Bandwidth Characteristic of Low-Profile Top-Loaded Monopole Antenna with Folded Rim

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1. Introduction

A radio-on-fiber system has been developed for enabling cellular mobile communication in radio-blind areas, such as highway tunnels and underground shopping malls [1], [2]. A distributed antenna system consisting of coaxial cables and couplers has been specifically designed for use in the aforementioned radio-blind areas [2], [3]. In an in-building antenna distribution system, the antenna is installed on the ceiling, and the hence a low-profile antenna is preferred. A top-loaded monopole antenna (TLMA) has been developed for use as a low-profile antenna. The TLMA that arranged with shorting cylinder or pins has a feature of low profile and the vertical polarization antenna by exciting TM_{01} mode [4], [5]. For bandwidth enhancement, triangular or trapezoidal plates are used as the radiating elements for the TLMA [6]. Based on them, TLMA was designed, and clarified impedance-matching techniques for and the bandwidth characteristics of a TLMA with oblique shorting pins, and the effects of the rim at the edge of the finite ground plane are also clarified [7]. However, the broadband characteristics cannot be achieved when the antenna height is less than 0.04λ.

This paper presents the bandwidth characteristics as variable size of finite ground plane. And, the bandwidth characteristics, when the folded rim is arranged, are also investigated. As a result, this shape is similar to cylindrical cavity resonator. Finally, the simulation results of the TLMA with folded rim are verified through measured impedance characteristics and radiation patterns.

2. Bandwidth Characteristics of Low-Profiled TLMA

The TLMA is designed to operate at 2 GHz. Fig. 1 shows the configuration and structural parameters of TLMA with rim. r is the radius of the finite ground plane, and it is initialized 0.55λ. h and h_{rim} are the height of antenna and rim, respectively. However, h_{rim} is assumed not to exceed h, because higher value of them will be determined as the height of antenna. L_{ring} is the width of upper part of the folded rim.

Fig. 2 shows the bandwidth and gain characteristics of TLMA without rim [7]. The maximum bandwidth is observed at h = 0.1λ. The variation of gain is less than 1 dB when h is varied. Fig. 3 shows the bandwidth characteristics for variable h_{rim}. When h_{rim} = 0.12λ and 0.06λ, the maximum bandwidth is shown at h = 0.1λ, and the bandwidth from 2% to 5% increases due to the effects of rim. However, when the antenna height is less than 0.04λ, there is no effect of rim.

Fig. 4 shows the bandwidth characteristics of variable r. The bandwidths with r = 0.55λ is about 15% broader than that with h = 0.67λ. In addition, when h = 0.45λ, the bandwidths change sharply in the range of h = 0.06λ ~ 0.1λ. The finite ground plane size of the TLMA with rim affects its bandwidth characteristics, and the bandwidths become broader when the finite ground plane size decreases.

3. Top-Loaded Monopole Antenna with Folded Rim

To achieve the broadband characteristics at $h \leq 0.04\lambda$, the folded rim is arranged at the edge of TLMA, and its effect is examined. Fig. 5 shows the bandwidth characteristic for variable L_{ring}. The antenna height and the radius of the ground plane are fixed with $h = 0.04\lambda$ and $r = 0.55\lambda$. The maximum value of the bandwidth is 23% at $L_{ring} = 0.18\lambda$. Fig. 7 shows the bandwidth characteristic for variable r. The maximum value of the bandwidth is observed at $r = 0.5\lambda$. When $r \leq 0.5\lambda$ and $r > 0.5\lambda$, $L_{ring} = 0.16\lambda$ and 0.18λ, respectively.

4. Experiments Performed on TLMA with Folded Rim

In order to verify the simulation result, the TLMA is fabricated with the optimum parameters ($h = 0.04\lambda$, $r = 0.5\lambda$, $L_{ring} = 0.16\lambda$) for the maximum bandwidth. Fig. 7 shows the photograph of the fabricated TLMA with the folded rim. The input impedance and VSWR characteristics are shown in Fig. 8. The simulated and measured agree well. The measured bandwidth is 35% for VSWR ≤ 2. This value of the bandwidth is the same as that with $h = 0.07\lambda$ [7].

