EXPERIMENTAL STUDIES ON THE ELECTROMAGNETIC FIELDS AROUND A TWO-WIRE PARALLEL LINE

Hiroshi ECHIGO, Katsuhiro SATO
Faculty of Engineering, Tohoku Gakuin University
E-mail: echigo@tjcc.tohokugakuin.ac.jp

Abstract: It is well known that a two-wire parallel line (a pair of parallel wires) is fundamental one for the RF signal and energy transmission systems. It gives the basic concept and knowledge about the RF transmission and radiation phenomena that are the main issues of EMC research field. In this paper, experimental measurements of magnetic fields around a two-wire parallel line are described. Adding them, electromagnetic [EM] field patterns measured on a plane parallel with the line and with a certain distance from the line are given. It is also shown that the field patterns are useful to find the radiating portions on the line using the inverse projection method. The results obtained give the evidence that the waves are radiating mainly out of the feeding point, the line end and irregular parts attached on the line.

Key words: two-wire parallel line, electromagnetic radiation, inverse projection, field pattern.

1. Introduction

A two-wire parallel line (a pair of parallel wires) is one of the simplest and the most fundamental transmission line. It gives basic concepts on the transmission lines for students and engineers. In the circuit theory, it is treated as no radiating parts to explain the signal transmission circuits, to design VHF filters and etc. However, EMC field researchers have noticed that these transmission lines can radiate EM energy. Especially in digital equipments, a gross of transmission lines are used to transfer the information signals. The radiations from these lines are severe problems in the design and development of digital equipments. To reduce the radiation, it is very effective to know the portions having potential to radiate RF energy.

In this paper, 1) After confirming that the current flow was regular by measuring the magnetic field near the line, field patterns were measured in the Fresnel region. 2) Using obtained data of complex values, the radiating portions can be indicated after the inverse projection from the measurement plane to the source plane.

Our experiments showed that the line ends and irregularity on the line could cause the EM wave radiation. To reduce the radiation, covering the line ends with EM absorbing materials would be effective.

2. Experimental Systems

2.1 Two-wire parallel line

The parameters of the line that was used for our experiments are listed in Table 1. The parallel line is hanging from the ceiling of the room by the RF power feeding parts.

| Table 1 Parameters of the parallel two-wire line |
|-----------------|-------|
| Radius of the wire | 0.5 cm |
| Separation of the wire centers | 2.0 cm |
| Length | 2.0 m |
| Materials | Brass, (Al, Fe) |
| Characteristic impedance | 166 Ω |

2.2 Feeding parts

The feeding parts were settled at the upper end of the line, which could feed RF power to each wire independently through two coaxial cables. The
2.3 XY positioner
To scan the EM field around the line, XY positioner (D3425AV10-S) was used. This makes possible to move the arm vertically (Z-direction) and horizontally (X-direction) carrying the EM sensor (a small loop or a dipole antenna).

2.4 EM sensors
To measure the EM fields, a small-shielded loop and a shortened dipole antenna were used. The small-shielded loop is composed with a semi-ridged coaxial cable with its diameter 2mm. The loop radius is 1.0cm.

2.5 Measurement equipments
EM sensor output was led to Vector Volt Meter (VVM:HP8508A) or Spectrum Analyzer (MS2601B) through a coaxial cable (SUCOFLEX ) of 5m lengths and a pre-amplifier with 25dB gain.

2.6 Measurement site
The measurements were accomplished in an ordinal office room.
To reduce the reflection from the floor, EM absorbers were settled on the floor, especially on the area near the line end.

3. Magnetic Field near the Line
To confirm the current distribution on the line, the magnetic fields near the line were measured. Not to confuse the following explanation, xyz coordinate is set to the line configuration as shown in Fig.2.
To measure the near field when RF energy of 1GHz was supplied to the lines, small loop was scanned on the plane; $y=1.5cm, x=-10 \sim 10cm, z=60 \sim 200cm$, to make the field pattern. Fig.3 gives the results for resistive termination; 166ohm resistor. Fig.4 gives the magnetic field near one of two wires to show the current distribution on the wire. It proves that the current is flowing on the line without any irregularities.
These results well resemble to the simulation results of the current on the parallel transmission.

4. EM wave radiation out of the line
RF currents on any conductors in the space cause the EM waves according to the Maxwell Equations. Our lines with current flow unexceptionally radiate EM waves that form the EM environment in the office room. To confirm this fact, we measured EM field patterns on the vertical plane separated from the
line by 1.65m but parallel to x-z plane. The sensor was a dipole antenna with length less than a half wavelength. Measured electric field pattern are shown in Fig.5. The figure is for the antenna in horizontal orientation and the line terminated with short circuit. It is too complicated ones as like randomized fields.

5. Searching for Radiation Portions by the Inverse (or Back) Projection.

Using measurement data of complex numbers, substantially radiating portions can be found. As shown in Fig. 6, spreading data on the measurement plane are inversely projecting on the (source) plane including the parallel line. The inverse projection is expressed as shown Eq.1,

\[ I(x, z) = A \sum_{i,j} V(i, j)e^{ikr_{x,z,i,j}} \cdot r_{x,z,i,j} \quad (1) \]

where \( V(i,j) \) is the complex voltage value measured at point \((i,j)\) on the measurement plane, \( k \) is wave number given as \( 2\pi/\lambda \) and \( r_{x,z,i,j} \) is the distance between the point and the inverse projected point \((x,z)\) on the inverse projection plane.

\( I(x,z) \) is value that is proportional to the intensity of radiating sources where \( A \) is proportional constant.

Considering that the measurement plane locates in the Fresnel region, it can be expected that inversely projected data can have greater values since they have the coincident phase if the portions acts as radiating sources. Fig.8 show the inverse data on the plane including the line. To make spatial correspondence sure, Fig.7 indicates the line position on the source plane. The greater portions of the back projected data are brighter in these figures. One can notice that the line end portions have higher levels.

To confirm this fact that EM waves are radiating from the line ends, other line with a half-length was tested. The result is given in Fig.9. In this case, the brighter portion was coincident with the line end position. Figure 10 show that irregularities of the line cause radiation.

Metal pieces were attached on the middle of both 2 m lines. Just at the position, higher level appeared on the source plane taking the deference between for the cases of metal peace
attached and not.

6. Conclusion

The parallel two-wire line (a pair of parallel wires) is one of the simplest and the most fundamental transmission line. As in digital equipments, a lot of transmission lines are used to transfer the information signal between devices.

The radiations from these lines are severe problems in design and development of digital equipments. To reduce the radiation from them, it is very effective to know the portions having potential to radiate RF energy.

In this paper, these experimental results were given. 1) After confirming that the current flow was regular by measuring the magnetic field near the line, field patterns measured in the Fresnel region were shown.

2) Using obtained data of complex values, the radiating portions could be indicated after the inverse projection had formed the measured plane to the source plane.

According to our experiments, it would be true that the line ends and irregularity on the line can cause the EM wave radiation. To reduce the radiation, covering the line ends with absorbing material would be effective.

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