Bandwidth Characteristics and Downsizing Limitations of Card Antennas

#Tomomi FUJIOKA, Toshikazu HORI and Mitoshi FUJIMOTO
Graduate School of Engineering, University of Fukui,
3-9-1, Bunkyo, Fukui, 910-8507 Japan
fujioka@wireless.fuis.fukui-u.ac.jp

1. Introduction

Services of wireless broadband communication such as UWB communication system and WiMAX have been attracted much attention in recent years. In such the high-speed communication system broadband antennas are required. Various antennas are examined for the broadband antennas. In particular, printed antennas with simple constitution have been studied in recent years [1][2]. In addition, limitation of frequency bandwidth characteristics of the broadband antenna have been clarified [3].

In this paper, card antennas with simple structure are focused and the bandwidth characteristics to clarify the limitation of downsizing are examined. Effects of an aspect ratio of antenna shape, a location of feeding point and characteristic impedance on the bandwidth characteristics are discussed. Furthermore, limitation of downsizing is examined in the view point of lower frequency of the frequency band.

2. Structure of Card Antennas and Analysis Model

The analysis model of the card antenna is shown in Fig.1[4]. Here, a is height, b is width of the antenna. The ratio a/b is called as "aspect ratio" in this paper. The card antenna is composed of many metal pieces (conductor). We assume that the card antenna has symmetric structure in consideration of parallel feeding. The distance from the feeding point to the edge of the antenna is d.

The antenna characteristics are calculated by using a moment method (EEM-MOM).

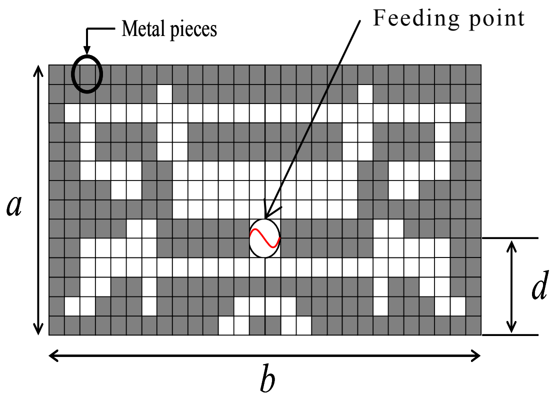

Figure 1: Analysis Model

3. Design and Evaluation of Card Antennas

As mentioned in Sec.2, the card antenna has a lot of parameters. To find an optimum structure which has wideband characteristics, a genetic algorithm are utilized to determine the parameters. Here, the information of metal pieces are expressed by 1 or 0, and the information are treated as gene in the genetic algorithm [5][6][7].

The objective function for optimization is expressed as Eq.(1).

$$O(x) = \alpha \cdot R.B(x) + (1-\alpha) \cdot k \cdot f_{\min} / f_0 , \qquad (1)$$

$$f_0 = \frac{C}{2(a+b)} .$$

Here, R.B.(x) is the relative bandwidth, $f_{\min} / f_0$ is the normalized lowest frequency of the band within 3.0 for VSWR (Voltage Standing Wave Ratio). C is the speed of light. The effect of downsizing for the antenna can be evaluated by $f_{\min} / f_0$ because the size of the antenna is determined by the lowest frequency. The coefficient α in Eq.(1) is a weight coefficient which control the priority between the relative bandwidth R.B.(x) and the normalized lowest frequency $f_{\min} / f_0$. When the weight coefficient is large, the relative bandwidth is treated as an important performance. The coefficient k is a normalizing factor.

4. Effects of Aspect Ratio on Bandwidth Characteristics

The influence of aspect ratio a/b on the characteristic of the bandwidth of the antenna is examined. The distance of feeding point from the edge d is 0.6λ, characteristic impedance of feeding line is 150 Ω . Figure 2 shows the relation between the normalized lowest frequency and relative bandwidth. The horizontal axis indicates the normalized lowest frequency $f_{\min} / f_0$, the vertical axis is the relative bandwidth. The parameter in Fig.2 indicates the aspect ratio a/b. The area in left side of Fig.2 means that the size of the antenna is small, and the area in upper side means that the antenna has wideband characteristics.

As shown in Fig.2, when the aspect ratio a/b = 2.3, the relative bandwidth becomes narrow. On the other hand, except the case of aspect ratio a/b = 2.3, the relative bandwidth is almost the same when the normalized lowest frequency is small. However when the aspect ratio a/b = 0.5, the relative bandwidth is wider than the other case. In Fig.2, the maximum relative bandwidth is 170% and minimum normalized lowest frequency is 0.46.

