Performance evaluation by MIMO transmission in small rocket

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1 Introduction

Development of rockets without people which is represented by Hayabusa etc. has attracted much attention. In the rockets which are frequently re-used, *health monitoring system* which supervises inside rockets is one of key important issue for improvement in operability and/or urgent return judgment [1]. Although communication between the sensors inside the rocket are connected by wires in the current system, in order to accurately check the state in the rocket, the weight of the rocket becomes very heavy due to a large number of sensors. In this paper, we solve this problem by employing a wireless communication in the small rocket. Moreover, MIMO (Multiple Input Multiple Output) transmission [2] is incorporated in the wireless system inside the small rocket for further improvement on bit rate. However, since the propagation characteristics are not clarified inside the small rockets, in this paper we investigate the characteristics of 2×2 MIMO transmission by using a ray-tracing simulation and measurement using the small rocket which is actually used in *health monitoring system*.

2 Channel capacity evaluation by ray-tracing simulation

Figure 1 shows the model used in ray-tracing simulation and measurement. Array antenna at the transmitter and receiver is placed inside the rocket. In this paper 2×2 MIMO transmission is evaluated as the antenna arrangement, x-axis and y-axis arrangements, where the array is located at x-axis and y-axis, are evaluated. The sleeve antenna whose directional is omni-directional is used and the frequency was set to 2.4 GHz. The channel capacity is evaluated when changing the element spacing [2]. The element spacing was changed from 0.25 to $3\lambda_0$ in x-axis arrangement, 0.25 to $10\lambda_0$ in y-axis arrangement, respectively. The height of the antenna was set to 0.6 m from bottom of the rocket. A metal is assumed as the material of the rocket, and the number of reflection for the ray-tracing simulation was three.

Figure 2 shows the channel capacity versus the element spacing. As can be seen in this figure, when the element spacing is less than $1\lambda_0$, the channel capacity is not

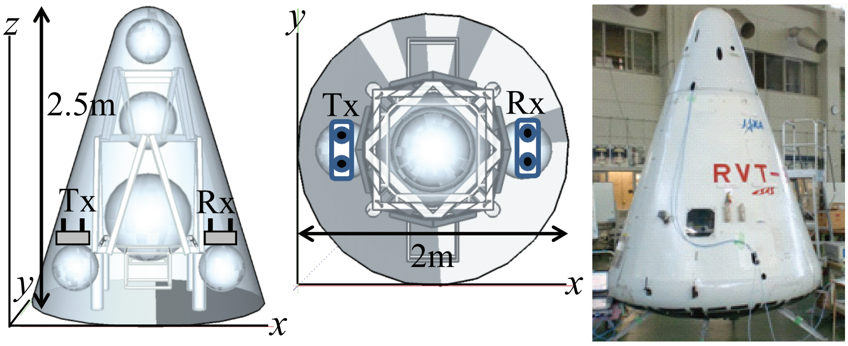

Figure 1: Rocket model in the calculation and measurement.

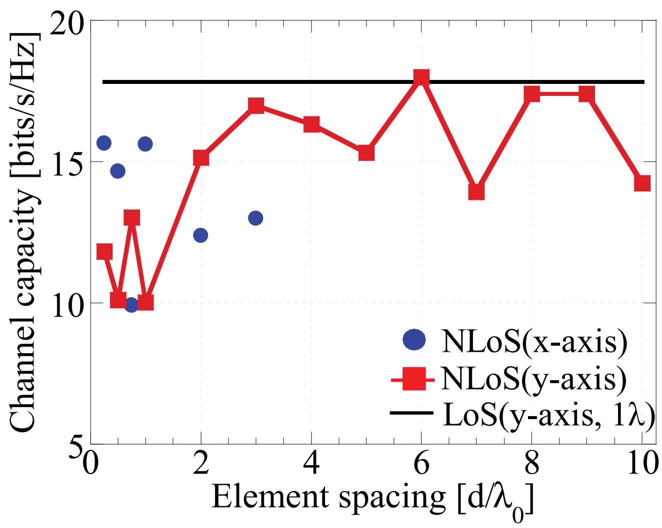

Figure 2: Channel capacity versus element spacing.

improved regardless of antenna arrangement. On the other hand, when the element spacing is $3\lambda_0$ on y-axis arrangement, it is shown that the same channel capacity can be obtained compared to that without any obstacle inside the rocket (LoS, y-axis, $1\lambda_0$ in Figure 2).

Figures 3 and 4 denote the eigenvalue distribution in the x-axis and y-axis arrangements. As shown in Figures 3 and 4, the high channel capacity is obtained when 1^{st} eigenvalue, i.e. the SNR is large. Moreover, the channel capacity is high when the ratio between 1^{st} and 2^{nd} eigenvalues is small with the same SNR condition. For example, when $d = 1\lambda_0$, channel capacity becomes 15.6, 10.0 bits/s/Hz at x-axis and y-axis arrangements, respectively. As shown in Figures 3 and 4, $10\log_{10}(\lambda_1/\lambda_2)$ is 3.3 and 16.9 dB in x-axis and y-axis arrangements, respectively. Hence, it is shown that the ratio of 1^{st} and 2^{nd} eigenvalues greatly affects on the channel capacity.

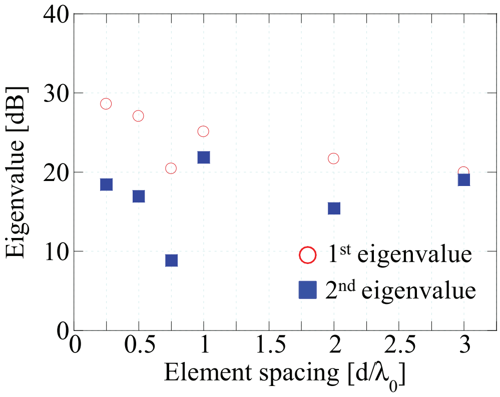

Figure 3: Eigenvalue versus element spacing (x-axis arrangement).

