

Effects of Ferrite Core on EMI and Signal Transmission for HDMI

Yuang-Shung Lee

Department of Electronic Engineering
Fu Jen Catholic University
Taiwan, R.O.C.
e-mail: lee@ee.fju.edu.tw

Hai-Hwa Hu

Department of Electronic Engineering
Fu Jen Catholic University
Taiwan, R.O.C.
e-mail: alexhu@msi.com.tw

Abstract—The effects of ferrite core on electromagnetic interference (EMI) for high definition multimedia interface (HDMI) cables by analyzing both HDMI compliance test specification (CTS) and EMI measurement results are presented in this paper. Measurement methods like HDMI CTS are used to show the effects of ferrite core on signal transmission for HDMI cable. Simulations results are used to validate the several factors contributing to ferrite core in a differential cable and their impacts on EMI. Both the experimental results and simulations show a clearly trend of decreased EMI that corresponds to the ferrite core. The results indicate the need for ferrite core cable specification for high speed HDMI cables to better facilitate compliance with FCC and CE EMI regulations and HDMI CTS.

Keywords: HDMI, EMI, CTS

I. INTRODUCTION

In recent years, the popularity of high-definition, multichannel audio and video has grown rapidly. Radiation resulting from transmission of high-definition, multi-channel audio and video data at high frequencies often interferes with the operation of surrounding digital circuitry. Most existing audio video connectors and cables fail to meet the demands of low EMI at today's and near future high clock and data speeds. One such existing connector intended for transmission of high definition multi-channel video and audio data is the High Definition Multimedia Interface [1], which fails to meet the EMI requirements at high clock speeds. The existing HDMI EMI results show that merely mitigating EMI for the cable by changing its mechanical features. This suggests that the effect of ferrite core on EMI and HDMI CTS should also be studied.

II. HDMI CABLE ASSEMBLY

The HDMI (High Definition Multimedia Interface) is, as its name suggests, a media interface intended for transmission of high-definition, multi-channel audio and video data [1]. The HDMI cable shown in the HDMI block diagram Fig. 1, carry four differential pairs - three data pairs and one clock pair. There will be a certain amount of skew at the transmitter/connector interface because of several non-ideal attributes such as clock rise and fall time, length and impedance mismatch asymmetries. Assuming ideal conditions at the transmitter/connector interface, the differential clock signal gets gradually skewed as it propagates and cable loss mismatches producing the most skew at the receiver. This skew in the differential cable pair cable creates a common-mode current on the shield that radiates, causing EMI [4]. This radiated EMI increases with increase in skew.

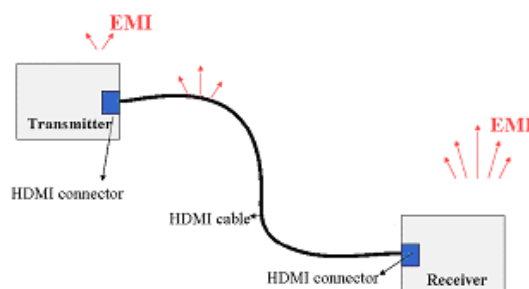


Fig. 1. Block diagram of HDMI

III. EFFECTS OF FERRITE CORE ON HDMI CTS

Measurements were taken using a Tektronix HDMI CTS, which is capable of judging compliance HDMI signal specification, these of the control cables and other test equipment [2]. One HDMI system source accommodates a HDMI connector (receptacle and terminated plug). Connect to HDMI cable, shown in Fig. 2(a). One with two ferrite cores the other without ferrite core. The other side of the PCB, shown in

Fig. 2(b), has 4 matched differential traces three data pairs and one clock pair with surface mount connectors [1,3].



Fig. 2(a)

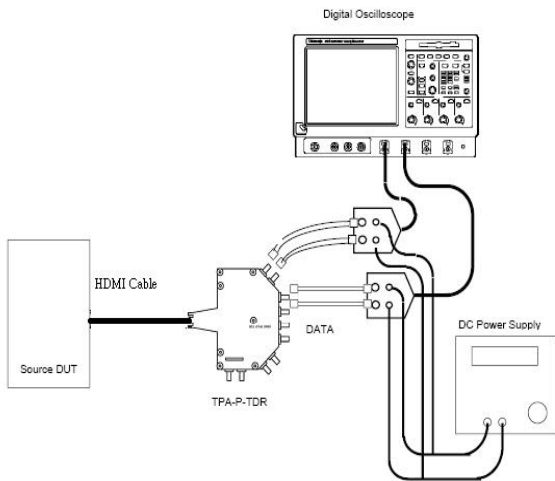


Fig. 2(b)

Fig. 2(a) HDMI cable, one with two ferrite core the other without ferrite core (b) measurements of Clock-Data Tests (Differential Signal Measurements)

The differential clock-Data is fed with a forwarded clock pulse using an One HDMI system source. The CTS as a function of time domain measured HDMI Compliance Data Eye pattern, Differential Clock Jitter, Duty cycle, Rise/Fall Time, Differential Data Rise/Fall Time. The result as Fig. 3[5]

