The Influence of the Dielectric Thickness upon Transmission / Radiation Characteristics of MSL with a bend

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Abstract: According to the advance of the home appliance including mobile communications and personal computers, the interference caused by the unwanted electromagnetic waves emitted from the circuits in its equipment becomes severe problem, especially in the case of high data transmission speed. In order to develop the effective way for this problem, first of all, it seems necessary to make clear the characteristics of the transmission line with a bend. First in this paper, we discussed about the influence of the dielectric thickness upon the characteristics of the MSL having three types of bend's shape, such as a 90-degree bend, a 45-degree bend and a circularly curved bend. Next, from the practical viewpoints, we recommended a 90-degree bend with a small corner-cut which has comparatively better, not the best performance characteristics especially in the case of large dielectric thickness, in spite of its simple construction.

Key words: MSL, Bend, Dielectric Thickness, Radiation, Transmission, Suppression, FDTD

1. Introduction

According to the advance of the home appliance including mobile communications and personal computers, the interference caused by the unwanted electromagnetic waves emitted from the circuits in its equipment becomes severe problem, especially in the case of high data transmission speed.   This is attracting attention as an EMC problem and it has recently become an important problem for designing the electric systems to control the undesirable electromagnetic waves from various electric devices. In order to develop the effective way for this problem, it seems necessary to make clear the characteristics of the transmission line with a bend.   Several previous studies such as [1], [2], [3], have dealt with the subject of Microstrip line (MSL) having discontinuities or bends. Particularly, concerning to a single MSL with a bend, for example, the suppression of unwanted electromagnetic waves by altering the bend's shape has been reported [4]. Furthermore, some papers [5], [6] have also discussed the mechanism of the radiation from a bend. And they pointed out that by a resonance-like phenomenon in the line-width direction after the bend, unwanted

electromagnetic waves have been emitted at a specific frequency band when the frequency of the incident wave is almost a resonant frequency at the line-width. In most of these studies, however, the dielectric thickness is relatively small compared to the line-width (W), that is, around 0.3-0.5W. In the case of actual circuit boards, the typical and well-used size of line-width (W) and the dielectric thickness are 100 μm and 200 μm, that is, the dielectric thickness is corresponding to 2W. From the practical viewpoints, it is significant to clarify the influence of the dielectric thickness. So far as we know, the quantitative studies as to this point have not been performed so much. First in this paper, we discuss about the influence of the dielectric thickness upon the characteristics of MSL having three types of bend's shape, such as a 90-degree bend, a 45-degree bend and a circularly curved bend. Next, from the practical viewpoints, we recommended a 90-degree bend with a small corner-cut which has comparatively better, not the best performance characteristics especially in the case of large dielectric thickness, in spite of its simple construction.

2. Transmission / Radiation Characteristics of MSL with a Bend

2.1 Analytical Model

Figure 1 shows the structure of the bent MSL used in the analysis. The shapes of the bends in MSLs were set to a 90-degree bend (a), a 45-degree corner bend (b), a circularly curved bend (c) and a 90-degree bend with a small corner-cut (d) for which we will discuss later. For line parameters, W is a line-width [mm] (W = 2 mm, in this paper), h is a dielectric thickness [mm], ε_r is a relative dielectric constant (ε_r = 4.68, in this paper), s is a 45-degree bend cut-length [mm] and r is a curved bend's radius [mm]. A FDTD analysis is used, assuming that the line is a perfect conductor and lose of both line and dielectric materials are zero. For FDTD analysis, 0.5 mm-cubic cells are used and PML is prepared on each boundary between analytical domains for non-reflective termination. The observation point is fully away from the power feed point, given by F. A is the observation point before the bend and B is the observation point after the bend.
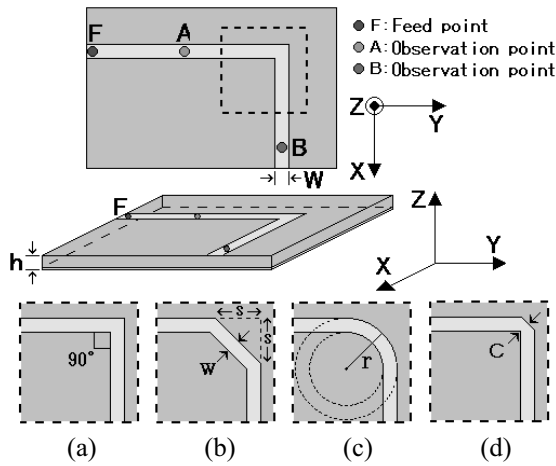
Fig. 1 Analytical Model of bent MSLs

