EXPERIMENTS OF VOIP USING WIMAX SYSTEM AND FADING SIMULATOR WITH TWO-PATH MODELS FOR AERONAUTICAL SCENARIOS

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Abstract

In this paper, we study the performance of VoIP over WiMAX systems. We assume a two-path model for airport surface communications and experiment by using a multipath fading simulator. We evaluate the R-factor when the mobile speed and delay time are changed. We use an R-factor of 80 which is defined in ED-136 as a threshold where VoIP can be used for air traffic control (ATC). When the delay time is 0 -20ns i.e., the horizontal distance is over 40m and if the mobile speed is under 50 km/h, the R-factor is over 80. On the other hand, in takeoff and landing scenarios when the mobile speed is over 300 km/h, it is difficult to keep the quality of VoIP and some improvements in the receiver are needed.

Introduction

In order to implement high speed data communication systems on an airport surface, IEEE802.16 - 2009 (WiMAX : Worldwide Interoperability for Microwave Access) based systems called AeroMACS (Aeronautical Mobile Airport Communication Systems) are considered. It is important to evaluate the quality of VoIP over wireless communication systems because AeroMACS may be used for voice based ATC (Air Traffic Control) service.

As AeroMACS is based on the WiMAX standard, we use existing WiMAX systems for simple experiments to estimate the performance of AeroMACS. We evaluate the voice quality using the R-factor in our experiments. Also, the typical environment of airport surface communications is line of sight (LOS) which consists of direct and ground-reflected waves. This environment is dominant in most areas of an airport. Therefore, we assume two path models for airport surface propagation.

We setup a mobile terminal with a commercial WiMAX USB dongle and a WiMAX base station emulator. Also, we set up a multi path fading simulator between the mobile terminal and the base station emulator. We varied the parameters of the two path models such as maximum Doppler frequency and delay time.

With the setup stated above, we evaluated the R-factor and packet loss. We used EUROCAE (European Organization for Civil Aviation Equipment) ED-136[1] as an evaluation criterion. As a result of the evaluation, we found that VoIP for ATC is possible in apron scenarios while some improvements in the receiver are needed for take-off and landing scenarios.

Related Work

Some experimental results related to the evaluation of VoIP over WiMAX systems were reported. Han, et al. [3] evaluated the quality of VoIP over WiBro which is a WiMAX based system in use in Korea. They used the E-model of ITU-T Recommendation G.107[2] as a performance measure. Pentikousis, et al. [4] reported the results of field experiments using a WiMAX system with point to multi point communications. They evaluated the performance of VoIP and Video Streaming in LOS(line of sight) and NLOS(non-line of sight) environments. Halepovic, et al. [5] also evaluated the performance of VoIP and Video Streaming using commercial WiMAX service in Canada. However, fixed WiMAX systems were used in [4][5]. On the other hand, Henriques, et al. [6] evaluated the performance of VoIP using mobile WiMAX with different service classes in LOS and NLOS environments. There were several reports on research concerning field experiments in an urban area.

