Configuration of Adaptive Array Mounted on Vehicle

Takuya MATSUDA[1], Mitoshi FUJIMOTO [1], Toshikazu HORI [1],
Takanobu TABATA [2], Satoshi HORI [2]
[1] Graduate School of Engineering, University of Fukui
3-9-1, Bunkyo, Fukui, 910-8507 Japan, t-matsuda@wireless.fuis.u-fukui.ac.jp
[2] Kojima Press Industry Co., Ltd.,
3-30, Shimoichiba, Toyota, Aichi, 471-8588 Japan

Abstract

In this paper, effect of array configuration, directivity of element, control method, and losses in feeding cables on SINR characteristics of the adaptive array on a vehicle is examined. As the result, in most cases, it was clarified that X-type feeding network was the most excellent in feeding network, and MMSE had the most excellent performance in control methods.

Keywords: SINR Vehicle Feeding Network

1. Introduction

Land mobile propagation channels become a multipath propagation due to reflection, diffraction, and scattering caused by objects around the mobile stations. Therefore, the reception performance deteriorates when mobile terminals are moving in such a multipath propagation environment [1]. Under this environment, the reception technology using two or more antennas is utilized to improve the reception quality. However effect of various parameters such as the element space, the directivity of each antenna element, and the control scheme are not necessarily verified enough. Moreover, it is necessary to consider the loss in the cables of feeding network when two or more antennas are used [2].

In this paper, the SINR characteristics of adaptive array antennas on vehicle is examined. Here, the array configuration, the directivity of antennas element, and the control method are treated as parameters, the SINR characteristics of the array antenna is examined under considering losses of feeding cables. First of all, the effect of the loss in the cables on SINR characteristics is examined where the control method is treated as one of the parameters. Next, the effect of the directivity of each antenna element on the SINR characteristics is examined.

2. Analysis Condition

2.1 Directivity and Array Configuration

Directivity $G(\phi)$ of each antenna element follows Eq.(1). The parameter α in Eq.(1) is variable that show sharpness of directivity. As shown in Fig.1, the beamwidth of the directivity broadens when α is enlarged, and narrowed when it is reduced. α=0 correspond to omnidirection.

$$G(\phi) = \cos \alpha\phi \tag{1}$$

Figure 2(a) shows the arrangement of the antenna elements on the vehicle, and (b) shows model of the arrangement in the following simulations. Antenna elements are located on four corners of the roof of the vehicle. Four antenna elements are located on the *x*-*y* plane in simulation model, and *d* is the distance between the antenna elements. In addition, as shown in Fig.3, the elements are mounted toward for all sides of the vehicle.

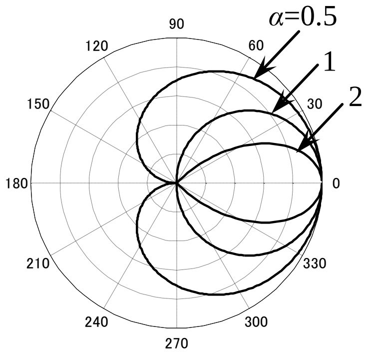
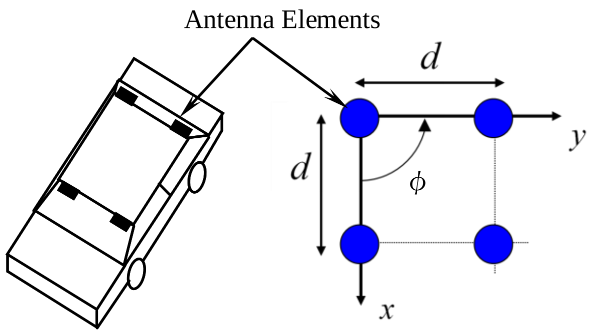


Figure 1: Element Pattern



(a): Arrangement of Elements (b): Simulation Model

Figure 2: Modelling of Array Configuration

2.2 Control Method [3][4]

Here, the following three control methods are evaluated.

(1) Switching Diversity: The antenna element which has maximum reception power is selected.
(2) MRC(Maximum Ratio Combining): The beam is steered to the direction of the desired wave.
(3) MMSE(minimum mean-square-error): The gain in the direction of the interference is suppressed.

