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Design and Research on High-Speed Ethernet Information Module

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Abstract*:* This paper mainly designs and researches the seven kinds of information module with the highest speed of Ethernet transmission. Their technical essentials and design methods are analyzed and expounded in the aspects of impedance matching, crosstalk elimination and contact zone design. In design process, computer electromagnetic simulation software is chosen and simulation model is built to aid design and verify it. Test instrument is selected according to international standard regulations and information module samples are tested according to test methods to verify the feasibility of design method. In test result, the external crosstalk performance of link can be optimized through the research on the external crosstalk of connector.

Keywords High-speed Ethernet, Electromagnetic performance, Crosstalk

INTRODUCTION

Ethernet is a family of computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN).[Rabie, et. al., 2010] It was commercially introduced in 1980 and first standardized in 1983 as IEEE 802.3, [Yu 2013] and has since been refined to support higher bit rates and longer link distances[Thomas, et. al., 2014]. Over time, Ethernet has largely replaced competing wired LAN technologies such as token ring, FDDI and ARCNET[Glew, et. al., 2009]. The original 10BASE5 Ethernet uses coaxial cable as a shared medium, while the newer Ethernet variants use twisted pair and fiber optic links in conjunction with hubs or switches. Over the course of its history, Ethernet data transfer rates have been increased from the original 2.94 megabits per second (Mbit/s)[Oh, et. al., 2011] to the latest 100 gigabits per second (Gbit/s). The Ethernet standards comprise several wiring and signaling variants of the OSI physical layer in use with Ethernet. Type-VII standard greatly raises the speed of Ethernet transmission [Lee, et. al., 2011]. It becomes the future development direction of copper cable transmission. As for single-line bandwidth, it is expanded from 250MHz (Type-VI) to be 600MHz. In this case[Kreitlow, et. al., 2015], cabling products face a new challenge. As the part which can most influence the performance of link, connector faces a much larger problem. Information module is required to be delicate in design. Up to now, type-VII cabling products have not been put into market. The main design technology is mastered by minority foreign manufacturers [Straka, et. al., 2012]. It is the focus in a new round of competition of cabling products [Zhang, et. al., 2013].

This paper will further technically analyze and optimize the information module in the three aspects of contact part design, impedance matching and crosstalk suppression. In addition, compatibility & matching problem is considered. Finally, analyses in relevant aspects are integrated to design the structure of Type-VII module. Computer simulation and test are then utilized to verify the design.

OPTIMIZATION OF INSERTION LOSS AND RETURN LOSS

Low insertion loss and high return loss is one of the objectives pursued in connector design. Two factors influence the objective: the contact status of plug and socket; impedance matching status on signal transmission route. This part designs and optimizes the information module in above two aspects to achieve more superior performance.

The good contact status of plug and socket is the basic guarantee of decreasing contact resistance and optimizing direct-current resistance parameters. Apart from that, bad contact can easily cause reflection of signal on contact interface, which worsens insertion loss[Pizano-Escalante, et. al., 2013]. Therefore, it is necessary to optimize the design of contact spring strips to make connectors contact reliably.

According to electric contact theory, contact resistance = shrink resistance + film resistance. Film resistance is related to material of film and the thickness of surface oxide film. Shrink resistance is related to contact pressure. When contact pressure increases, the two contact surfaces mutually get close and the quantity of contact points increases. Therefore, the real contact area increases. When average contact area remains unchanged, shrink resistance will decrease and the deformation of contact points changes from elastic deformation to be plastic deformation[Cota, et. al., 2011]. The contact surface can be flattened permanently and shrink resistance will decrease. Therefore, the increase of contact pressure in certain degree can decrease contact resistance.

The contact spring strip of common RJ45 socket and its equivalent mechanical model can be seen in figure 1.