Fig. 9 shows the radiation patterns of the TLMA. The measured frequencies are as follows: 1.8, 2.0, and 2.2 GHz. The maximum gain is observed in the range of 30°–60° and 300°–330°. The peak gains are 2.9 dBi at 1.8 GHz, 3.7 dBi at 2.0 GHz, and 3.2 dBi at 2.2 GHz. The omnidirectional patterns are observed at horizontal plane.

5. Conclusion

This paper presents the input impedance, bandwidth, and gain characteristics of a TLMA with the folded rim. When the rim is installed on TLMA, the size of finite ground plane affects the bandwidth characteristics. When the folded rim is arranged, the broadband characteristics can be achieved at $h \leq 0.04\lambda$. Finally, the TLMA was fabricated and the measured bandwidth was 35%, and the peak gain was 3.7 dBi.

References

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[7] W. Kim, N. Michishita, and Y. Yamada, "Low-Profile Top-Loaded Monopole Antenna with Oblique Shorting Pins," 39th European Microwave Conference, Rome, Italy, Oct. 2009.

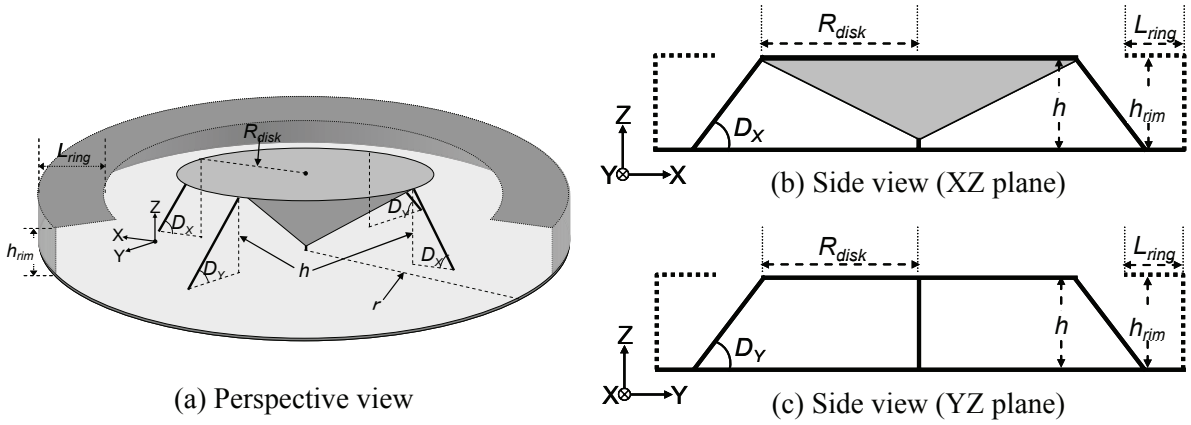


Fig. 1: Configuration of TLMA with rim.

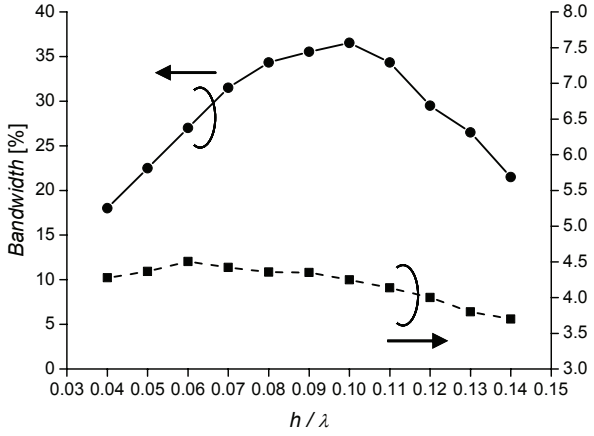


Fig. 2: Bandwidth and gain without rim.