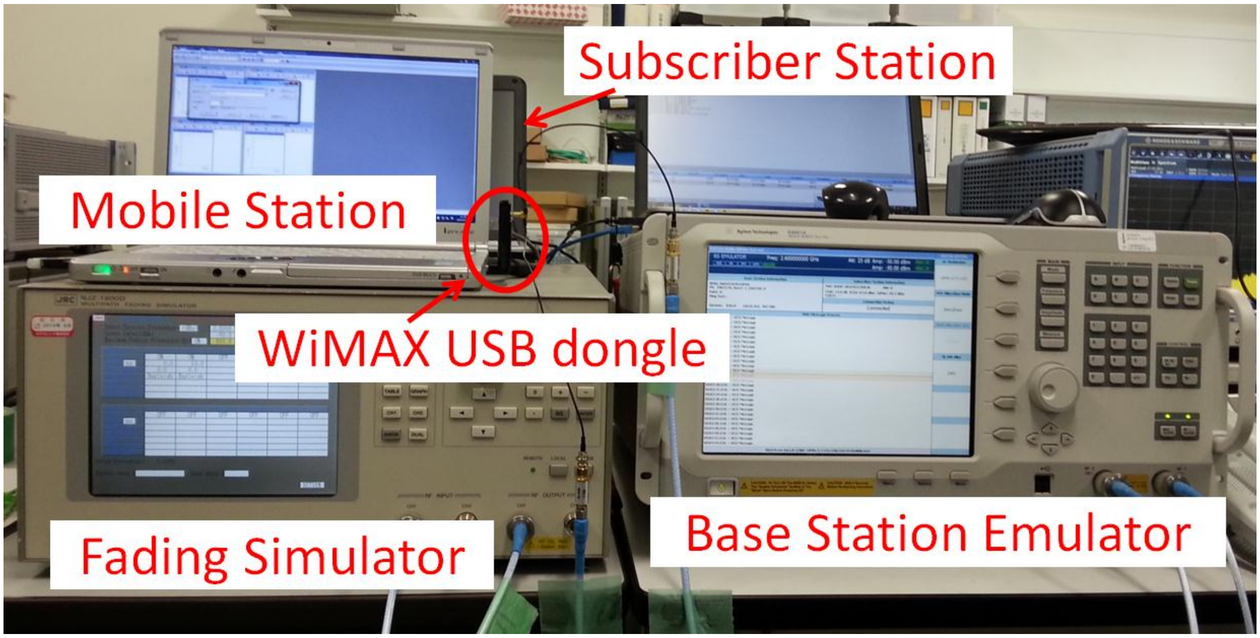

Figure 1. Experimental Setup.

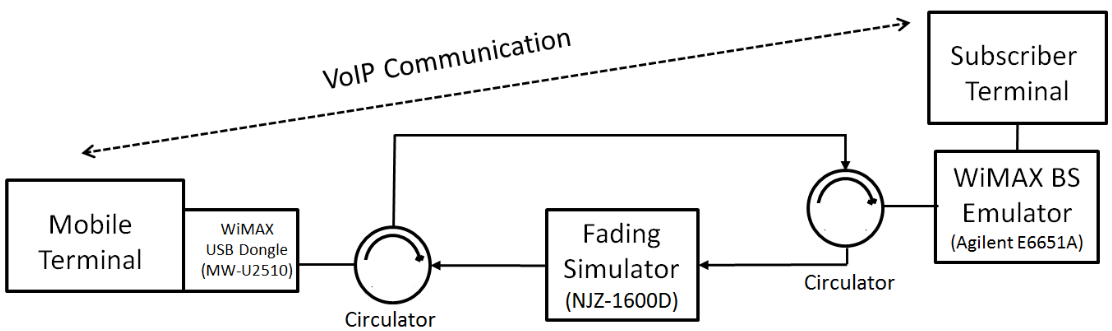

Figure 2. Block Diagram.

However, there were few studies regarding the experiments on an airport surface. Also, the effects of mobile speed on the quality of VoIP were not considered in previous work. In this paper, we study the relationship between mobile speed and the quality of VoIP in an airport surface environment.

Setup and Methodology

In this section, we explain our experimental system and methods. Also, we describe our channel models for the airport surface. Finally, we describe the performance measures for quality of VoIP for aeronautical purpose.

