Radiation from a Parallel-Two-Wire Line Covered with Dielectric Tube

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Abstract: The Parallel-Two-Wire Line (PTWL) couples to the dielectric tube transmission mode and radiate electromagnetic wave strongly. Since this becomes to a cause of unnecessary electromagnetic waves, it is extremely important to elucidate this phenomenon. With this objective, we used a PTWL covered with a dielectric tube, and analyze experimentally the electromagnetic coupling between PTWL and the dielectric tube, and radiation. It was found that at the resonant frequency of the dielectric tube, even a small wavelength of the tube couples strongly with PTWL and emitted electromagnetic waves. When the line length exceeded half the wavelength, the tube emitted electromagnetic waves stronger than those of the antenna used as reference.
Key words: Dielectric antenna, parallel two wire line, electromagnetic coupling, dielectric tube.

1. Introduction

At low frequency, dielectric structures used in electronic equipment, circuits etc. are not usually problematic as electromagnetic emitters or receptors, since they are electrically negligible. In the near future, however, when the frequency will become much greater than that used today, the problem of dielectric structures will become important as new sources of radiation or receptors of unnecessary electromagnetic waves. Near the dielectric tube transmission mode, most of the PTWL energy is converted to the dielectric tube transmission mode and radiated as electromagnetic waves.[1]-[3] This phenomenon thus generates unnecessary electromagnetic waves. It would therefore be vitally important to elucidate the electromagnetic coupling between dielectric substance and transmission line, and the phenomenon of radiation.

HE_{11} mode is the most fundamental mode of the dielectric tube and has n=1 component, the PTWL has as well having electromagnetic component of n=1 as the main component. Accordingly, the PTWL couples strongly with the HE_{11} mode of the dielectric tube and the experimental line radiate electromagnetic waves. We therefore conducted an experimental study of the coupling between dielectric tube HE_{11} mode and the PTWL, and the resulting radiation.

2. Structure of experimental line and measuring method

2.1 Structure of experimental line

The experimental line is fed to a PTWL by balance mode. The structure of experimental line is shown in Fig. 1.

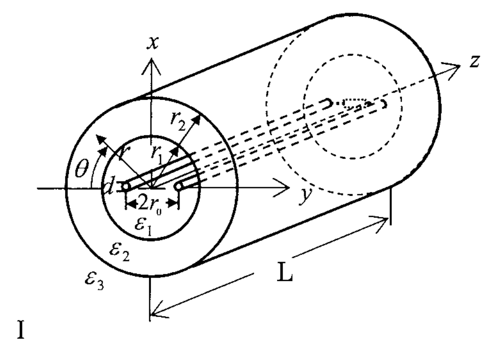

Figure 1. Parallel-Two-Wire-Line Covered with dielectric tube

Various factors would affect the characteristics of transmission and radiation, including the diameter of the PTWL, the space between the wires, the relative positions of dielectric tube and PTWL, and the medium constant, diameter, inside diameter/outside diameter and length of the dielectric tube. With these factors as parameters, we experimentally analyzed the coupling between the PTWL and the dielectric tube, and the radiation characteristics.

Medium constant and sectional forms of the experimental line are as shown in Table 1.

Table 1. Medium constant and sectional forms of dielectric tubes

Line type	Relative dielectric constant	r_1/r_2	Diameter [m]	Length L/λ_0
Type A	115	0. 77	0. 0385	0. 15~1. 9
Type B	91	0. 77	0. 0385	0. 15~1. 1
Type C	91	0. 76	0. 0326	0. 15~1. 0
Type D	42	0. 60	0. 0405	0. 6~1. 7

λ_0 = free space wavelength

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2.2 Transmission loss measuring method

For measuring transmission loss, the graphical calculation method of scattering matrix was used.[4] The absolute values of S_{11} and S_{12}, elements of the S matrix, were determined by graphic algebra. Transmission loss α is obtained using the following equation:

$$\alpha = -10\log_{10}\frac{|S_{12}|^2}{1-|S_{11}|^2} \text{ [dB]} \qquad (1)$$

3. Transmission loss characteristics

3.1 Transmission loss and radiation field

Transmission loss refers to the loss of electric power fed to the PTWL during passage through the dielectric tube. If the line is short and loss due to the PTWL and dielectric medium is negligible, the amount of transmission loss presumably reflects the amount of electric power converted by the coupling from the PTWL to the transmission mode of the dielectric tube. Fig. 3 shows example experimental

