A study on the radiation loss from bent transmission lines

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Abstract

This paper deals with the radiation loss of bent transmission lines. Through this study, we suggest the most effective shape of a tranamission line connecting two points from the standpoint of radiation. We have used MoM(Method of Moments) for numerical analysis and we have found that the simplest right angle bend is the best in the sense of the least radiation loss. This theoretical expectation was confirmed experimenatally.

1. Introduction

An important aspect of electromagnetic interference is the coupling of external(either intentional or unintentional) electromagnetic waves to the transmission lines and electronic systems, and there have been published a lot of papers on this subject [see our resent paper by Omid et al.(1997)[1] and references therein]. The problem opposite to this electromagnetic coupling, is the radiation of undesired electromagnetic waves from various electronic devices, which may lead to their interference to other electrionic systems. In this relation, the radiation from a bent transmission line is of essential importance in the EMC field, though there are extremely few reports on this subject. Because, the PCB configuration and some transmission lines have generally a bend. So, this paper deals with the quantitative estimation of such a radiation from a bent transmission line by means of the full-wave electromagnetic theory in order to suggest what kind of bend structure is suitable when designing the bend structure(a simple bend, bend with many coners etc.). These theoritical estimations can be confirmed by the experiments.

2. Diffent shapes of bent lines and radiation

Fig.1 illustrates transmission line models with bends. In order to make a comparison of radiation from the different kinds of bent lines, we consider such different kinds in Fig.1; n=1 indicates a bend with right angle, n=2 corresponds to the case of two corners, n=4 correspondes to the case of four corners and the last one is a quarter of a circle(as indicated later by circle). There are some reports which have dealt with the radiation loss from a bent part of transmission lines[2][3]. In this paper, we estimate the radiation loss of each shape for the line models in

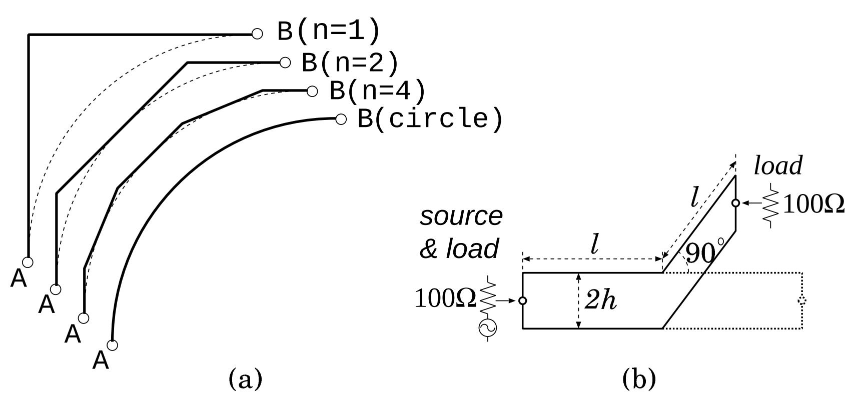

Figure 1: The models of bent transmission lines

Fig.1 by means of the use of NEC2, which is the general software of MoM. Fig.1(b) illustrates the Lecher conducting wire for the numerical computations with NEC2. For each line the line space is 2h=60[mm], the load of each terminal is 100[Ω], and the overall length of linear transmission line and a line with right-angle bend(n=1) is 2ℓ=900[mm], for a bend with two corners(n=2), 2ℓ=745[mm], for the bent line with four corners(n=4), 2ℓ=716[mm], and a for circular track, 2ℓ=706[mm]. Frequency band of analysis is 50MHz -1.2GHz. The height of the transmission lines h=30[mm] from the ground is $\lambda/10$ at 1GHz. In addition, we do not take matching with transmission lines of the trailing end.