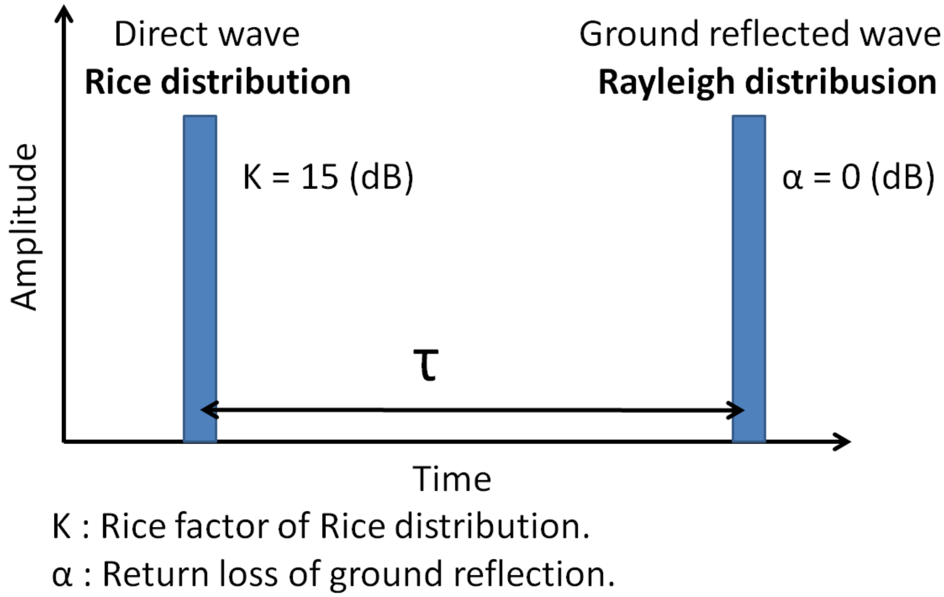

Figure 3. Two-path Model.

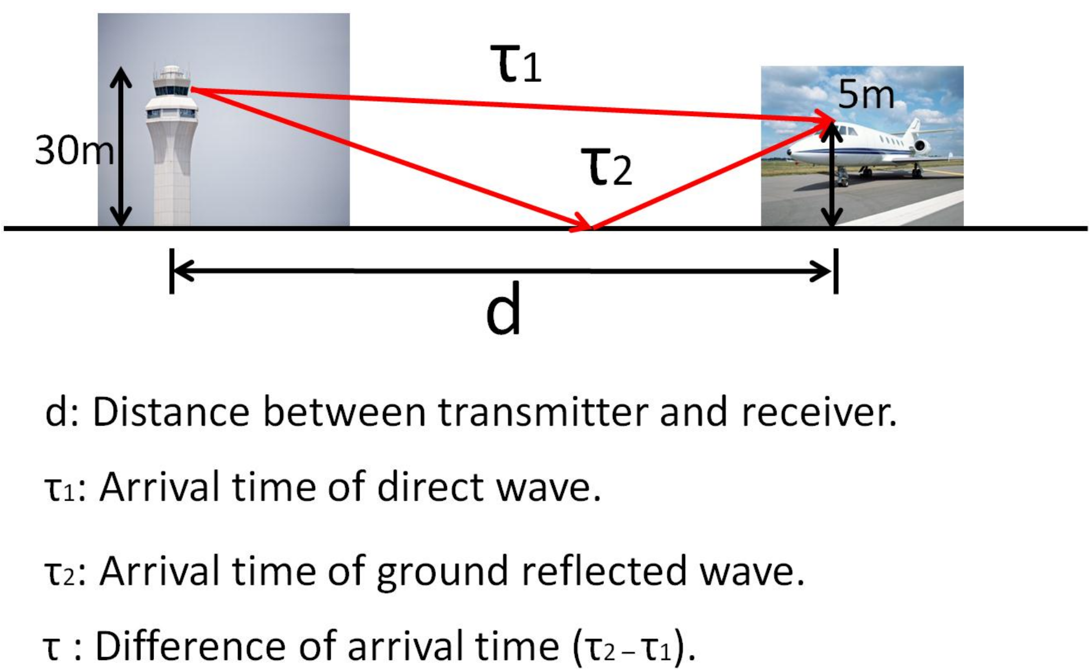

Figure 4. Parameter Setting of Fading Simulator.

A. *Experimental Setup*

Figure.1 shows our experimental setup and Figure.2 shows a detailed block diagram of our system. We setup a multi-path fading simulator between the base station emulator and the mobile station. In order to focus on the performance of the mobile station, we add fading only to the downlink direction by using a circulator as shown in Figure.2. We used a Shinsei corporation MW-U2510 WiMAX interface as a mobile station. We used an Agilent, E6651A as a base station emulator. Also, we used a Japan Radio Co., Ltd NJZ-1600D as the multi-path fading simulator and we set parameters described in the next subsection in the simulator.

