EVM and BER Evaluation of C band New Airport Surface Communication Systems

Kazuyuki Morioka*†, Naoki Kanada*, Shunichi Futatsumori*, Junichi Honda*,
Akiko Kohmura*, Naruto Yonemoto* Yasuto Sumiya* and David Asano†
*Electronic Navigation Research Institute 7-42-23, Jindaiji-higashi, Chofu, Tokyo, 182-0012, Japan.
Email: {morioka, kanada, futatsumori, j-honda, kohmura, yonemoto, sumiya}@enri.go.jp
†Shinshu University, 4-17-1, Wakasato, Nagano, 380-8553, Japan.
Email: {s09t255,david}@shinshu-u.ac.jp

***Abstract*—AeroMACS (Aeronautical Mobile Airport Communication System) is proposed for future airport surface communication system in the C band. In this paper, we report the results of an experiment at Sendai airport in Japan to evaluate the AeroMACS. Our base station covers the approximately 3km×1km rectangular airport surface with a transmitter power of 1W. A BER (Bit Error Rate) of less than 10^{-6} is required at the physical layer in order to realize reliable data communication systems. However, measurement of the BER is difficult especially in field experiments because another data link is required to inform the receiver of the correct transmitted symbols. Therefore, we calculate the relationship between EVM (Error Vector Magnitude) and BER by computer simulation, then translate the EVM which is measured in the experiment into BER. The results show that 64QAM-3/4 can be used with a BER of less than 10^{-6} in 64.3% of the LOS (Line Of Sights) area and 64QAM cannot be used in almost all NLOS (Non Line Of Sights) areas at Sendai airport.**

I. Introduction

Recently, air traffic is increasing especially at large airports. In order to realize more efficient and safer air traffic management systems, it is important to cooperate with people and facilities at an airport by using data communication systems. However, the capacity of current aeronautical data communication systems is very low. Therefore, higher capacity and safer data communication systems are required.

AeroMACS (Aeronautical Mobile Airport Communication System) is being developed in order to provide a new broadband wireless ground communication system for airports. With AeroMACS it is possible to realize Mbps order transmission rates, so applications which require high data rates, such as surveillance videos and meteorological images, can be realized. This contributes to the establishment of more efficient air traffic management systems. AeroMACS is based on existing WiMAX (Worldwide Interoperability for Microwave Access) systems to construct a new system at a low development cost. Now, the 5091MHz - 5150MHz frequency band is allocated for AeroMACS. In the U.S., an AeroMACS prototype system was established at Cleveland Hopkins International Airport (CLE) and the results of large scale experiments are reported in [1][2]. Also, in Japan, some results are reported on the evaluation of AeroMACS systems[3][4][5].

In this paper, results of experiments at Sendai airport using existing WiMAX measurement tools are reported. A BER (Bit Error Rate) of less than 10^{-6} is required at the physical layer in order to realize reliable data communication systems. However, measurement of BER is difficult especially in field experiments because another data link is required to inform the receiver of the correct transmitted symbols. First, we calculate the relationship between EVM (Error Vector Magnitude) and BER by computer simulation, then we get EVM values which achieve a BER of 10^{-6} for each MCS (Modulation and Coding Scheme). Finally, we measure the EVM using field experiments and evaluate the value in terms of possible MCS.

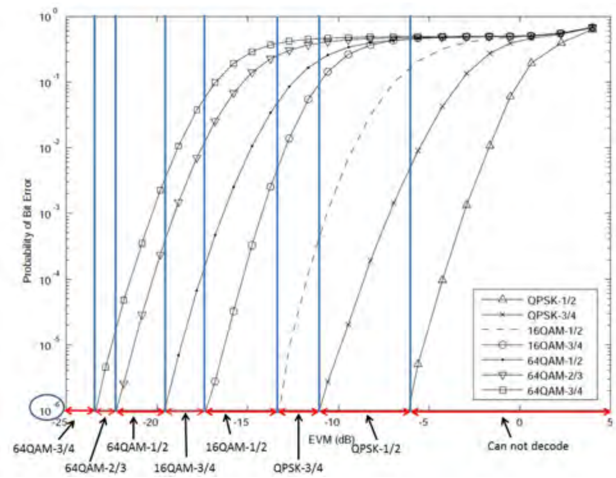

Fig. 1. EVM v.s Bit Error Rate by computer simulation

II. Relationship between EVM and BER

The EVM indicates how far received signals are from the desired position. The EVM can be described as follows.