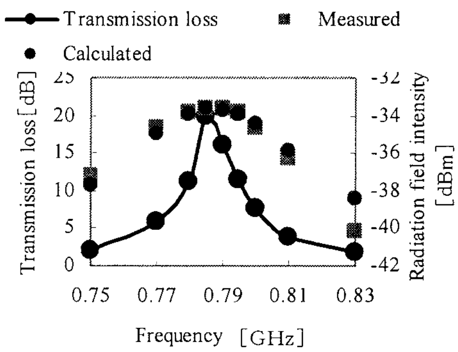


Figure 2. Transmission loss and Radiation field intensity (Type A)

results of transmission loss and radiation field (type A) measurement for a line of length $0.583\lambda_0$ (f = 785MHz). It shows transmission loss characteristics similar to a resonant curve and at the near frequency of HE_{11} mode, the transmission loss peak is as high as 20dB. The measurement results show that the peak frequency of transmission loss agrees with that the peak frequency of radiation field intensity. This means that most of the energy fed to the PTWL was converted to HE_{11} mode and radiated as electromagnetic waves. The HE_{11} mode frequency (λ_0/λ_g = 1.2) of a semi-infinite length dielectric tube is 727MHz, but the actual resonant frequency is 785MHz. It is considered that the higher resonant frequency caused by the lowering of the dielectric tube's equivalent relative constant, due to the edge effect of the tube. Since the mean radiation power at transmission loss peak frequency is greater than the mean radiation power of the reference antennas (half-wave dipole antenna and double-ridged waveguide horn antenna), most of the transmission loss is radiated as an electromagnetic wave. The calculated result of radiation field intensity assuming that the entire transmission loss is radiated, agree with the measured results.

3.2 Line length and transmission loss characteristics

The amount of transmission loss greatly depends on the line space of the PTWL. We call optimum line space that maximizes transmission loss.

The peak values of transmission loss versus line lengths are shown in Fig. 3. The Figure shows that the shorter the line, the greater the transmission loss per unit length, and that transmission loss is not proportional to line length. Even if the line is short, there is strong coupling and radiation of electromagnetic waves.

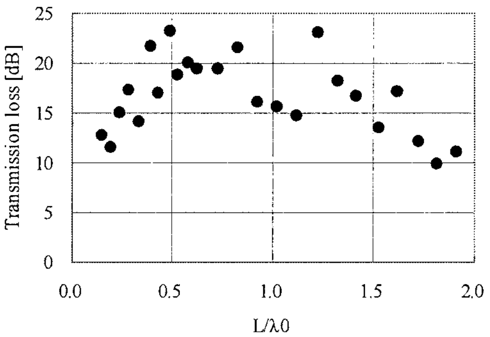


Figure 3. Transmission loss peak values vs. Line length (Type A)

The peak values of transmission loss for various lengths versus line space are given in Fig.4. The Figure shows that transmission loss value depends greatly on line space, that transmission loss of more than 20dB is possible at any length, and that the longer the line, the narrower the optimum line space.

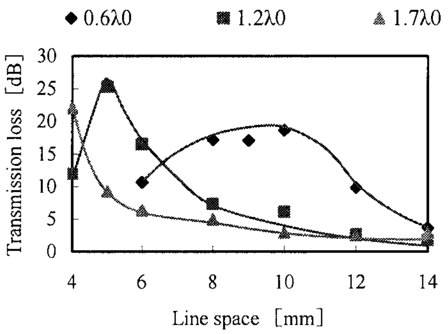


Figure 4. Transmission loss peak vs. Line space (Type B)

4. Radiation characteristics

4.1 Near field of a very short dielectric tube

To study the mechanism of radiation from a dielectric tube, a three-wavelength long PTWL was terminated at the characteristic impedance and a 0.15-wavelength long dielectric core was attached to the feeding point to measure the near electromagnetic field. Since the radiation field polarization plane is parallel to the PTWL, the near electromagnetic field was measured by moving a small dipole antenna in parallel with the PTWL at a height of 0.045m from the center of the line.

