Low-loss Design of Dielectric-tube-supported Metal Rod Transmission Line at THz Frequencies

Y. Shinhama*(1), F. Kuroki (1), and K. Miyamoto(2)
(1) National Institute of Technology, Kure College, Japan e-mail: s.yuki20010506@gmail.com; kuroki@kure.kosen-ac.jp
(2) Miyamoto Device Development Co., Ltd., Japan; e-mail: miyamoto@miyamotokiki.com

THz frequencies have attracted much attention for construction of novel applications such as chemical testing and medical sensors. As a candidate for the transmission media in the THz bands, the dielectric-tube-supported metal rod transmission line (DTM-line) [1, 2] has been proposed. In this paper, the transmission loss was optimized. The details are shown as follows.
As shown in Fig. 1, the DTM-line consists of a metal rod inserted into a dielectric tube being sandwiched by a below cutoff parallel metal plate housing, whose spacing was set at 75 µm so as to be the cutoff frequency of 2 THz. The material of the dielectric tube was assumed to be the PTFE with a relative dielectric constant of 2.1 and a dielectric loss tangent of 0.001 because of its low loss nature beyond millimeter wave frequencies. The metal rod was assumed to be the copper with a conductivity of $5.8 \times 10^7 \mathrm{S/m}$. The transmission loss at a frequency of 1 THz was calculated as a function of diameters to be from 10 µm to 60 µm in 10 µm steps. The result is shown in Fig. 2. It is obvious that minimum transmission loss was obtained by choosing the diameter of the metal rod to be 30 µm because the conductor loss became high for large diameter while the dielectric loss became high for small one. The calculated cutoff frequency of the first higher mode is also depicted in this figure. It became low as the diameter became large because the effective width between the metal plate and surface of the metal rod became wide. From this fact, the diameter was selected to be 30 µm.
For comparison, the transmission losses of typical transmission media such as the coplanar waveguide and the NRD-guide [3] are summarized in Tab. 1 together with that of the DTM line. The transmission loss of the DTM-line is much lower than that of the coplanar waveguide as well as that of the NRD guide because the effective conductivity of the metal rod may be no so poor than that of the etched metal surface of the printed transmission line.
Figure 3 shows the calculated transmission characteristics of the DTM line. It is obvious that this guide has a low loss nature as well as a low dispersion in the frequency ranges from DC to 1.5 THz.

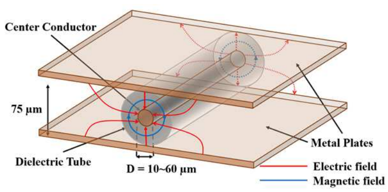

Figure 1. Structure of DTM-line.

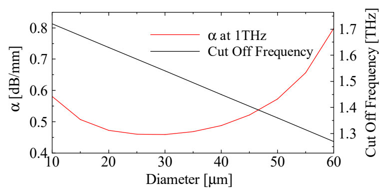

Figure 2. Calculated transmission loss and cutoff frequency of the first higher mode versus diameter of metal rod.

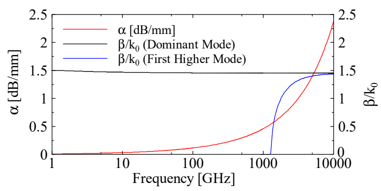

Figure 3. Calculated normalized phase constant and transmission loss versus frequency.

Table 1. Comparison with typical transmission media.

	Coplanar Waveguide	NRD-Guide	DTM-Line
Frequency	1.0 THz	1.5 THz	1.0 THz
Transmission Loss	8.0 dB/mm	1.0 dB/mm	0.6 dB/mm

References

[1] F. Kuroki, K. Miyamoto, and S. Kitabayashi, "Modified Low-loss Tri-plate Transmission Line for Millimeter-Wave Integrated Circuits (In Japanese)", IEICE Trans., Vol. J99-C, No.12, pp.566-571 (2016)
[2] Y. Shinhama, M. Sakamoto and F. Kuroki, "Transmission Characteristics of Dielectric-tube-supported Metal Rod Transmission Line THz Wave Band (In Japanese)", IEICE Electronics Society Conf. 2021, C-2-45 (Sept. 2021)
[3] F. Kuroki, H. Ohta, T. Yoneyama, "Transmission Characteristics of NRD Guide as a Transmission Medium in THz Frequency Band", Proc. of 30th Infrared and Millimeter Wave Conf. (2005)