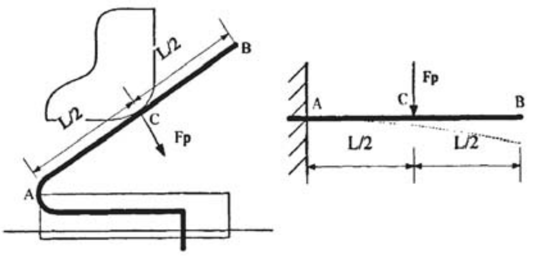

Figure 1 The contact spring strip of common RJ45 socket and its equivalent mechanical model

The deflection curve equations of its mechanical model are shown in formula (1):

$$\begin{cases} \omega = -\dfrac{Fx^2}{6EI}(3a - x), 0 \le x \le a \\ \omega = -\dfrac{Fa^2}{6EI}(3x - a), a \le x \le l \end{cases} \quad (1)$$

In the formula: E is the Young modulus of material; I is the axis' centroidal principal moment of inertia; a is the distance between point A and point C. x is the distance between point A and certain point on the axis.

In case of $a = \dfrac{l}{2}$ and $x = \dfrac{l}{2}$, the deflection of point C is $\omega_c = -\dfrac{Fl^3}{24EI}$.

Because of particularity of the connector described in this paper, the design of contact spring strip is improved as figure 2.

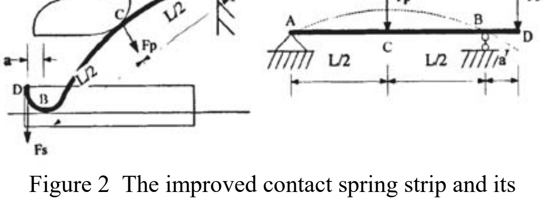

Figure 2 The improved contact spring strip and its equivalent mechanical model

When pre-tightening force Fs=0, point A, point B and point C are collinear and only contact pressure Fp is born. The deflection curve equations of the model are shown in formula (2):

$$\begin{cases} \omega = -\dfrac{Fbx}{6EIl}(l^2 - x^2 - b^2), 0 \le x \le a \\ \omega = -\dfrac{Fb}{6EIl}\left[\dfrac{l}{b}(x-a)^3 + (l^2 - b^2)x - x^3\right], a \le x \le l \end{cases} \quad (2)$$

In the formula: E is the Young modulus of material; I is the axis' centroidal principal moment of inertia; a is the distance between point A and point C; b is the distance between point B and point C; x is the distance between point A and certain point on the axis.

In case of $a = \dfrac{l}{2}$, $b = \dfrac{l}{2}$ and $x = \dfrac{l}{2}$, the deflection of point C is $\omega_c = -\dfrac{Fl^3}{48EI}$.

It indicates that: contact pressure doubles that in previous form when pre-tightening force Fs=0 and the deflection of contact spring strips are equal. In order to guarantee the reliability of contact, initial pre-tightening force Fs is added at point D. This force can be regarded as the concentrated moment at point B: MB=FSa. Equation of deflection curve is shown below:

$$\omega = -\frac{Mx}{6EIl}(l^2 - x^2) \quad (3)$$

In the equation: E is the Young modulus of material; I is the axis' centroidal principal moment of inertia; x is the distance between point A and certain point on the axis.

In case of $M_b = F_s a$ and $x = \dfrac{l}{2}$, the deflection of point C is $\omega_c = -\dfrac{F_s a l^2}{16El}$.

When plug contacts socket, the deformation will be overcome to work to increase contact pressure Fp and enhance the reliability of the contact. Through adjusting pre-tightening force Fs, contact pressure can be changed and controlled.

According to superposition principle, contact pressure overcomes initial deformation to work. The increment $\vartriangle F_p$ can be got from simultaneous above two equations:

$$\vartriangle F_p = \frac{3F_s a}{l} \quad (4)$$

IMPEDANCE MATCHING AND CABLING OPTIMIZATION

As for high-frequency signal transmission, the internal impedance matching of connector is an important factor that influences insertion loss and return loss. Cabling determines impedance matching.

