electromagnetic wave propagation in rectangular shaped tunnels at $f = 2.6425\,GHz$. The main target for this work was the more accurate knowledge of the propagation characteristics in tunnel at DMB(Digital Multimedia Broadcasting) service.

2. Ray Launching Method

For indirect methods, also called ray launching, a number of rays are launched from the transmitter in arbitrary directions and traced until they eventually hit the receiver or until they surpass a certain maximum attenuation. Each ray is traced in space and wave propagation is calculated according to geometrical optics, reflection, scattering etc. Although this method has a multiple ray problem, the major advantage of ray tracing offers excellent applicability to curved shaped structures[3][4].

The multiple ray problem can be seen on Fig.1 that several “identical rays” reach the receiver. If receiver is reached by multiple direct rays, each representing a distinct wavefront, the power of a received signal is different from the accurate results. The reason for this difference is that there is only one physical wavefront reaching the receiver on the direct propagation path in reality. To overcome this problem, we have used the fixed radius of receiver and the ray density normalization(RDN) technique[3]-[5].

The fundamental concept of ray density normalization is as follows. Instead of trying to avoid the existence of multiple rays, it is assumed that several multiple rays are present on each physical propagaton path. The number of these rays is determined, and this number is used to normalize the contribution of each ray to the total field[1]-[5],[7]. For example, the number of multiple rays is theoretically given by M , the coherent summation of all rays belonging to the same propagation path

ISBN: 89-86522-78-0 94460©KEES

leads to

$$P_{R,total}^{C} = \left| \sum_{l=1}^{M} \frac{V_{R,l}^{C}}{V_0} \right|^2 = \left(M \frac{V_R{}^{C}}{V_0} \right)^2$$
$$= (M)^2 T_P{}^2 \frac{4\pi}{N} n_d X_F^{C\,2} . \qquad (1)$$

Where T_p is a propagation transfer factor which comprises the effect of reflection, scattering. N is the number of launching ray at the transmitter, and n_d is the value of ray density per unit area. The weight, X_F^C, which correct the received total power is given to the following equation.

$$X_F^C = \frac{1}{n_d A} \cong \frac{1}{M} , \qquad (2)$$

,where A represent area according to the length of a ray trajectory.

3. Simulation and Measurement

3-1. Simulation approach

Almost train tunnels are either of rectangular or arched shape. But we assume that tunnel is a rectangular shape whose dimensions are 7.8m×6.745m. And transmitter is situated at the origin, 0.2m from the left wall and 2.7m above ground. The left wall and above ground distance of between receiver and transmitter is 3.4m and 1.5m, respectively. To illustrate this issue, the configuration is depicted in Fig.2. The tunnel paths in simulations are given by Fig.3 and the curve tunnel has a variable radius of curvature. For both tunnels, the parameters of the building materials in the simulation correspond to dry concrete($\varepsilon_r = 5 - j0.1$). The results has been calculated at $f = 2.6425\,GHz$, and considered transmit antenna pattern. In simulation, transmitter launched 15,000,000 rays for accuracy, the radius of receiver is fixed on 0.1m and we calculated the simulation results with (1) and (2).

3-2. Measurement setup

The measurement setup is shown in Fig.4. A yagi antenna whose gain has a $14\,dBi$, is used as transmitter at $f = 2.6425\,GHz$. The input power of the antenna $P_T \approx 26\,dBm$ is employed by a DMB transmitter. The received power level is measured incorporating a spectrum analyzer and having DMB mobile phone. In measurement, the tunnel has an arch shape and its course consists of combinations of straight and curved sections. Normally the curves have a constant radius of curvature. We have measured the received power for the region that is between Bupyeong-samgeori and Incheon City Hall subway station. Thus we have gotten the data for two cases, the straight and the curved tunnel whose radius is 300m.

4. Conclusion

In Fig.6, the straight tunnel results are given by (a) and the curved tunnel results are shown by (b). The results show a marked difference in propagation loss: the path-loss exponent, $\alpha_{straight} = 3.2,$ and $\alpha_{curved} = 4.0,$ for a straight and a curved tunnel, respectively. The reason that path-loss exponent is high in a curved tunnel is that there is no direct wave but only the reflected waves, which attenuates rapidly with distance due to multiple reflections. Also the measurements are lower path loss level than the simulation. The reason for difference between measurement and simulation is that the there are many articles in measurement environment.

The research deals with the prediction and the measurement of electromagnetic wave propagation in rectangular shaped tunnels at $f = 2.6425\,GHz$. This work is focused on acquiring the more accurate knowledge of the propagation characteristics in tunnel at DMB(Digital Multimedia Broadcasting) service.