We measured the mobile speed properties by varying the maximum Doppler frequency. We calculated the maximum Doppler frequency as follows.

$$f_d = v\, f_c \cos\theta / c.$$

Here, we set f_c to 5120MHz which is an AeroMACS band. v (m/s) is the speed of the aircraft and c is the speed of light. The transmit power of the base station emulator is the value that results in a mean RSSI (Received Signal Strength Indicator) at the mobile terminal of -65dBm.

B. *Airport Surface Channel Model*

A typical environment on an airport surface is line of sight (LOS), so direct and ground-reflected waves are dominant in the most areas in an airport [7]. Therefore, we assume two path models for airport surface propagation in this paper. Also, we assume that the power of the direct path and delay path are the same for the worst case scenario. Figure 3 shows a model of radio propagation in a typical airport surface environment. We assume that the transmitter is set at a height of 30m on a tower and the receiver antenna is set at height of 5m on top of an aircraft.

As shown in Figure 3, d is the horizontal distance between the transmitter and the receiver. $\tau_{1,}\tau_2$ are propagation times of the direct wave and the reflected wave respectively and τ is the difference between them. Also, $r_{1,}r_2$ are direct distances of the direct wave and the reflected wave respectively. Then, the relationship between the horizontal distance d and the delay time τ is given geometrically as follows.

$$\tau = \left(\sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2}\right)/c.$$

Here, h_t and h_r are the height of the transmitter antenna and receiver antenna respectively. Also, c represents the speed of light. Table 1 shows examples of the relationship between d and τ . As shown in Table1, if the transmitter antenna is set at a height of 30m, and the receiver antenna is set at a height of 5m, then the delay time is almost zero when the distance is over 3000m. Also, the delay time becomes about 20ns when the distance is around 40 m.

Table 1. Relationship between the horizontal distance and delay time.

d (m)	*τ (ns)*	*d (m)*	*τ (ns)*
Over 3000	0	160	6
1000	1	120	8
500	2	90	10
250	4	40	20

Next, we use the multi-path fading simulator to emulate the airport surface environment assumed above. The parameters which are used in the multi-path fading simulator are the number of paths, the distribution of each path and the attenuation of the delay path. In this paper, we assume an equivalent power two-path model so the number of paths is 2 and the attenuation is 0dB. Also, we set the distribution of the direct path to be a Rice distribution which is commonly used with LOS environments and the K-factor of the Rice distribution is 15dB which is a typical value for airport environments [8]. Also, we set the distribution of ground reflected path to be a Rayleigh distribution which is a common assumption for the delay path. Figure 4 shows a model of the parameters which are used in the fading simulator in an LOS environment.

C. *Performance Measures*

We use the R-factor as a performance measure to evaluate the quality of VoIP over WiMAX system in this paper. The R-factor is a value which indicates the quality of voice standardized by ITU-T Recommendation G.107 [2]. The R-factor is determined by measured parameters such as noise, volume, echo and delay. The maximum value is 93.2 and higher scores indicates higher quality. The EUROCAE document ED-136 [1] says that the R-factor shall be more than 80 when VoIP is used for ATC (air traffic control). Therefore, we use this value as a threshold which indicates whether or not VoIP can be used for air traffic control purposes.

We use Rworks, Inc, ASTEC Eyes for VoIP as a measurement software tool which automatically measures the R-factor according to the E-model of ITU-T Recommendation G.107 [2]. We set the codec format to G.711. The payload size is 160 bytes and the transmit interval is 20ms, so the bandwidth per channel becomes 64kbps. We transmit and receive the above packets at the mobile station and subscriber station for about 2 minutes then evaluate the R-factor and packet loss rate.

Experimental Results

At first, we show some results in an LOS environment. The distribution of the direct wave is a Rice distribution and the K-factor of the Rice distribution is K=15dB according to the literature [8]. Also, we assume the distribution of the reflected wave to be a Rayleigh distribution. The mean received signal strength indicator (RSSI) is -65dBm. We vary the delay time and the mobile speed then we evaluate the R-factor and the packet loss.