The speed of signal transmission along transmission line is determined by effective dielectric constant of the medium that electric-power line gets through. The larger effective dielectric constant is, the slower signal transmission will be and the longer the delay of the signal transmitted in the form will be. Among micro-strip lines, as for power line, dielectric constant is a compound value. A part of it lies in dielectric material and the other part of it lies in air. The precise pattern of field distribution and the mode of covering dielectric material will influence the eventual effective dielectric constant and the actual transmission speed of signal. In odd mode, most electric-power lines are in air; in even mode, most electric-power lines are in material. Because of this, the effective dielectric constant of the signal in odd mode is slightly smaller than that of the signal in even mode. Therefore, the signal in odd mode can be transmitted faster [Jieting, et. al., 2010]. In strip lines, dielectric materials around conductor are uniformly distributed. As for electric-power lines, effective dielectric constant always equals conductor dielectric constant. It is not related to voltage mode. In strip lines, the transmission speed of the signal in odd mode equals that in even mode.

Differential signal is transmitted in odd mode; common-mode signal is transmitted in even mode. Differential mode is used in twisted-pair of Ethernet to transmit signal, but some factors transform differential signal to be common-mode signal, such as asymmetrical signal lines and the mismatch between drivers. With the enlargement of mismatch between two signal lines, the size of common-mode signal magnifies correspondingly. If the transmission speed of odd-mode signal is different from that of even-mode signal, terminal signal will distort largely. Therefore, in the PCB of connector, strip lines shall be preferentially chosen as the transmission mode of signal.

The connector described in this chapter uses the typical differential pair with characteristic impedance 100Ω . Single-line impedance is 60Ω ; line width is 10.1mil; main line distance is 8.1mil. The strip line with width 25mil between two planes is the main PCB line. Above data is calculated by Allegro software.

The first-order model of single-ended transmission line is a n-section lumped circuit model described by capacitance in unit length and loop inductance in unit length. The characteristic impedance and delay of single-ended transmission line can be calculated in formula (5):

$$\begin{cases} Z_0 = \sqrt{\dfrac{L_L}{C_L}} \\ TD = \sqrt{L_L C_L} \end{cases} \quad (5)$$

In the formula: Z0 is the characteristic impedance of single-ended transmission line; LL is the loop inductance in unit length; CL is the capacitance in unit length; TD is the delay of line.

This model can be generalized to double lines with coupling. Figure 3 shows the equivalent circuit model of double lines with coupling.

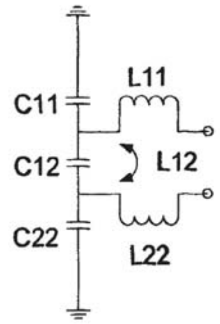

Figure 3 N-section lumped circuit model of coupling transmission line

When differential pair is driven in odd mode, the impedance of single line is the characteristic impedance in odd mode. In this case, the equivalent capacitance of single line will be:

$$C_{odd} = C_{11} + 2C_{12} = C_{Load} + C_{12}$$

Pre-research on the methods of eliminating external crosstalk

In type-VII standard, external crosstalk is put forward as the new test parameter for permanent link. In general case, this parameter mainly tests the anti-crosstalk performance of cables without being regarded as the performance index of connector. However, as a part of link, connector exerts certain influence on the parameters of the performance of link. Considering the aspect of enhancing the overall performance of link, connector designer shall attach importance to it. This part will research the methods of eliminating the external crosstalk at connector.

The formation of external crosstalk at connector

In most circumstances, information modules are laid on panel in parallel. In UTP (Unshielded Twisted Pair) transmission mode, different connectors will mutually disturb. IDCs are put on compensatory link board to output signal to twisted-pair. Because of large area of IDC, the IDC of different information modules can form capacitors which are similar to parallel boards. High-frequency signal can pass them to form interference from different cables. It is the external crosstalk of link.