$$EVM = \frac{1}{L}\sum_{l=1}^{L}\left(\frac{1}{N}\sum_{k=1}^{N}\sqrt{\frac{|r(l,k)-a(l,k)|^2}{|a(l,k)|^2}}\right). \tag{1}$$

Here, L is the number of OFDM symbols and N is the number of sub-carriers. Also, $r(l,k)$ and $a(l,k)$ are the received signal and desired signal at the k-th sub-carrier and l-th symbols, respectively.

A BER (Bit Error Rate) of less than 10^{-6} is required at the physical layer in order to realize reliable data communication systems. However, direct measurement of the BER is difficult

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TABLE I. MCS AND EVM WITH A BER OF LESS THAN 10^{-6}

MCS	EVM (dB)
QPSK-1/2	-6.32
QPSK-3/4	-11.32
16QAM-1/2	-13.16
16QAM-3/4	-17.24
64QAM-1/2	-19.47
64QAM-2/3	-22.24
64QAM-3/4	-23.29

TABLE II. IEEE802.16E OFDMA

Center Frequency	5120MHz
FFT Size	512
Channel Bandwidth	5MHz
Subcarrier Frequency Spacing	10.94kHz
CP Ratio	1/8
Frame Length	5ms

especially in field experiments because another data link is required to inform the receiver of the correct transmitted symbols. Therefore, we calculate the relationship between EVM and BER by computer simulation in this section. Figure 1 shows the relationship between EVM and BER calculated by computer simulation. We use the IEEE802.16 model of Mathworks Matlab & Simulink for computer simulations. Also, we assume an AWGN (Additive White Gaussian Noise) channel in the simulations. '1/2' in the figure means that convolutional coding with a coding rate of 1/2 is used. Table I shows possible MCS (Modulation and Coding Scheme) and EVM values to achieve a BER of 10^{-6} as calculated from Figure 1.

III. MEASUREMENT SETUP

We established an AeroMACS evaluation system at Sendai airport, which is a middle size airport in Japan, to evaluate the received AeroMACS signals based on the IEEE802.16e (WiMAX) standard. The center frequency used was 5120MHz, and the system bandwidth was 5MHz. We use OFDM frames which have an FFT size of 512 and a subcarrier spacing of 10.94kHz. The duplex scheme is TDD (Time Division Duplex), and a guard time is inserted between the DL (Down Link) data and the UL (Up Link) data. We received the IEEE802.16e signals using a moving measurement vehicle. A summary of IEEE802.16e is described in Table II.

Figure 2 shows the transmission system. We use SMU200A, a Rohde&Schwarz Vector Signal Generator for transmission. The amplitude and power modules are cascaded and the signal is transmitted with a power of 1 W. We use a Moxa ANT-WSB5-ANF-12 transmitter antenna and set it on a 30 m high tower as shown in Figure 2. Figure 3 shows a block diagram of the transmission system. An OFDM frame is transmitted from the SMU200A by sending a command from the control PC. The signal goes through the amplifier module, then 1 W signals are generated. Finally, the signal goes through a LPF (Low Pass Filter) to reduce out of band signals. Then the signal is transmitted from antenna. In order to protect the circuit, several circulators are inserted in the transmission system.

Figure 4 shows the receiver system. A 5GHz receiver antenna is set on the ceiling of the measurement vehicle, and is connected to measurement tools in the vehicle. We use Sensor