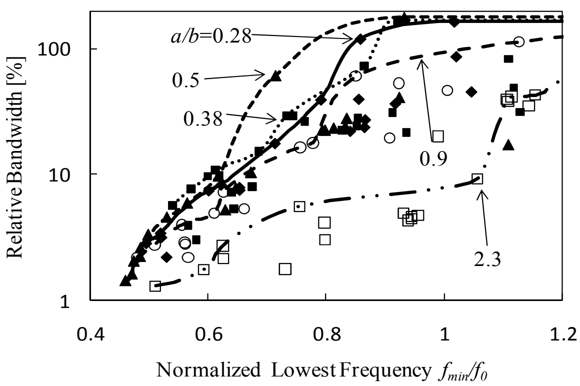

Figure 2: Relation between normalized lowest frequency and relative bandwidth

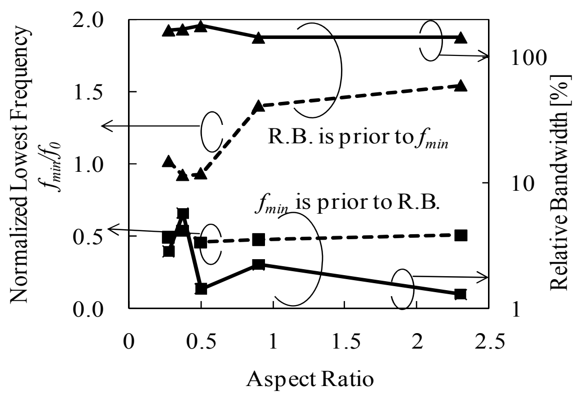

Figure 3: Relation between aspect ratio and bandwidth characteristic

Figure 3 shows the effects of the aspect ratio a/b on the normalized lowest frequency and relative bandwidth. The upper two lines are the case when α=1.0, namely, the relative bandwidth (R.B) is prior to the normalized lowest frequency ($f_{\min} / f_0$). In opposite, the lower side two lines are the case when α=0, namely, the normalized lowest frequency has priority to the bandwidth characteristics. We can see from Fig.3 that the normalized lowest frequency does not depend on the aspect ratio when the lowest frequency has priority. On the other hand, when the relative bandwidth has priority, small aspect ratio is preferable to obtain both features of small size and wideband characteristics.

5. Effects of Feeding Position on Bandwidth Characteristics

The effects of a feeding point on bandwidth are investigated. Here, the aspect ratio a/b is fixed as 0.5. Figure 4 shows the relationship between normalized lowest frequency and the relative bandwidth. The parameter in Fig.4 is the distance from the feeding point to the edge of the antenna. The characteristic impedance of the feeding line is 150Ω.

It is shown in Fig.4 that the relative bandwidth doesn't so depend on the location of the feeding point. However, when d=0.083λ, it is suitable to obtain the broadband characteristics. In addition, when the d=0, it is suitable for downsizing.

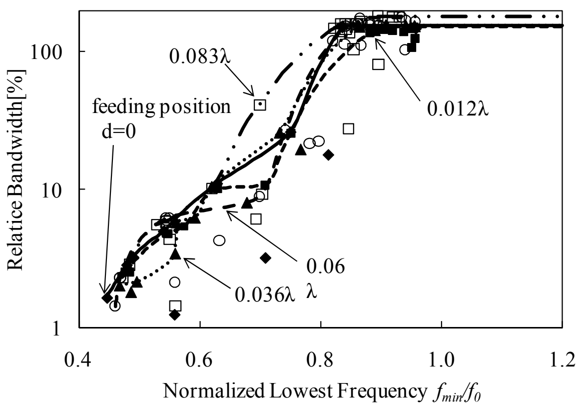

Figure 4: Relation between normalized lowest frequency and relative bandwidth

Figure 5 shows the variation of the normalized lowest frequency and the relative bandwidth when a feeding position is changed. The upper two lines are the case that the relative bandwidth is prior to the normalized lowest frequency. In opposite, two lines at the lower side are the case that the normalized lowest frequency has priority to the bandwidth characteristics.