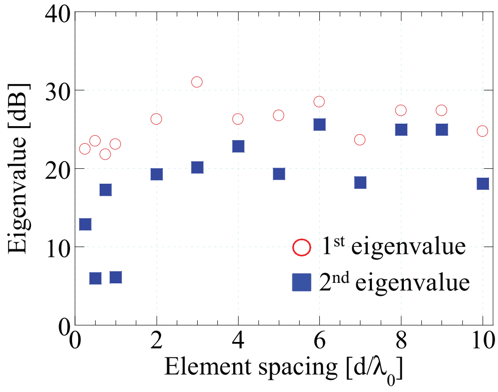

Figure 4: Eigenvalue versus element spacing (y-axis arrangement).

3 Evaluation of bit rate inside an actual small rocket

In order to confirm the possibility of MIMO transmission in an actual rocket, we conducted the measurement inside the rocket in Figure 1 by using MIMO-OFDM signals. The experimental conditions are shown below. The measurement frequency is 2.4 GHz band, the signal bandwidth is 10 MHz. Other parameters can be referred in [3]. In this measurement, the internal structure is a configuration with frames and the central sphere. The antenna arrangement is x-axis with 1 λ_0.

Figure 5 and 6 show the received power at x-axis and y-axis arrangements. The received power for each sub-carrier is plotted in these figure. As can be seen in these figures, since the received power is greatly changed by the subcarrier, it is confirmed that there is a multipath rich environment inside the rocket. Moreover, since the received powers are different among all the channel responses, it is clarified that the spatial correlation is very low.

Figure 7 shows the bit rate versus transmission power. The results that one and two data streams are transmitted are plotted in this figure. As this figure shows, it is confirmed that the bit rate can be improved in proportion to the transmission power. For example, a very high bit rate with 64 Mbits/s with the transmit power of –20 dBm is achieved. Looking at the transmission power from –20 to –10 dBm, although the bit rate is saturated with one stream data transmission, the bit rate can be improved according to the transmission power when two data streams is transmitted. Hence, it is confirmed that 2×2 MIMO transmission can be realized inside the rocket.

4 Conclusion

In this paper, we evaluated the possibility of MIMO transmission inside the small rocket. When the element spacing is $3\lambda_0$ on y-axis arrangement, it is shown that the same channel capacity can be obtained compared to that without any obstacle inside

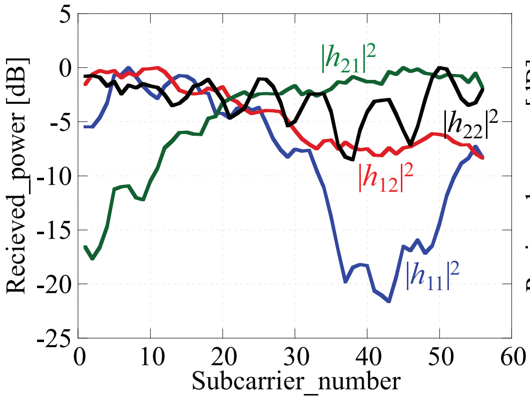

Figure 5: Received power at x-axis arrangement.

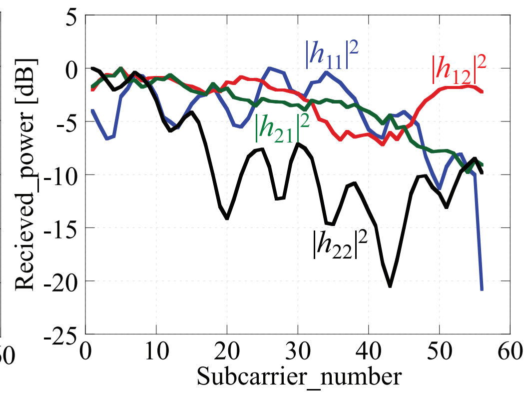

Figure 6: Received power at y-axis arrangement.

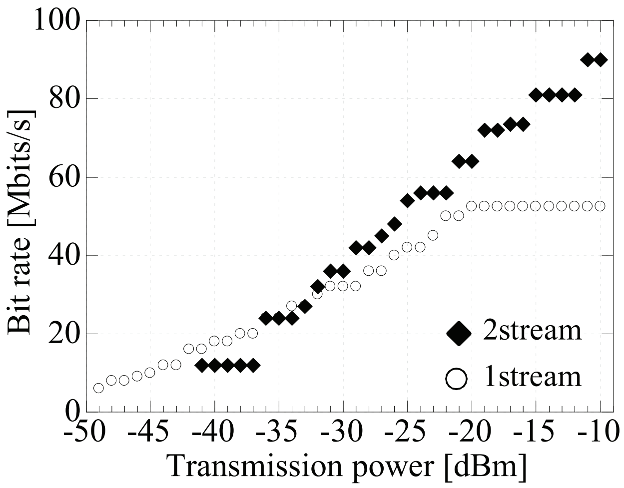

Figure 7: Bit rate versus the transmit power.

the rocket. It is shown that the channel capacity is high when the ratio between 1^{st} and 2^{nd} eigenvalues is small with the same SNR condition. A very high bit rate with 64 Mbits/s with the transmit power of –20 dBm is achieved when considering an actual small rocket. Looking at the transmission power from –20 to –10 dBm, although the bit rate is saturated with one stream data transmission, the bit rate can be improved according to the transmission power when two data streams is transmitted. Hence, it is confirmed that 2×2 MIMO transmission can be realized inside the rocket.

References

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