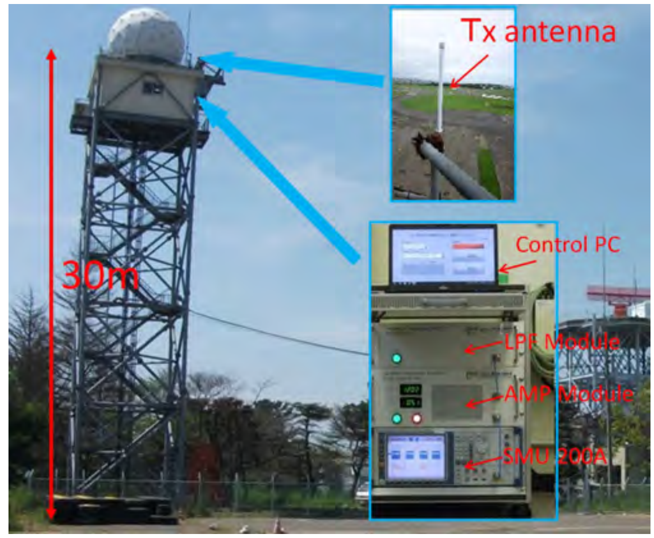

Fig. 2. Tx System

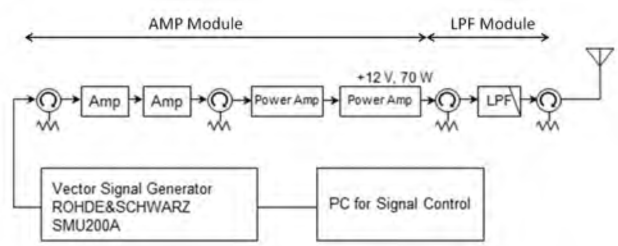

Fig. 3. Block Diagram of Tx System

Systems S65-5366-4M as the 5GHz receiver antenna which is designed for aeronautical MLS (Microwave Landing System). We use N9020A, an Agilent Technologies Spectrum analyzer, for the receiver system. Signals from the receiver antenna go through a pre-amplifier module and are analyzed by the N9020A. Received signals and performance indicators such as RSSI (Received Signal Strength Indicator), CINR (Carrier to Interference and Noise Ratio), EVM (Error Vector Magnitude) are saved in the control PC. At the same time, GPS data from a GPS antenna is recorded by the control PC. We use a Nikon-Trimble GeoExplorer 6000 as the GPS receiver.

Figure 5 shows a block diagram of the receiver system. For the pre-amplifier module, two LNAs (Low Noise Amplifiers) with a total gain of 46dB and a band-limiting filter are used in order to amplify weak signals. Also, circulators are inserted to protect the receiver circuit.

Using the measurement systems above, we made measurements on the ground of the airport using the measurement vehicle travelling at a speed of 30km/h. Here, we could not travel faster than 30km/h because of the security regulations of Sendai airport.

IV. EXPERIMENT RESULTS

In this section, we provide the results of experiments to evaluate AeroMACS signals at Sendai airport. We categorize

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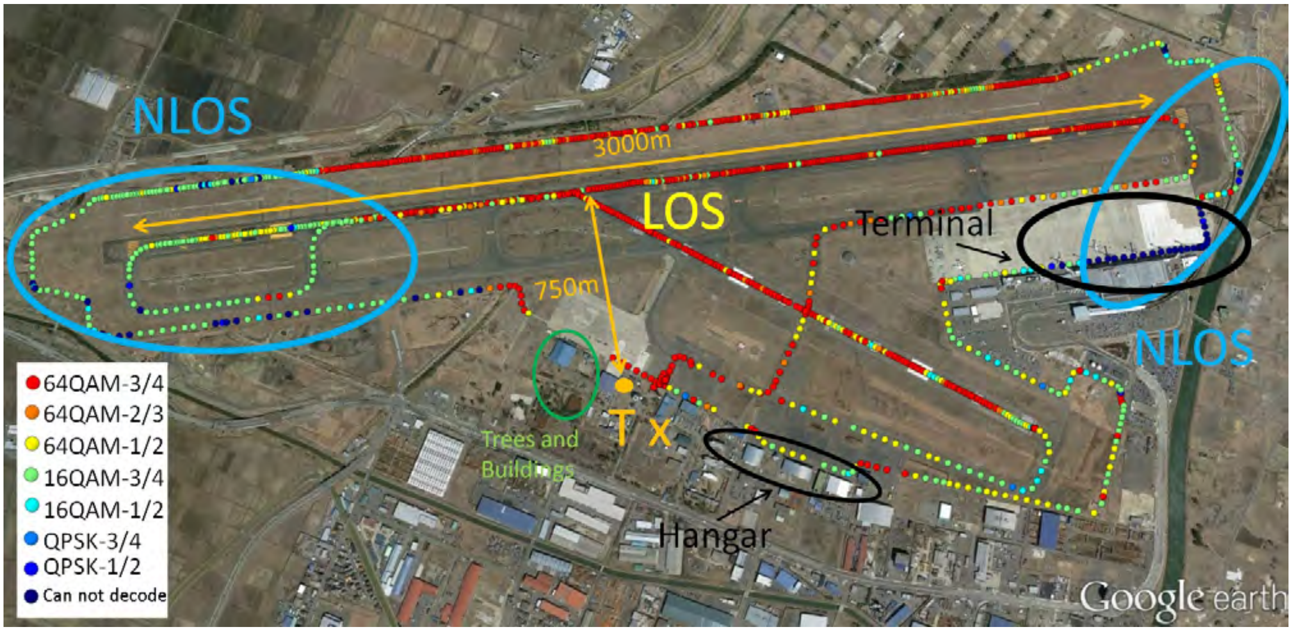