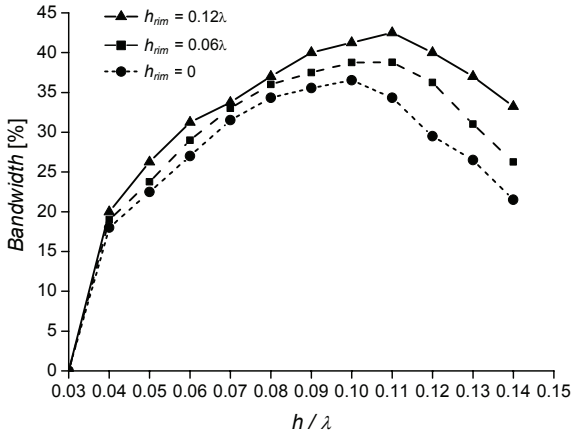


Fig. 3: Bandwidth for variable h_{rim}.

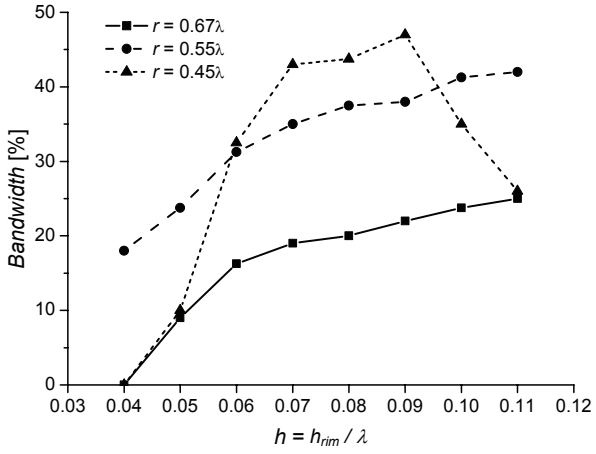


Fig. 4: Bandwidth for variable r.

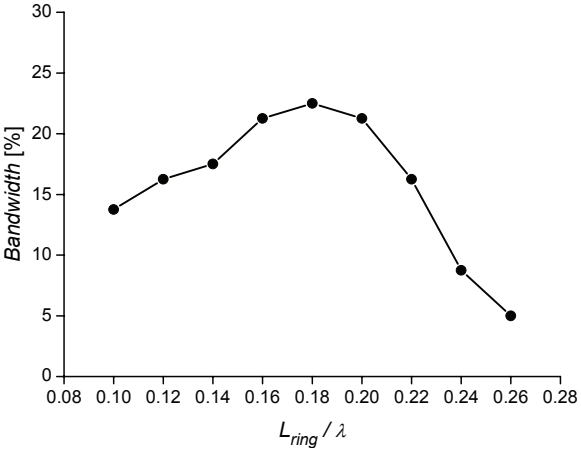


Fig. 5: Bandwidth for variable L_{ring}(h = 0.04λ).

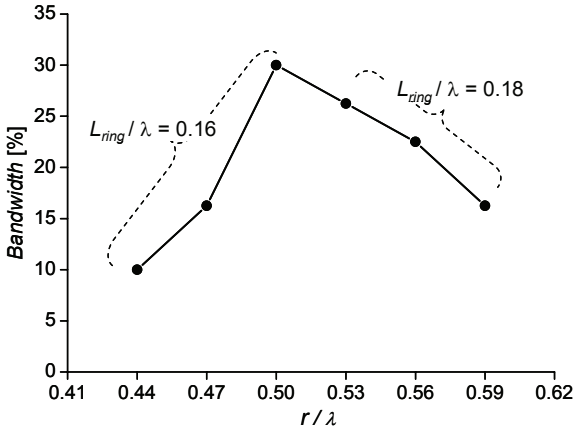


Fig. 6: Bandwidth for variable *r* with folded rim.