2.3 Feeding Network

Here, three kinds of shape of feeding network shown in Fig.4 are examined that connect each antenna element. Figure4 (a) is a case that a combiner is located at the center of four antenna elements, and it is called X-type. Figure4 (b) is a case that a combiner is located at the position of one element in four elements, and it is called Arrow-type. Figure4 (c) is a case that a combiner is located at the intermediate of two elements, and it is called K-type.

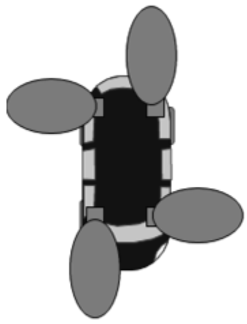
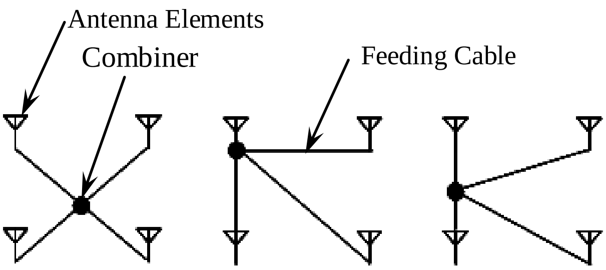


Figure 3: Directivity of Element on Vehicle



(a) X-type (b) Arrow-type (c) K-type

Figure 4: Feeding Network

3. Effect of Control Method and Feeding Network on SINR Median

Effect of the loss of the cables on the reception quality is analyzed. Here, the SINR median is used as an evaluation factor. The SINR median is the median value of the SINR obtained in case of all that the direction of desired wave and the interference are changed independently.

Figure 5 shows the result. A horizontal axis is a loss caused by the cables per 1m, and the vertical axis is the SINR median. Here, the parameter of the element pattern is α=1, and the interval of the antenna element is 2.5λ(λ:wavelength).

It is found From Fig.5 that MMSE shows a high SINR value compared with Switching Diversity and MRC. Moreover, it is found that X-type network has high tolerance for the cable loss in each control method.

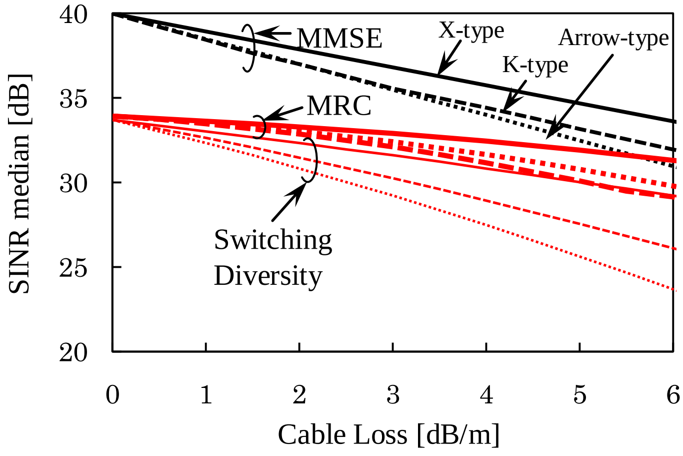


Figure 5: Effect of Control Method and Cable Loss

4. Effect of the Directivity of Antenna Element on SINR

4.1 Tolerance Value of Cable Loss

Here, the tolerance value of cable loss is used as an evaluation factor. This value shows the allowed cable loss for a specific SINR median. If this value is large, the high SINR median can be easily obtained.

4.2 Effect of Directional Pattern of Element on SINR

Figure 6 shows the effect of directional pattern on SINR median. The horizontal axis is α that is parameter of directional pattern, and the vertical axis is the tolerance value of cable loss that can keep 30dB of SINR median. Here, the intervals d of the antenna elements are fixed at 2.5 λ .

In Fig.6, when α is smaller than 1.2, namely, the beamwidth of the element pattern is wide, MMSE indicates a high value compared with Switching Diversity or MRC. When α is increased, the difference of each control methods becomes small. Therefore, it can be said that the difference of superiority or inferiority between the control methods becomes small, when the directional patterns of elements are sharp.

The tolerance value of cable loss is increased most at α=0 in case of MMSE, and it is most increased at α=1.2 in case of MRC and Switching Diversity. Moreover, the tolerance value of cable loss is 0 when α is less than 0.8 in case of MRC and Switching Diversity. This means that 30dB of SINR median cannot be achieved by MRC or Switching Diversity.

