# Crosstalk and Electromagnetic Radiation Measurements of Some Specific Cables


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ABSTRACT

In this work, the crosstalk and the electromagnetic radiation characteristics of some specific interconnecting cables such as twin-lead and tri-lead are studied experimentally. The crosstalk is measured by sending a pulse signal down to the active line and measure the response in the quiet line by an oscilloscope. Whereas the electromagnetic radiation measurement is carried out within a TEM cell. Both time and frequency domain responses are measured. From the results, we found that both the crosstalk and the radiation of twin-lead cable is stronger than that of the tri-lead cable.


## I. INTRODUCTION

As data transmission rate in high-speed computer or communication system are increasing, the characteristics of interconnecting cables are then becoming more and more important in designing a signal transmission system of good quality and low error rate. In fact, single wire running is the simplest interconnection method but its characteristic impedance can be quite unstable or and will cause significant signal distortion due to coupling.

Cable coupling is mainly affected by three factors, namely, the size of conductor cross section, the spacing between conductors, and the dielectric constant of the surrounding material. When tight impedance control is required, interconnecting cables such as twin-lead, tri-lead, and miniature coaxial cables are commonly used (Fig. 1). Their crosstalk analyses are, therefore, quite important and was first developed by Paul [1,2]. In this work, we study the crosstalk of some specific types of cables experimentally. Moreover, the electromagnetic radiation characteristics of these cables are also measured for the reference of EMC designers.

## II. CROSSTALK ANALYSIS AND MEASUREMENT

To study the crosstalk, we used the moment method and the finite element method to calculate the cable coupling capacitance matrix as given by

$$C_{i,j} = \left.\frac{Q_i}{V_j}\right|_{V_k=0,\ k\neq j} \qquad (1)$$

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where $Q_i$ is the charge on the conductor surface $S_i$ and $V_j$ is the voltage applied on the conductor surface $S_j$.

When the spacing between the conductors is large enough, for simplicity, the thin dielectric layer around the conductor can be ignored. And the moment method can be used to calculate the capacitance matrix [3,4]. With this method, the potential distribution can be written as

$$V(\vec{r}) = \sum_i \int_{S_i} G(\vec{r}|\vec{r}')\cdot\rho(\vec{r}')\, ds' \qquad (2)$$

where $\rho(\vec{r}')$ is the charge density on the conductor surface. To solve Eq.(2), each conductor is divided into 18 regions for numerical calculation. From the charge neutrality one can solve the charge distribution on each conductor at the same time, which can then be used to calculate the capacitance between conductors. For twin- and tri-lead cable analyses, cables of 50-ohm characteristic impedance are used. Their diameters are 0.2268 mm and 0.2546 mm, respectively. To investigate the orientation dependence of the crosstalk for these two types of cable, we calculate the coupling capacitance and backward crosstalk coefficient $K_b$ both horizontally and vertically, where $K_b$ is given by

$$K_b = \frac{1}{4}\left[\frac{C_m}{C} + \frac{L_m}{L}\right] \qquad (3)$$

where C and $C_m$ are the self- and mutual capacitance, L and $L_m$ are the self- and mutual inductance. The results are shown in Fig. 2. As can be seen from the figure, when the cable spacing is small, the coupling capacitance of a twin-lead cable is larger than that of the tri-lead cable. For the tri-lead cable, it can be seen the vertical coupling is stronger than that of the horizontal. Theoretically, these results can be understood by calculating the electric field distribution around the conductors. The contour of the equipotential lines are plotted as shown in Fig. 3. Obviously, the field distribution of the tri-lead cable is more localized due to the field lines are confined by the two ground leads, which significantly reduces the crosstalk effect. And for the tri-lead cable, its vertical field confinement is weak, so the vertical coupling is stronger than that in the horizontal.

When the dielectric layers are thick or the cables are close enough, the effect of dielectric surrounding must be considered. Moreover, as its shape is not of simple geometry, it is better to use the finite element method to calculate the coupling capacitance. In this work, ANSOFT FEM program is used [5]. For simplicity, one of the conductors is set to be 1 V, and all the other conductors are grounded. The electric potential and field distributions are calculated first, and then the charges on each conductor, which is found by integrating the electric field around the conductor as given by

$$Q = \int \epsilon\vec{E}\cdot d\vec{s} \qquad (4)$$

As the applied voltage is a unit voltage, the coupling capacitance is equal to Q numerically. The calculated backward coupling coefficients are shown in Fig. 4. From the results, it can be seen that the crosstalk is indeed larger in twin-lead than that in the tri-lead and, in this case, $K_b$ is smaller than that without surrounding layer. Fig. 5 shows the field distribution of a twin-lead cable with and without a dielectric surrounding layer. And it can be seen that the field lines of twin-lead cables with dielectric surrounding layers are more concentrated in the middle region than that without.