Fig. 6. MCS map where BER is less than 10^{-6}

Fig. 4. Rx System

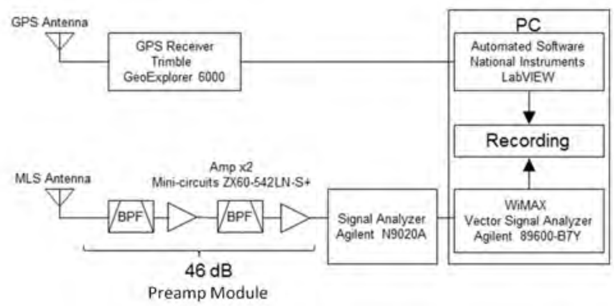

Fig. 5. Block Diagram of Rx System

the measurement area into LOS (Line-of-Sight) areas and NLOS (Non-Line-of-Sight) areas. The strength of the received signals in the NLOS areas is very weak because these areas are behind buildings and trees as shown in figure 6. We analyzed data we obtained at 954 points in LOS areas and at 351 points in NLOS areas. Figure 6 shows a MCS map where the BER is less than 10^{-6}. Figure 6 shows that we cannot decode signals especially around the terminal area. This area is not only NLOS but also surrounded by buildings, airplanes, and boarding bridges, so the effect of multi-path fading is large. Also, we can see that 64QAM cannot be used in front of the hanger and where the signal strength is weak in the LOS areas.

Figure 7 shows the EVM distribution in the LOS area. The horizontal axis is EVM and the vertical axis is the number of data points. Also, the MCS (Modulation and Coding Scheme) with a BER less than 10^{-6} are shown in the figure. The average EVM is -24.55dB and the standard deviation is 4.07.

Figure 8 shows the distribution of EVM in NLOS areas. The average EVM is -15.01dB and the standard deviation is 7.65 in NLOS areas. From figure 8, we can see values of EVM greater than -5 in NLOS areas, which means the signals cannot be decoded because the signal level is very low.

Table III summarizes the measurement results. The results show that 64QAM-3/4 with a BER of less than 10^{-6} can be used in the 64.3% of LOS areas when the base station is placed 750m away from the center of the main runway and the transmitted power is 1W. On the other hand, 16QAM-4/3 can be used in 52.7% of NLOS areas. Also, we cannot decode signals in 0.1% of LOS areas and 19.7% of NLOS areas. Finally, we found that we could cover almost all areas of a middle scale airport surface using only one base station with 1W transmitted power, if we position it appropriately.

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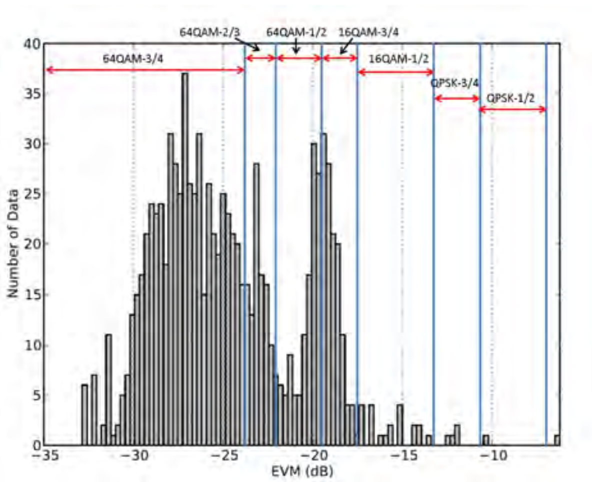