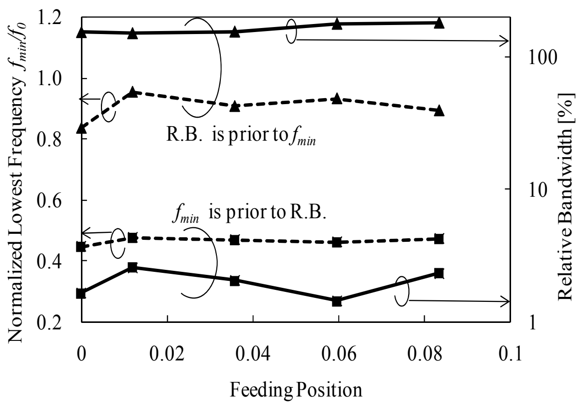

Figure 5: Relation between feeding position and bandwidth characteristics

We can see in Fig.5 that the lowest frequency is smallest when d = 0 and the bandwidth prior to the size even though the relative bandwidth does not depend on the feeding position. When the relative bandwidth is regarded as important, 177% of relative bandwidth can be achieved, then, the distance d is 0.083λ and the normalized lowest frequency is 0.9 f_0.

6. Effects of Characteristic Impedance on Bandwidth Characteristics

The influence of the characteristic impedance on bandwidth characteristics is examined. Here, the feeding position is fixed at d=0.083λ, the aspect ratio is 0.5. The relationship between the normalized lowest frequency and the relative bandwidth is shown in Fig.6. The parameter in Fig.6 is the characteristic impedance of the feeding line. It is shown in Fig.6 that when the required relative bandwidth is 100% or more, the characteristic impedance should be set to 300Ω. Because, when the characteristic impedance is 300Ω, the normalized lowest frequency is the smallest. However, when the required relative bandwidth is 100% or less, the antenna can be downsized by set the characteristic impedance at 150Ω. Because, the normalized lowest frequency is small and the relative bandwidth is large, when the characteristic impedance is 150Ω.

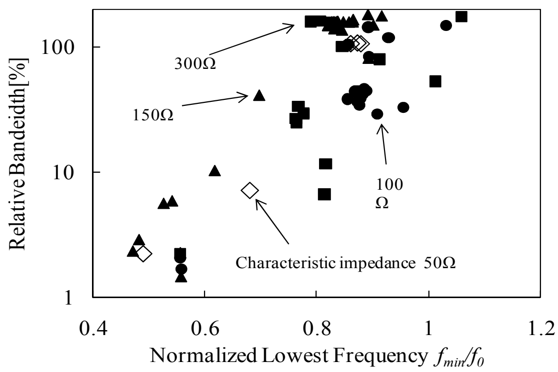

Figure 6: Relation between normalized lowest frequency and relative bandwidth

Moreover, it is found that wideband characteristics can not achieved when the characteristic impedance is 50Ω.

7. Conclusion

Bandwidth characteristics and downsizing limitation was clarified for a card antenna. To find an optimum structure which has wideband characteristics, the genetic algorithm was utilized.

First, the effect of aspect ratio *a/b* on bandwidth characteristics are examined. It was clarified that small aspect ratio was preferable to obtain both features of small size and wideband characteristics when the relative bandwidth has priority.

Next, the effects of a feeding point on bandwidth are investigated. The lowest frequency was the smallest when the bandwidth prior to the size and d = 0. When the feeding point was located at centre of the antenna and the relative bandwidth was regarded as important, 177% of relative bandwidth was achieved.

Finally, the influence of the characteristic impedance on bandwidth characteristics was examined. It was shown that if required relative bandwidth was more than 100%, the characteristic impedance should be set at 300Ω. However, when the required relative bandwidth was 100% or less, the antenna could be downsized by set the characteristic impedance at 150Ω.

References

[1] T. Hori: ”Broadband/ Multiband Printed Antennas,” IEEE Trans., Commun, vol.E88-B, no.5, pp.1809-1817, May 2005.

[2] T. Hori : ”Bandwidth Limitations and Downsizing Techniques of Ultra-Wideband Antennas,” iWAT2008, Chiba, Japan, IT21, Mar. 2008.

[3] T. Fujioka and T. Hori, M. Fujimoto : ”Bandwidth Characteristics of Card Type Small Antenna,” 2007 IEICE Society Conf., B-1-46, Sept. 2007. (in Japanese)

[4] M. Shimada and T. Hori, M. Fujimoto, T. Maruyama:” Design of Yagi-Uda Antennas Using Genetic Algorithm,” Proc. ISAP2004, Sendai, Japan, 2C4-6, Aug. 2004.

[5] T. Maruyama and F. Kira, K. Cho : ” Design of Multi-band Small Planar Antenna Using Novel Chromosome Generation Method for Genetic Algorithm” Proc. ISAP2004, Sendai, Japan, 3B3-2, Aug. 2004.

[6] H. Shimizu and Y. Sasaki : ”The Planar Antenna Optimization with 2-dimentional Genetic Algorithm,” 2006 IEICE General Conference, B-1-42, Mar. 2006.(in Japanese)