Figure 5 shows the R-factor versus the mobile speed in an LOS environment when the delay time is 1ns. This is the case when the horizontal distance is about 1000m. The horizontal axis is the mobile speed and the vertical axis is the R-factor. The modulation format used here is QPSK, 16QAM and 64QAM with rate 1/2 convolutional codes. The red line in the figure shows the R-factor threshold which is defined in EUROCAE Document ED-136 [1].

Figure 5 shows that if QPSK or 16QAM is used, the R-factor is larger than 80 when the mobile speed is 0 km/h. However, if 64QAM is used then sufficient voice quality cannot be obtained even if the aircraft is parked. Therefore, it is important to use a tolerant modulation format in order to keep sufficient voice quality.

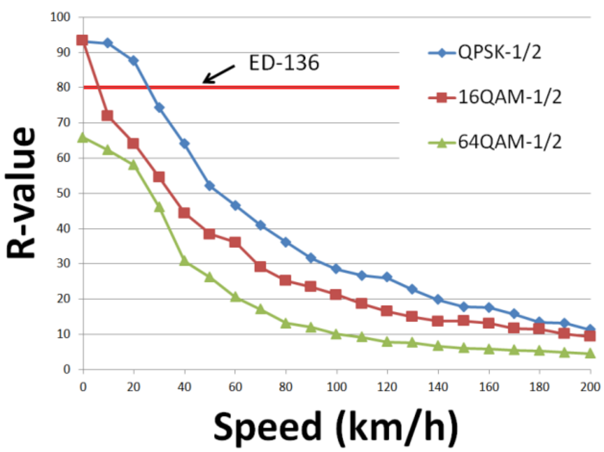

Figure 5. R-factor versus mobile speed in an LOS environment with τ =1ns and d = 1000m.

Figure 6 shows the packet loss versus the mobile speed in an LOS environment when the delay time is 1ns and the horizontal distance is about 1000m. The horizontal axis is the mobile speed and the vertical axis is the packet loss. Figure 6 shows that the packet loss increases as the mobile speed increases, so the reason why the R-factor becomes worse is that the packet loss increases and retransmission occurs resulting in a large VoIP packet delay.

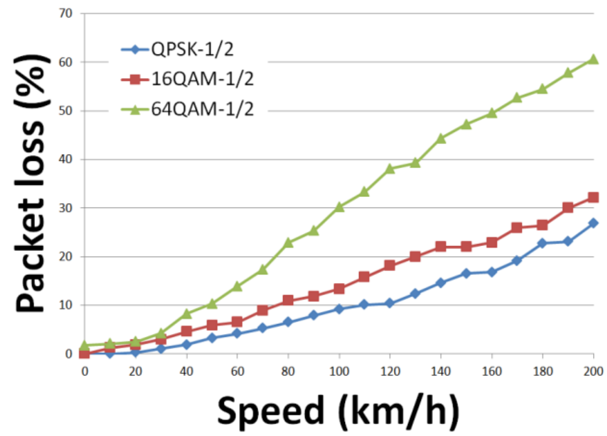

Figure 6. Packet loss versus mobile speed in an LOS environment with τ =1ns and d = 1000m.

Figure 7 and Figure 8 show the R-factor versus mobile speed and packet loss versus mobile speed respectively in an LOS environment when the delay is 10ns. The horizontal distance is about 90m. The results show the same trend as for τ =1ns.

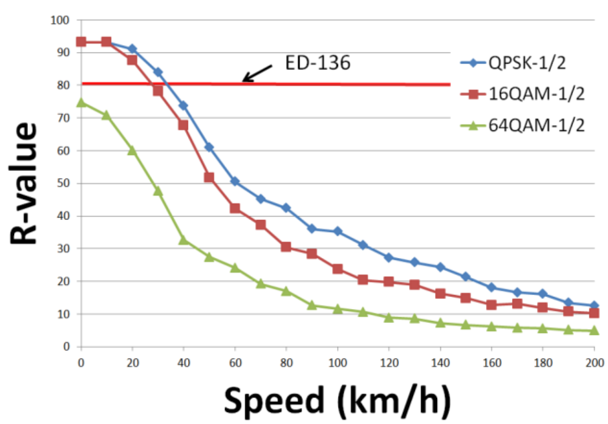

Figure 7. R-factor versus mobile speed in an LOS environment with τ =10ns and d = 90m.