Fig. 7. Error Vector Magnitude in LOS areas

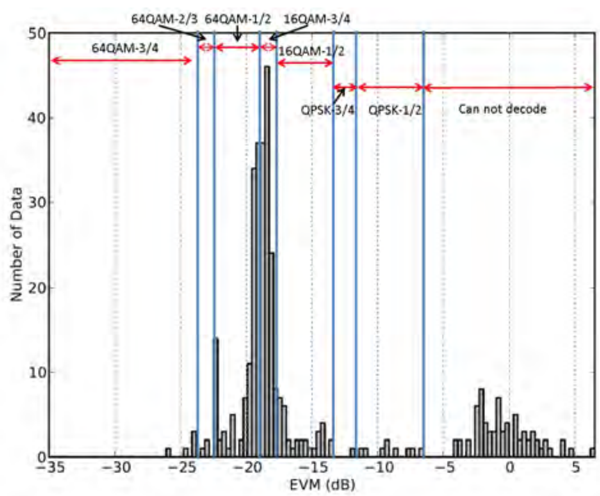

Fig. 8. Error Vector Magnitude in NLOS areas

V. Conclusions

In this paper, we reported the results of an experiment at Sendai airport in Japan to evaluate the AeroMACS. We used existing WiMAX measurement tools in the C band for the experiment. Our base station covers the approximately 3km×1km rectangular airport surface with a transmitter power of 1W. The EVMs of received signals were analyzed. The results showed that 64QAM-3/4 with a BER of less than 10^{-6} could be used in 64.3% of LOS (Line Of Sights) areas and 16QAM-4/3 could be used in 52.7% of NLOS (Non Line Of Sights) areas at Sendai airport. In future research, we will consider the optimal position and transmitter power of the base station to cover the entire airport. Also, we will study how to improve the performance by using MIMO (Multiple Input Multiple Output) techniques.

Acknowledgment

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TABLE III. EVM and Possible Modulation and Coding Schemes

	LOS	NLOS
Average EVM [dB]	-24.55	-15.01
Standard Deviation of EVM	4.07	7.65
Percentage of 64QAM-3/4 (%)	64.3	1.7
Percentage of 64QAM-2/3 (%)	7.3	4.0
Percentage of 64QAM-1/2 (%)	13.8	12.0
Percentage of 16QAM-3/4 (%)	12.1	52.7
Percentage of 16QAM-1/2 (%)	1.9	7.1
Percentage of QPSK-3/4 (%)	0.4	0.3
Percentage of QPSK-1/2 (%)	0.1	2.6
Cannot decode (%)	0.1	19.7

References

[1] J. M. Budinger and E. Hall, “Aeronautical Mobile Airport Communications System (AeroMACS),”. National Aeronautics and Space Administration, Glenn Research Center, 2011.

[2] R. J. Kerczewski, R. D. Apaza, and R. P. Dimond, “AeroMACS System Characterization and Demonstrations,” in *Aerospace Conference, 2013 IEEE*. IEEE, 2013, pp. 1–10.

[3] N. Kanada, Y. Sumiya, N. Yonemoto, S. Futatsumori, and E. Isozaki, “Evaluation of Antenna Configuration for Aeronautical WiMAX at 5.1 GHz,” in *Wireless and Microwave Technology Conference (WAMICON), 2012 IEEE 13th Annual*. IEEE, 2012, pp. 1–4.

[4] ——, “MIMO Effect Evaluation for Aeronautical WiMAX in Airport at 5.1 GHz,” in *Integrated Communications, Navigation and Surveillance Conference (ICNS), 2012*. IEEE, 2012, pp. G3–1.

[5] N. Kanada, Y. Sumiya, N. Yonemoto, A. Kohmura, S. Futatsumori, J. Honda, and K. Okada, “Signal Evaluation on Airport Surface in 5.1 GHz Band,” in *Integrated Communications, Navigation and Surveillance Conference (ICNS), 2013*. IEEE, 2013, pp. 1–8.

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