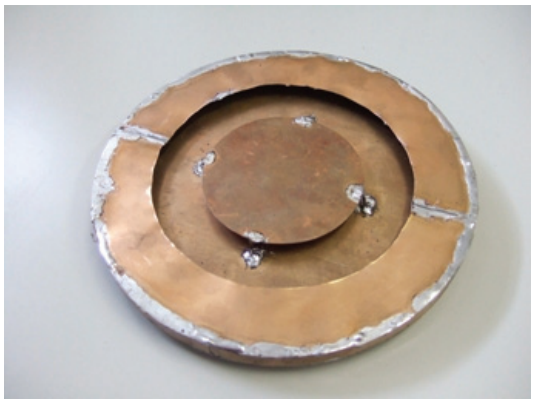
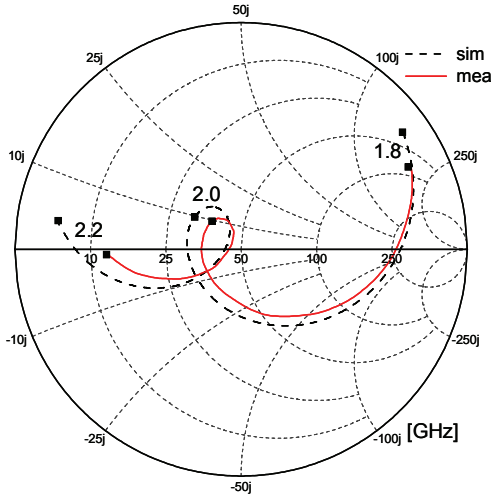
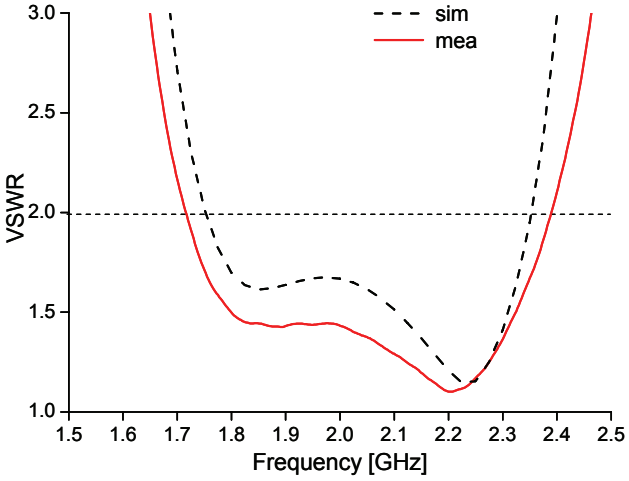


Fig. 7: Photograph of fabricated TLMA

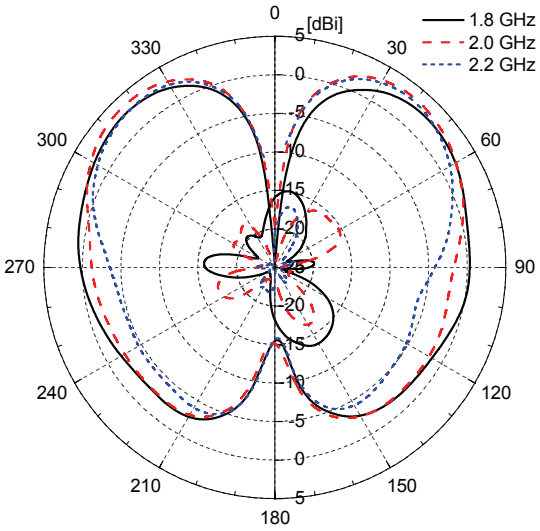


(a) Input impedance.

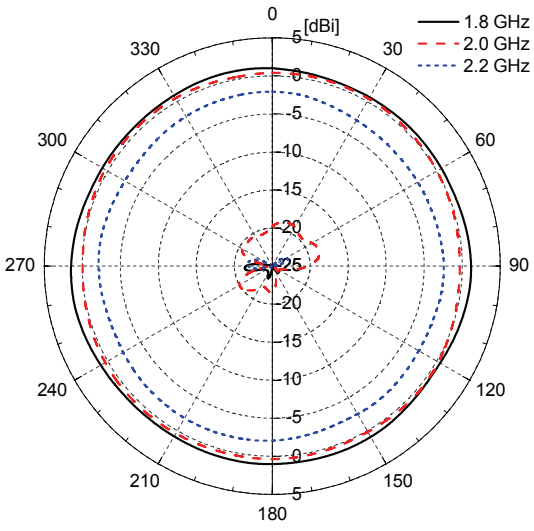


(b) VSWR.

Fig. 8: Impedance characteristics of TLMA



(a) ZX plane.



(b) XY plane.

Fig. 9: Measured radiation patterns for TLMA