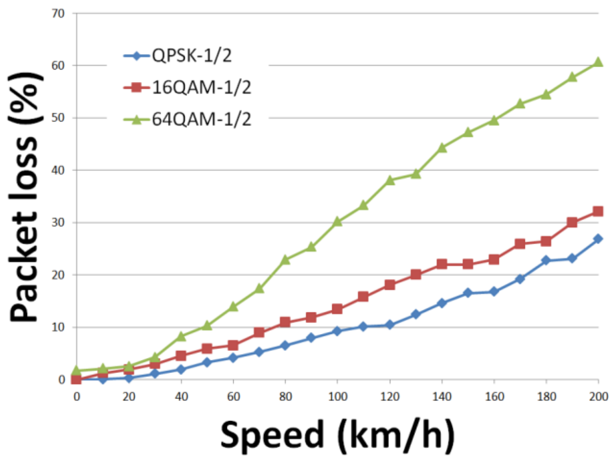

Figure 8. Packet loss versus mobile speed in an LOS environment with τ =10ns and d = 90m.

Figure 9 shows the mobile speed versus delay time when the R-factor is over 80 for short delays. The horizontal axis is the delay and the unit is ns. The vertical axis is the mobile speed and the unit is km/h. Figure 9 shows that VoIP for ATC is possible if the mobile speed is under 50km/h and the delay time is under 20ns.

Finally, figure 10 shows the delay time versus packet loss in an LOS environment. The horizontal axis is the delay time and the unit is ns. The vertical axis is packet loss. In the figure, the 0 km/h, 10 km/h, 20 km/h and 30 km/h cases are shown.

From figure 10, we found that the packet loss rate decreases as the delay time increases for short delays. Also, figure 10 shows that the packet loss is 0% when the delay time is 20ns, i.e., the horizontal distance is about 40m.