3. Numerical solution

We have used NEC2 for numerical analysis for this study. NEC2 is the software based on MoM, which is useful to analyze electromagnetic field. MoM is different from the approximate solution method based on the transmission line equation, and it solves the electromagnetic field directly, so that it is suitable for this study. We can obtain the current distribution, the input impedance of transmission line and the radiation loss by means of the use of MoM[4]. The transmission line is supposed to be a perfect conductor in this study, and we can neglect the heat loss of the transmission line. Looking at Fig.1(b) and the feeding point on the transmission line being considered to be free from reflection, then the power of incident wave P_{in} of the transmission line would be the sum of the power P_{ref} which is reflected from the overall transmission line, the power P_{h2} which is lost by heat at the load of the terminal, and the radiated pawer P_{rad} from the transmission line.

$$P_{in} = P_{ref} + P_{h2} + P_{rad} \tag{1}$$

The radiated loss means the amount of radiated power P_{ref} out of the incident power P_{in}. By using the reflection efficience $|\Gamma| = \sqrt{P_{ref}}/\sqrt{P_{in}}$, we can obtain the radiation loss like this,

$$Radiation\ \ loss = P_{rad}/Pin = (1-|\Gamma|^2)P_{rad}/(P_{rad}+P_{in}) \tag{2}$$

By means of the use of NEC2, we can obtain the current distribution of the line and input impedance. In additon to the resistance of the termianl, the reflection coefficient could be calculated, and then we can calculate Eq.(2).

4. Experiments

In order to confirm the validity of our numerical analysis, we tested it and compared it with the exprimental results. The configuration of the experimental model is illustrated in Fig.2. If it is possible to consider the ground of experiment model to be a perfect conductor and

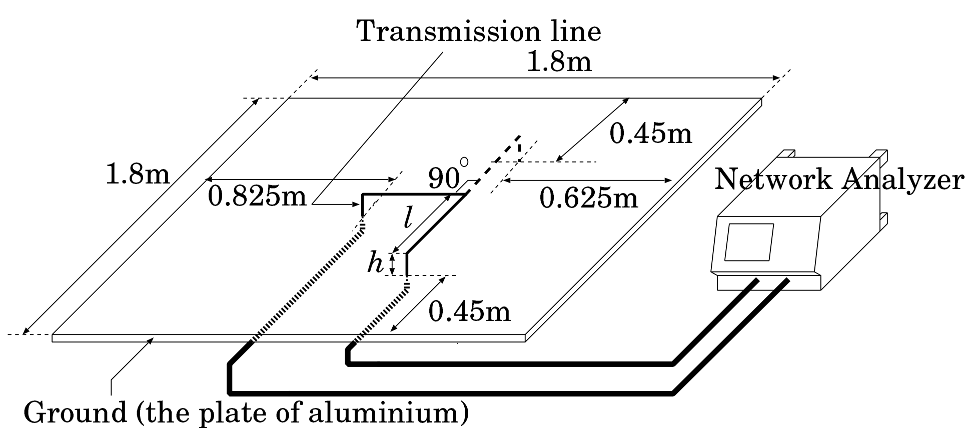

Figure 2: The exprimental setup

large enough, the experimental model is considered to the equivlent to the numerical one. S-parameters (S_{11},S_{21}) are mesured by means of the use of a network analyzer in the experiment, where S_{11} and S_{21} indicate the coefficient of reflection and transmission. The radiation loss can be estimated by the following equation.

$$1 - |S_{11}|^2 - |S_{21}|^2 = (P_{in} - P_{ref} - P_{h2})/P_{in} = P_{rad}/P_{in} \qquad (3)$$

5. Comparison between numerical results and experiments

Fig.3 illustrates the numerical result of radiation loss for each shape of bent transmission lines. n_1,n_2,n_4 and circle indicate the bent lines with one corner, two corners, and four corners and a circular line, respectively, and n_o means the linear line. For the numerical circular line model, we take the bent line with eighteen corners. The abscissa of Fig.3 indicates the overall length of a track divided by a wavelength. Frequency range is from 50MHz to 1.2GHz. It is rather difficult to have matching between the line and tailing end, because we want to change the wave frequency over a wide range, and we can notice standing patterns in Fig.3 due to this mismatching. However, Fig.3 suggests us a lot of useful informations on the radiation loss from bent lines. The radiation loss from a bent line with one corner(that is, right angle bend) is larger than that for a straight line by about 2-8%, but it is definite that it is smaller than that for the bend with many corners(n=2,4,18) by 2-7%. Also, we comment here that there is no significant difference in radiation loss for the bend lines with many corners(n$\geq$2 and circular). Hence, it can be concluded that the bend with right angle is the most strongly recommended in the sense of the least radiation loss, even though it is the simplest. When we consider no significant differences in radiation loss for the cases with more than two corners, a circular line is recommended, being superior over other bent lines with more corners in the sense of line length. In order to explain the above phenomenon, we made the following computations. The radiation loss from a transmission line with one bend is computed; bend angle is 45^o for n=2, 36^o for n=4 and 2.5^o for n=18 as in Fig.1 with the same total length. When the bend angle becomes bigger, we expect more raditaion loss. The radiation loss for the bend angle=2.5^o is nearly equal to that for the linear line, so that the bend angle and the number of bents contribute, in a complex manner, to the total radiation loss. This is because the discontinuity on the line excites different modes(other than TEM mode).