Among the modules laid in parallel, neighboring two modules can form this kind of interference. It is easily known that every line pair of almost every module can be influenced by the signal transmission of other connectors.

RESULTS AND CONCLUSIONS

This study designs and analyzes type-VII module on the basis of designing and analyzing type-VI module in the third chapter. Firstly, the design of contact spring strip is optimized to increase contact pressure and make it adjustable; contact resistance decreases to optimize DC resistance. Through analysis, strip line is chosen as the main PCB line. Differential line is designed to optimize return loss and balance parameters. The generation reason and elimination method of inductive crosstalk are analyzed to design “3+2” structure to restrain the inductive crosstalk produced in connector [Lafata, et. al., 2015]. On the basis of restraining capacitive crosstalk, near-end crosstalk parameters and far-end crosstalk parameters are optimized. Considering that type-VII module needs to be compatible with the RJ45 crystal head in type-VI and the lower, the compatibility with different kinds of crystal head shall be considered. LC cascaded structure can be used to adjust the compensation capacitor of different kinds of RJ45 crystal head: double-compensation structure is designed to integrate above several structures and optimization methods. At the same time, computer simulation and experiment is operated to verify the effectiveness of the structure and design method. For optimizing the external crosstalk parameters of link, this part researches the method of forming and restraining the external crosstalk of information module. A restraining method is put forward and verified in computer simulation.

REFERENCES

Cota P, Pavičić T. New technologies for improvement of characteristics in DSL access networks[C]//MIPRO, 2011 Proceedings of the 34th International Convention. IEEE, 2011: 511-516.

Glew, Charles A. "High performance, multi-media cable support-separator facilitating insertion and removal of conductive media." U.S. Patent No. 7,473,850. 6 Jan. 2009.

Jieting, Qiu, et al. "Development of control system in electromagnetic acquisition station based on ARM and Linux." Instrumentation and Measurement Technology Conference (I2MTC), 2010 IEEE. IEEE, 2010.

Kreitlow, Matthias, et al. "Robustness of Ethernet in complex aircraft environment." Electromagnetic Compatibility (APEMC), 2015 Asia-Pacific Symposium on. IEEE, 2015.

Lafata P. Estimations of G. fast transmission performance over phantom modes[C]//Telecommunications and Signal Processing (TSP), 2015 38th International Conference on. IEEE, 2015: 1-5.

Lee B T, Mazumder M, Mellitz R. High speed differential I/O overview and design challenges on Intel enterprise server platforms[C]//Electromagnetic Compatibility (EMC), 2011 IEEE International Symposium on. IEEE, 2011: 779-784.

Oh, Taehyoun, and Ramesh Harjani. "A 6-Gb/s MIMO crosstalk cancellation scheme for high-speed I/Os." IEEE Journal of Solid-State Circuits 46.8 (2011): 1843-1856.

Pizano-Escalante, L., et al. "Crosstalk cancellation on high-speed interconnects through a MIMO linear precoding." IEEE Transactions on Microwave Theory and Techniques 61.11 (2013): 3860-3871.

Rabie, Sameh, and Osama Aboul Magd. "Metro ethernet service enhancements." U.S. Patent No. 7,701,948. 20 Apr. 2010.

Straka, Frank M., and Masud Bolouri-Saransar. "Method and system for reducing internal crosstalk and common mode signal generation within a plug/jack combination." U.S. Patent No. 8,128,437. 6 Mar. 2012.

Thomas, Fabrice, et al. "High-performance high-speed spectrum analysis of laser sources with SWIFTS technology." SPIE OPTO. International Society for Optics and Photonics, 2014.

Yu S. IEEE 802.3 ‘Standard for Ethernet’Marks 30 Years of Innovation and Global Market Growth[J]. Press release IEEE, 2013.

Zhang, Jian, et al. "The study of embedded processing system on high-speed banknote sorting device." International Conference on Optical Instruments and Technology (OIT2013). International Society for Optics and Photonics, 2013.