To compare the results obtained by the moment method and the finite element method, a twin-lead cable of spacing 1.25 mm is analyzed by both methods. The corresponding coupling coefficients are 0.069 and 0.065, respectively, which shows the consistency of results obtained by both methods.

To measure the cable crosstalk, we use a pulse generator to send a pulse of 1 V voltage, 2 ns rise time, and 200 ns duration time, down to the active line and use an oscilloscope to observe the near-end crosstalk in the quiet line. From Fig. 4, we found the calculated results are quite agree with the experimental results. The slight difference may be due to the small impedance mismatch in the connectors, which can be further improved.

## III. RADIATION MEASUREMENT

For a better understanding of the characteristics, electromagnetic radiation measurement is also carried out within a TEM cell for these cables. Both time and frequency domain responses are measured. In the time domain measurement, cable under test ,supported by a thick dielectric material for electric isolation, is located at the upper cavity of the TEM cell. The cable is 30 cm in length and is terminated to 50 ohm load. A square pulse of 5 V voltage, 50 ns duration, and 100 ns period is generated by the pulse generator and fed into the cable. The experiment is carried out by changing the rise time from 1 ns to 10 ns and measuring the maximum output voltage. The results are shown in Fig. 6 and can be seen that the radiation of twin-lead cable is stronger than that of the tri-lead cable. When the rise time is shorter, the radiation becomes stronger. Obviously, this is because a faster rising pulse, includes more high frequency components, which enhance the radiation. In the frequency domain measurement, a HP-8444A tracking generator and a HP-8568A spectrum analyzer are used to measure the cable radiation spectrum. The results are shown in Fig. 7. Note that the upper bound of the frequency range is limited by the resonance frequency of the TEM cell, which is about 200 MHz. As can be seen from the figure, under 60 MHz, roughly, there is a 6-dB difference of the measured values between the twin-lead and the tri-lead cables. In the frequency range, 60 to 200 MHz, the radiated power of twin-lead cable is still higher on average.

## IV. CONCLUSION

In conclusion, we have successfully measure the crosstalk and the electromagnetic radiation of two specific types of cable, twin-lead and tri-lead, and found that the tri-lead cable should be better in noise and

EMI control. Detailed analyses of the results and other measurements such as higher frequency are of great interest.

## References


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[5] Ansoft Finite Element Analysis Program, Ansoft Inc. 1987.

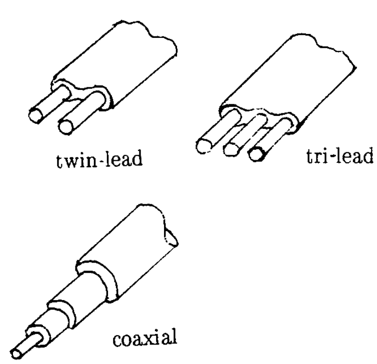




Fig. 1 Geometry of three kinds of cable.

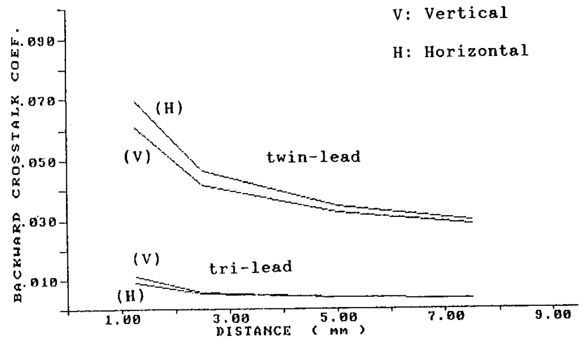



Fig. 2 Near-end crosstalk analysis by moment method without a dielectric surrounding layer.