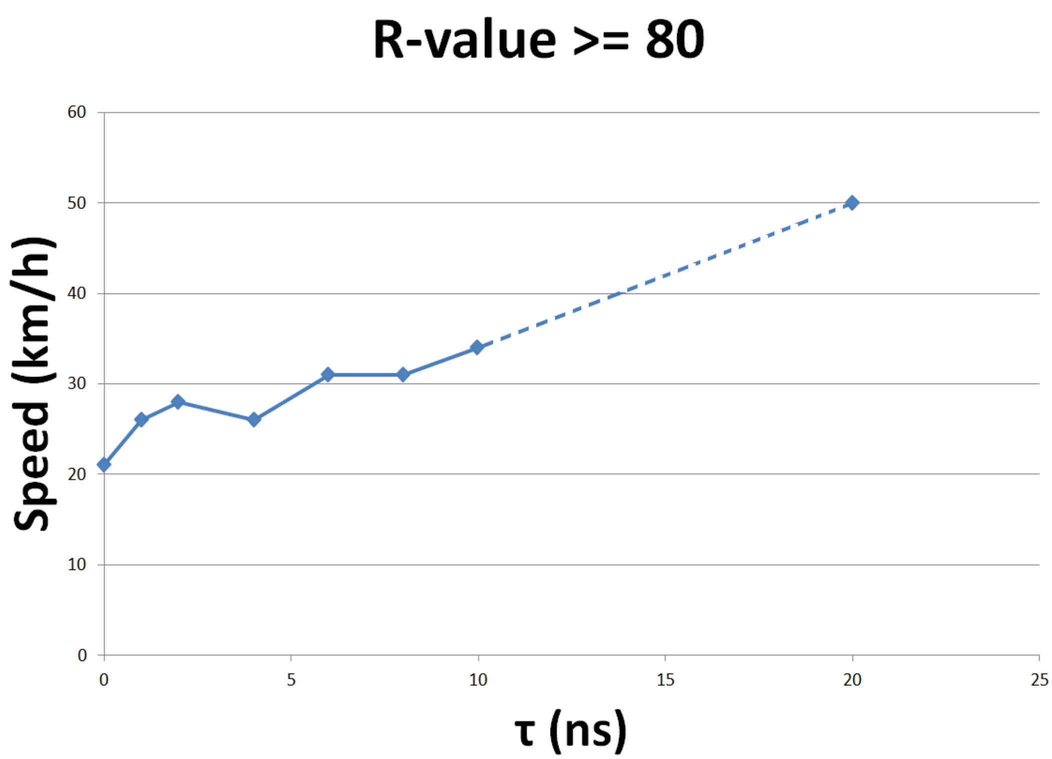

Figure 9. Mobile speed versus delay when the R-factor is over 80 for short delays.

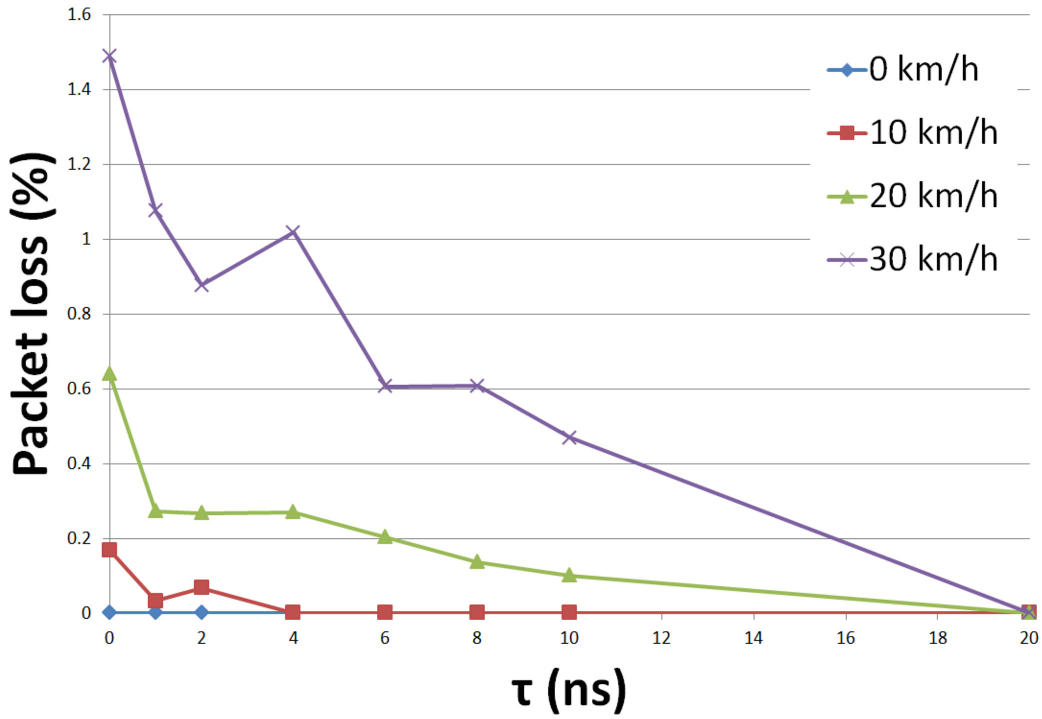

Figure 10. Packet loss versus delay for short delays.

Conclusion

In this paper, we studied the performance of VoIP over WiMAX systems. We assumed a two-path model for airport surface communications and evaluated the performance of VoIP by using a multipath fading simulator. We evaluated the R-factor when the mobile speed and delay time are changed. We used an R-factor value of 80 which is defined in ED-136 as the threshold whereVoIP can be used for air traffic control. If the mobile speed is under 50km/h, the R-factor is over 80. On the other hand, in takeoff and landing scenarios when the mobile speed is over 300 km/h, it is difficult to maintain the quality of VoIP. Therefore, it is a challenging problem to improve voice quality during high-speed movement.

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