2.2 Transmission, Reflection and Radiation

The incident and reflected components at point A, and the transmitted component at point B are separated in time domain and the spectrum for these data at each observation point are obtained by DFT, individually. The reflected power E_r and the transmitted power E_{tB} are normalized by the incident power E_i, and then, we can obtain Reflection and Transmission components defined as follows,

$$\left. \begin{array}{l} \text{Transmission} = \left| \dfrac{E_{tB}}{E_i} \right| \\[2ex] \text{Reflection} = \left| \dfrac{E_r}{E_i} \right| \end{array} \right\} \quad (1)$$

Additionally, assuming the loss of both MSL and dielectric materials is zero, Radiation component which is defined the radiated power from MSL normalized by the incident power E_i, is satisfied the following equation [1],

$$\left. \begin{array}{l} \text{Radiation} = 1 - \text{Transmission} - \text{Reflection} \\[2ex] = 1 - \left| \dfrac{E_{tB}}{Ei} \right|^2 - \left| \dfrac{E_r}{E_i} \right|^2 \end{array} \right\} \quad (2)$$

2.3 Analytical results

Here, we determine the optimum values of the bend parameters, such as the cut-length of a 45-degree bend s [mm] and the radius of a circularly curved bend r [mm], by using the calculated data with the smallest dielectric thickness h = 0.5W in this analysis.

According to our studies, best transmission / radiation characteristics can be obtained when a corner cut-length s is 4w in a 45-degree bend and a curvature radius r is 10w in a curved bend. In the case of a circularly curved bend, however, considering the fact that an actual PCB well uses multiple MSLs rather than single ones, the circuit design applied the optimum bend parameter of r =

10w, may not be practical due to the large space required. Therefore, the transmission characteristics of a 45-degree bend and a circularly curved bend were analyzed by using the bend parameters of s = r = 4w which realizes the same space factor.

Figures 2(a), 2(b), 2(c) and 2(d) show the analytical results, where h = 0.5W, W, 2W and 3W, respectively. In these figures, for reference, we also present the results of a circularly curved bend with r = 10W which requires a large space. From Fig. 2(a), we can see that as the thickness is small (0.5W), we can obtain best characteristics especially in the case of a circularly curved bend, that is, a 45-degree bend suppresses the radiation better than that of a 90-degree bend and a circularly curved bend exhibits the best radiation suppression. In Fig. 2(b) where h=W, a circularly curved bend shows improved transmission and suppressed radiation when compared with a 90-degree bend.

At 10 GHz and greater, transmission of the circularly curved bend are better than those of a 45-degree bend. In Fig. 2(c) where h = 2w, a circularly curved bend shows better transmission than a 90-degree bend but lower transmission and higher radiation than a 45-degree bend. In Fig. 2(d) where h = 3w, both a 45-degree bend line and a circularly curved bend line show transmission characteristics closer to those of a 90-degree bend . When compared with a circularly curved bend, a 45-degree bend shows higher transmission and lower radiation. Considering these results, a 45-degree bend is better
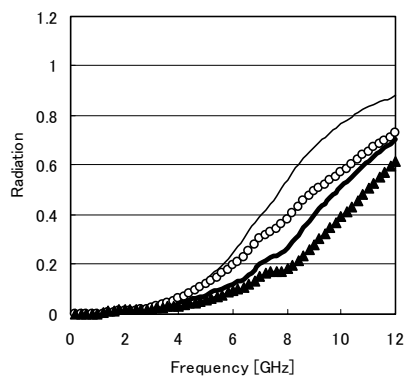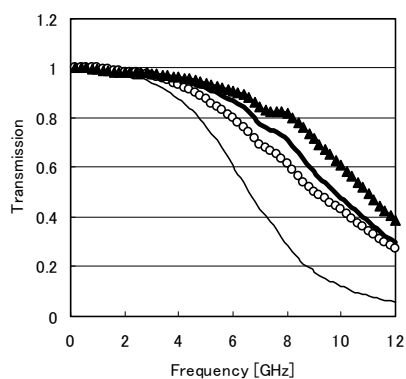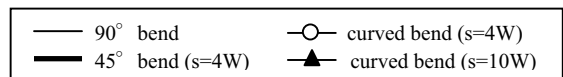