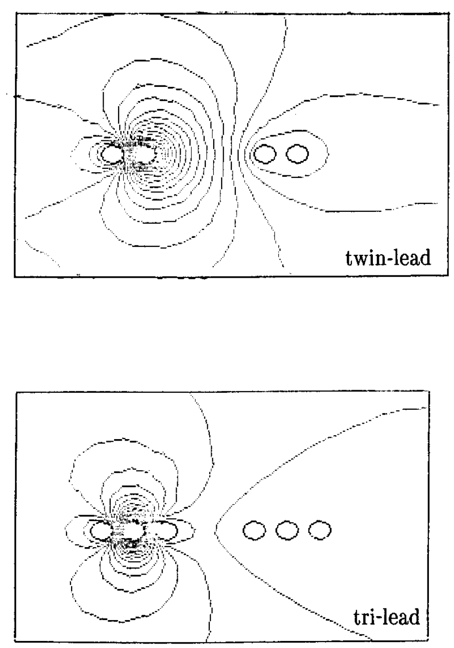



Fig. 3 Field distribution of twin- and tri-lead cables

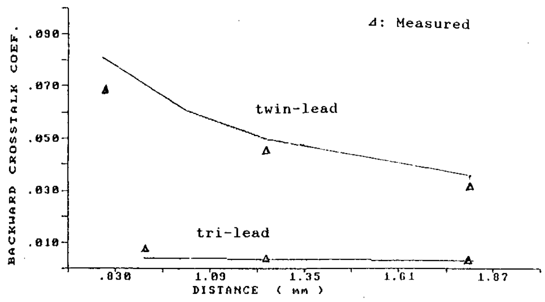



Fig. 4 Horizontal near-end crosstalk analysis by the finite element method with a thick dielectric layer.

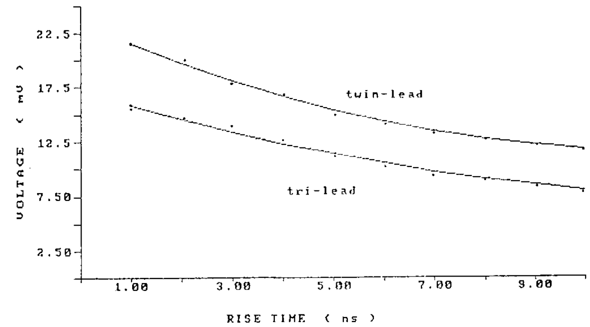
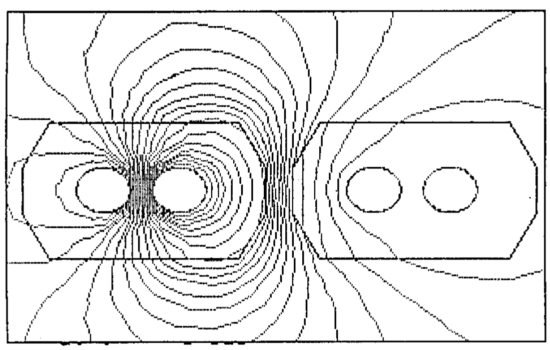
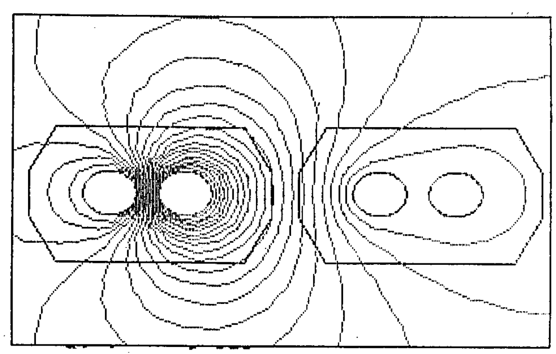



Fig. 6 Cable radiation: time domain measurement



(a)



(b)

Fig. 5 Comparison of twin-lead cable field distribution (a) with and (b) without a thick dielectric layer

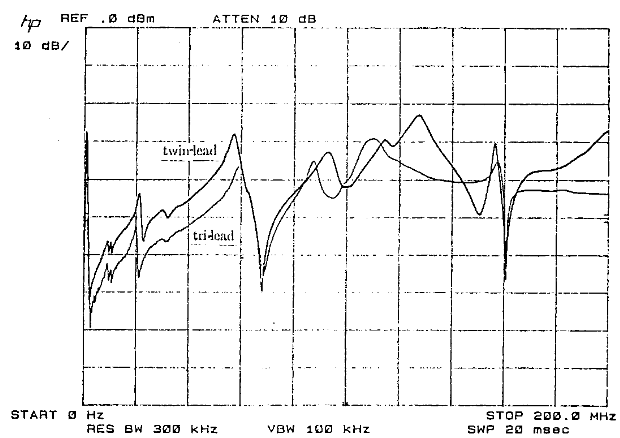



Fig. 7 Cable radiation: frequency domain measurement