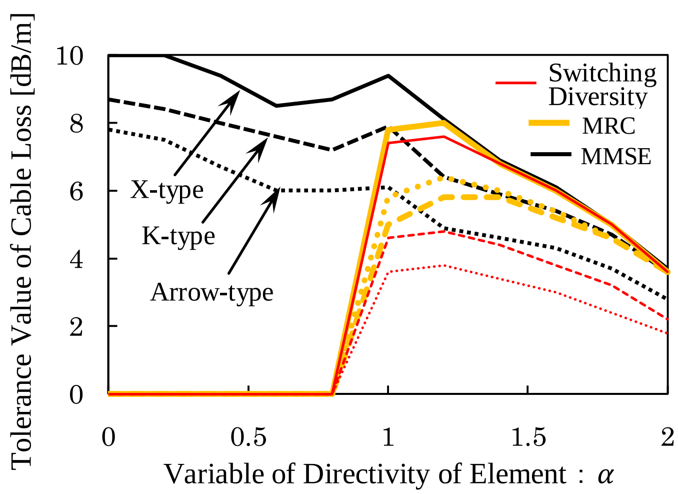


Figure 6: Effect of Directivity of Element

5. Effect of Amplitude of Desired Wave

Figure 7 shows effect of amplitude of desired wave on SINR. Here, the intervals of the antenna elements are fixed at 2.5 λ. The horizontal axis is amplitude of desired wave, and the vertical axis is the tolerance value of cable loss that can keep 30dB of SINR median. The amplitude of the interference is assumed to be 0dB, and the thermal noise is assumed to be -40dB compared with the interference.

It is found From Fig.7 that MMSE has the most excellent performance when desired wave is less than 7dB. In addition, when amplitude of desired wave is enlarged, the difference between the control methods is hardly seen. Moreover, X-type feeding network is the best when the amplitude of desired wave is small. On the other hand, K-type feeding network is the best when the amplitude of desired wave is large.

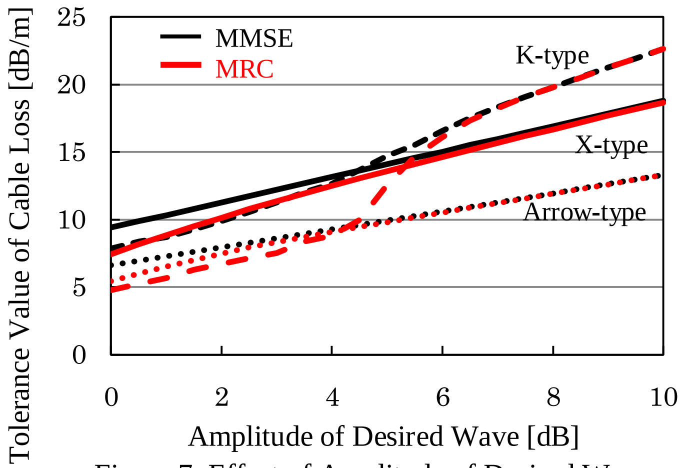


Figure 7: Effect of Amplitude of Desired Wave

6. Conclusion

Effect of element pattern, a control method, amplitude of signal, and the loss in the cable on the SINR characteristics of the mobile communications was examined.

In most cases, it was clarified that X-type feeding network was the most excellent in feeding network, and MMSE had the most excellent performance in control methods. When the parameter α of the directional pattern was paid attention, it was found the tolerance value of cable loss had the most excellent value at α=1.2 in case of MRC and Switching Diversity. When the amplitude of desired wave was enlarged, it was understood that the tolerance value of cable loss had the most excellent value at K-type feeding network.

References

[1]F. Terada, M. Fujimoto, T. Hori, "Effect of element patterns on diversity reception," Proc. ISAP2009, Bangkok, Thailand, Oct. 2009.

[2]T. Matsuda, M. Fujimoto, T. Hori, T. Tabata, S. Hori, "SINR characteristics of adaptive antennas for vehicle," IEICE Tech. Rep., AP2010-116, Nov.2010 (in Japanese).

[3]N. Kikuma, "Adaptive signal processing with array antenna," Science and technology publishing company, Inc., 1998 (in Japanese).

[4]M. Fujimoto, T. Hori, "Effect of antenna element characteristics on antenna pattern control of array antenna," IEICE Tech. Rep., AP2005-96, Oct.2005 (in Japanese).