(a)　h = 0.5w

(b)　h = w
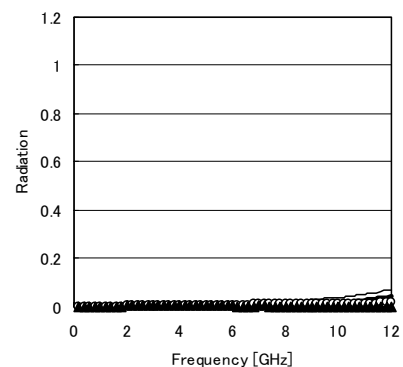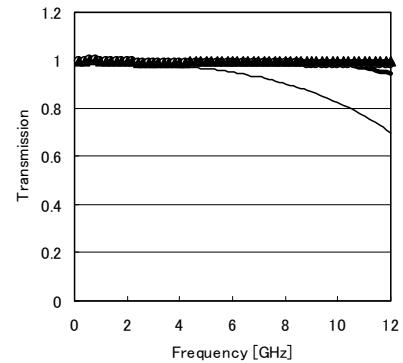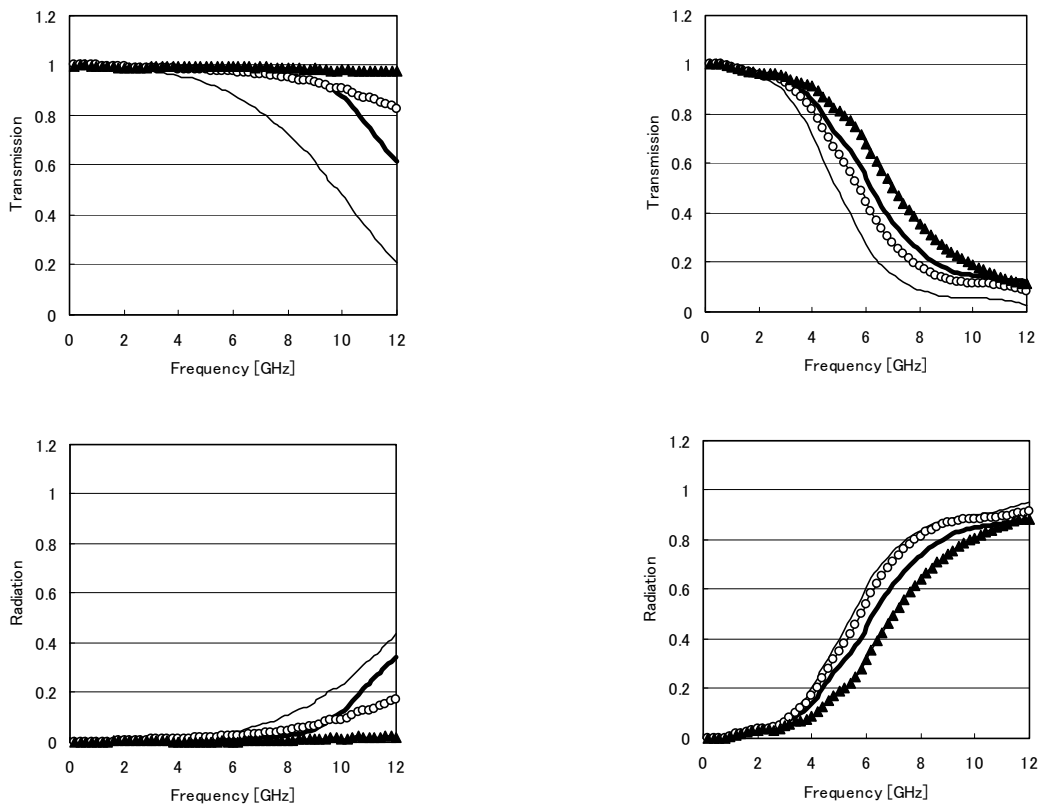
(c)　h = 2 w

(c)　h = 3 w

Fig. 2 Transmission / Radiation Characteristics vs.
dielectric thickness h when s = r = 4 w

———	90° bend	—O—	curved bend (s=4W)
━━	45° bend (s=4W)	—▲—	curved bend (s=10W)

than a circularly curved bend line if the dielectric thickness is great and the space factor is taken into account.