6. Conculusion

This study shows that the simplest transmission line with right angle bend is a more effective shape in the signal transmission than any other bends with more corners(even circle). This numerical analysis result was confirmed by an experiment as in Fig.4.

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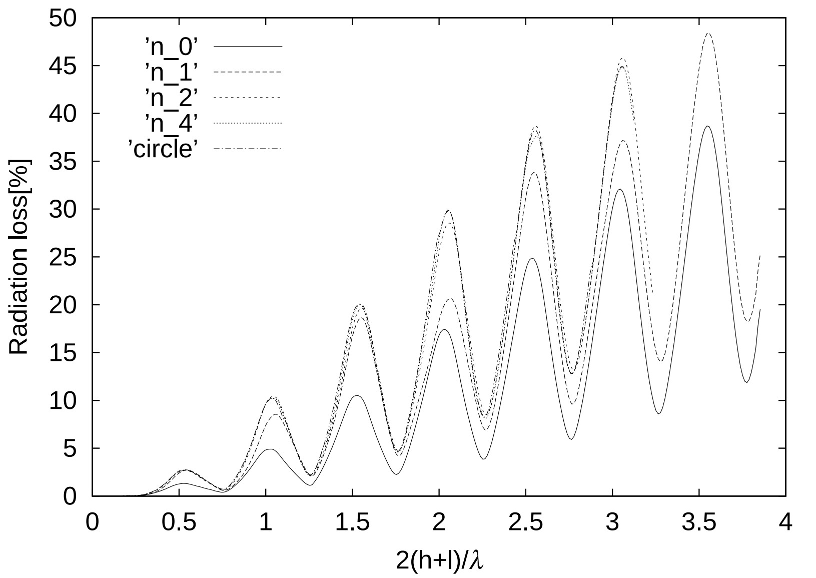

Figure 3: The numerical result on radiation loss. (n_0 indicates a linear line, n_1 means a bend with right angle, n_2 and n_4 mean the bends with two and four corners, Circle indicates a circular line.)

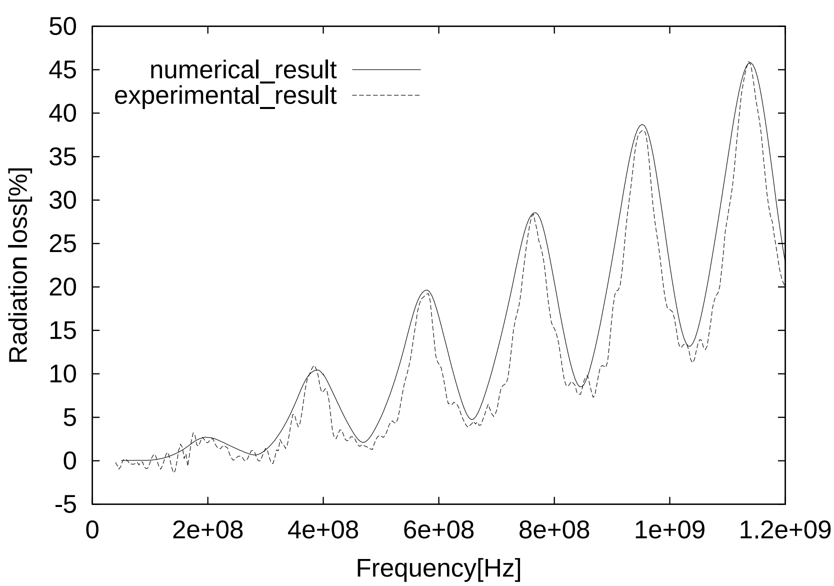

Figure 4: The comparision with the exprimental (broken line) and the numerical results (full line) in the case of n=2.