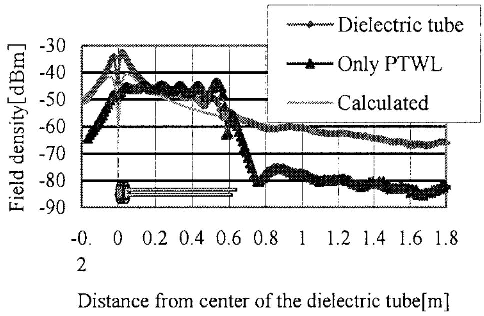


Figure 5. Near field of the dielectric core (Type C)

Fig. 5 shows the electromagnetic field when only the PTWL was attached. In this case, it is seen that immediately after the antenna passes beyond the PTWL, the field intensity is rapidly attenuated and that the radiation from the PTWL is insignificant. Then, when a very short dielectric tube is attached to the feeding point, field intensity near the dielectric core becomes quite a bit larger and the radiation field from the dielectric tube is evident.

4.2 Directivity of experimental line

The directivity of a very short dielectric tube is shown in Fig.6. The directivity of E-plane is almost omni directional, and that of H-plane is closely

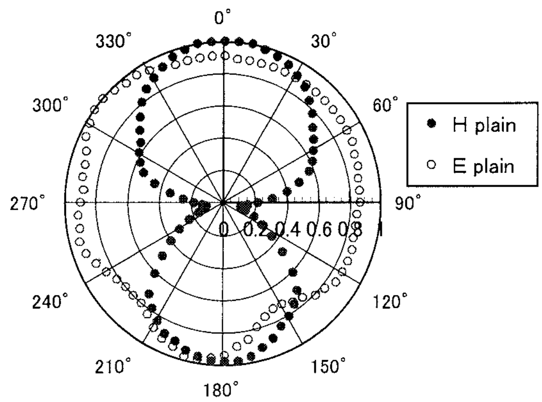
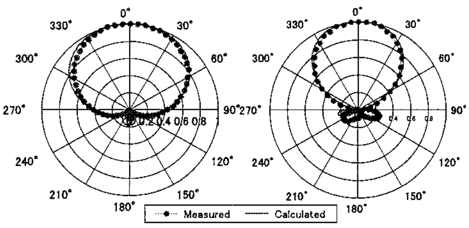


Figure 6. Directivity of short dielectric core (Type C, L=0.15 λ_0)

resembles the letter 8. This is similar to the directivity of a small loop antenna.

4.3 Directivity for various dielectric tube lengths

The experimental line has end fire directivity in the direction of transmission line; as the dielectric tube length increases, directivity becomes narrower and gain improves, as shown in the Fig.7. However, transverse to the transmission line of H-plane directivity is always minimum values. On the basis of these experimental results, the dielectric tube can be considered as an array antenna in which radiation sources having directivity similar to that of a small loop antennas are placed side by side on the axis of the dielectric tube.



L=0.6 λ_0 L=1.04 λ_0

Figure 7. Directivity of E-plane (Type B)

4.4 Radiation efficiency

To obtain the radiation efficiency of the experimental line, actual gain was measured by comparing the mean radiation power achieved by feeding the same power to the experimental line and the reference antenna. Experimental result of actual gain for various lengths versus line space is shown in Fig. 8 The Figure shows that at the peak transmission loss frequency, each length of the experimental line has larger radiation efficiency than the reference antenna.

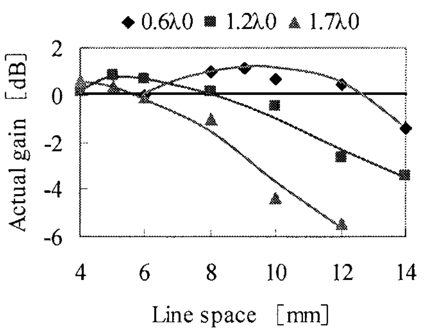


Figure 8. Actual gain vs. Line space (Type B)

5. Conclusion

The comparatively short PTWL covered with dielectric tube radiate strong electromagnetic waves, since almost all the transmission energy is converted into the dielectric tube transmission mode near the frequency of the dielectric tube HE_{11} mode.

It is very important to study the phenomena that coupling between transmission line and dielectric structure

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