Next, a 90-degree bend with a small corner-cut shown in Fig. 1 (d) is studied, which can be expected from the point of space factor. Figure 3 shows the relationship between the optimum C and the dielectric thickness h with respect to transmission, reflection and radiation characteristics. (Here C is the cross-length drawn in Fig. 1). From this figure, we can see that as the dielectric thickness is set to 4 mm (corresponding to 2W), the optimum C is 0.4 mm. Figure 4 shows the transmission and radiation characteristics of a 90-degree bend with a small corner-cut, where W = 2 mm, h = 2W and C = 0.4 mm. For a comparison, those of a 90-degree bend and a 45-degree bend under the same condition are also shown. From this figure, it is noticed that the characteristics for both a 45-degree bend and a 90-degree bend with a small corner-cut are almost the same. Strictly speaking, that of a 45-degree bend is slightly superior to that of a 90-degree bend with a small corner-cut, however, from the practical
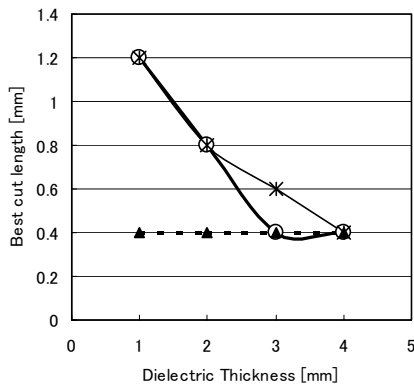
Fig 3 Optimum cut-length vs. Dielectric Thickness
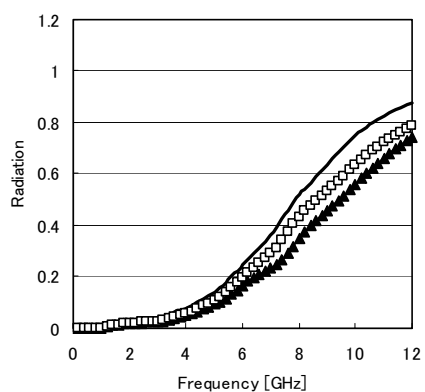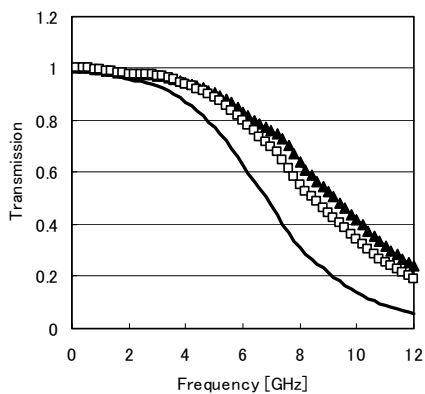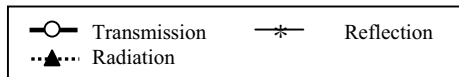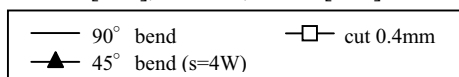of a 90-degree bend with a small corner-cut

Fig. 4 Transmission / Radiation Characteristics of a
90-degree bend with a small corner-cut when
W = 2 [mm], h = 2 w, C=0.4[mm]

viewpoint, the configuration of a 45-degree bend is more recommendable with respect to the space factor. Namely, since actual circuit boards use multiple MSLs, not a single line, the space factor will also become a significant point to be considered.

3. Conclusion

From the practical viewpoints, it is significant to clarify the influence of the dielectric thickness. First, this paper described the transmission characteristics of microstrip lines as related to dielectric thickness. Considering the effect of bend shapes on frequency characteristics, a 45-degree bend line and a circularly curved bend having equal space factors were compared. A circularly curved bend has been reported to have the greatest radiation suppression with an increase of dielectric thickness, but a comparison indicated that a 45-degree bend have better transmission characteristics than a circularly curved bend. The results indicate that it may be better to use a 45-degree bend than a circularly curved bend under some cases if the space factor and easy fabrication of multi-line circuits having large dielectric thickness is considered. Next, from the practical viewpoint, we recommended a 90-degree bend with a small corner-cut which has comparatively better, not the best performance characteristics especially in the case of large dielectric thickness, in spite of its simple construction.

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