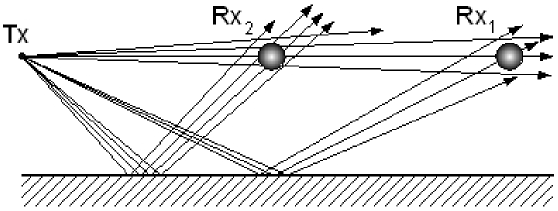


Fig.1. The multiple ray problem using a fixed radius of receiver

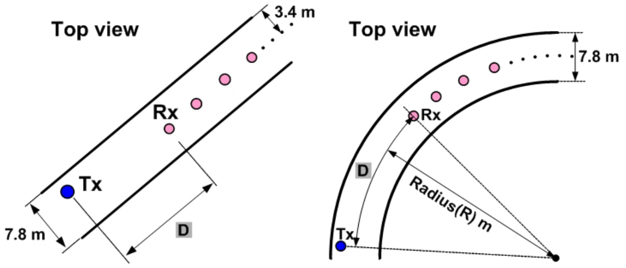


Fig.3. The position of both Tx and Rx in the straight and curve tunnel

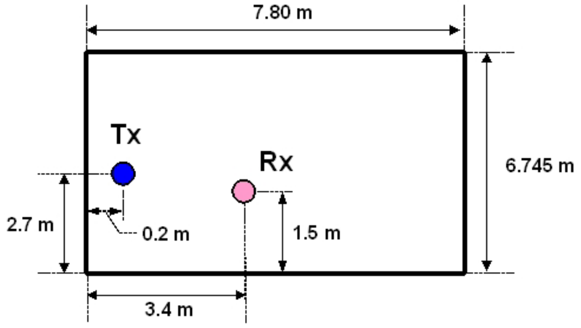


Fig.2. Rectangular tunnel model and simulation conditions

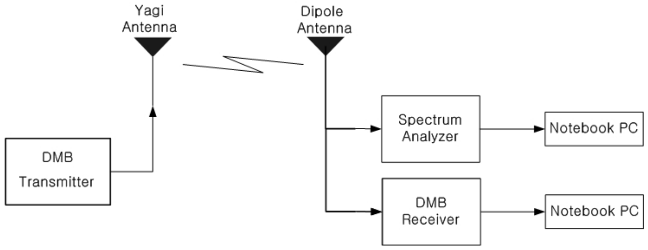


Fig.4. The block diagram of a measurement system

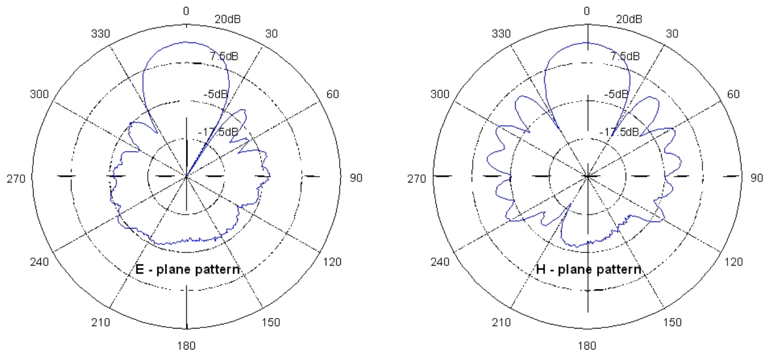
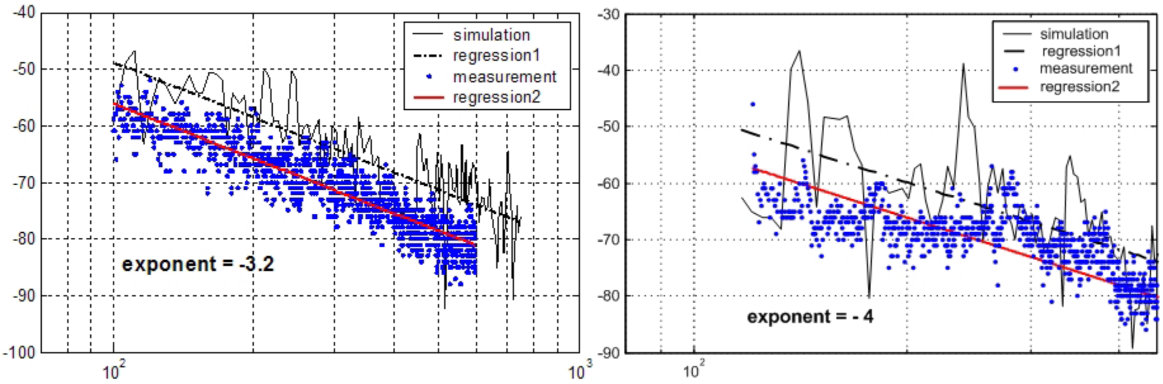


Fig.5. The antenna pattern at the transmitter (Yagi antenna)



(a) (b)

(a) The straight tunnel results (path-loss exponent = -3.2)

(b) The curved tunnel($R = 300$) results (path-loss exponent = -4.0)

Fig.6. Path-Loss and Regression results in the simulation and the measurement

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