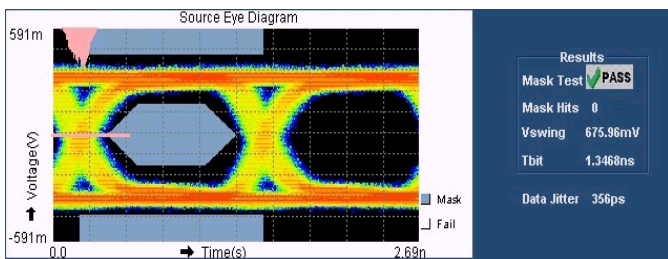


Fig. 3(a)

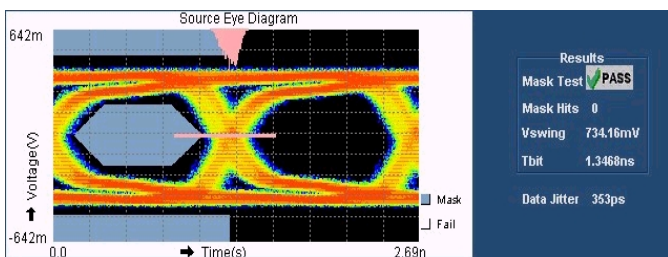


Fig. 3(b)

Fig. 3(a) Eye diagram use HDMI cable without ferrite core (b) Eye diagram use HDMI cable with ferrite core

The eye diagram is created by taking the time domain signal and overlapping the traces for a certain number of symbols. The overlapping signals show us a lot of useful information and this called the eye diagram shown in Fig. 4[6]

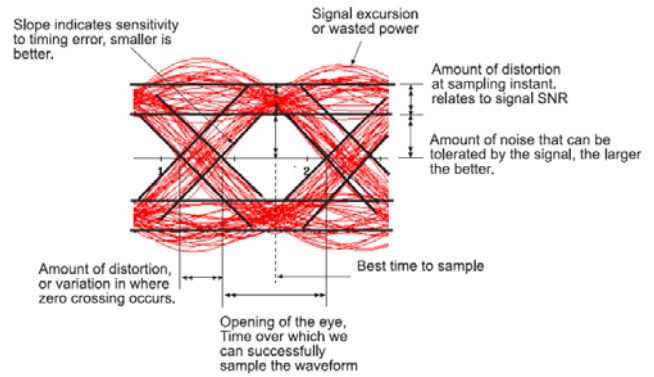


Fig. 4 Eye diagram basic information

The slope of eye diagram determines how sensitive the signal. Due to the ferrite core decrease the slope of eye diagram, eye diagram use HDMI cable without ferrite core is better than eye diagram use HDMI cable with ferrite core. Ferrite core has some influence to HDMI eye diagram. But both HDMI cable with and without ferrite core can pass eye diagram requirement. [7]

IV. EFFECTS OF FERRITE CORE ON HDMI CABLE EMI

In order to study the effects of ferrite core in the HDMI cable EMI, we setup test device in EMI chamber as shown in Fig. 5. Then we get the EMI measurement result Fig. 6(a). The EMI measurement result use HDMI cable without ferrite core Fig. 6(b). The EMI measurement result use HDMI cable with ferrite core. The EMI as a function of frequency domain measured HDMI EMI Data shown in Fig. 7. The EMI response of the differential cable can be found due to ferrite core.



Fig. 5 Setup test device in EMI chamber

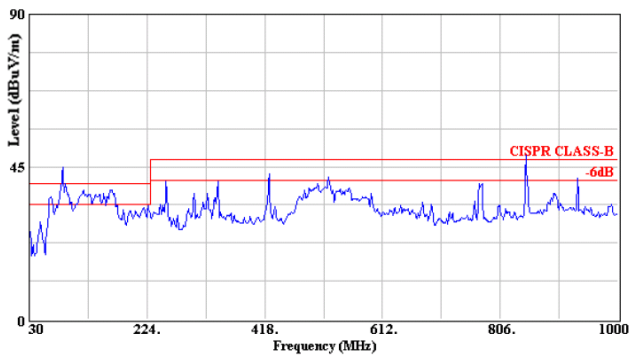


Fig. 6(a)

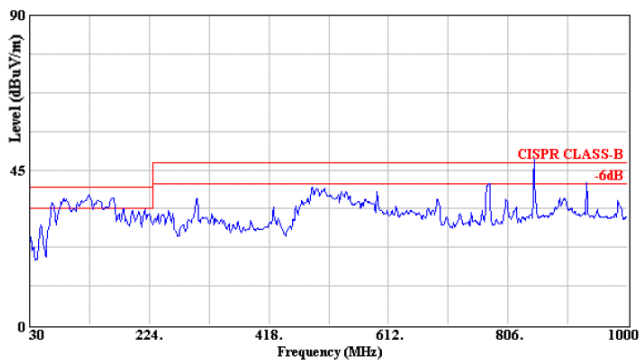


Fig. 6(b)

Fig. 6(a) The EMI measurement result use HDMI cable without ferrite core (b) The EMI measurement result use HDMI cable with ferrite core

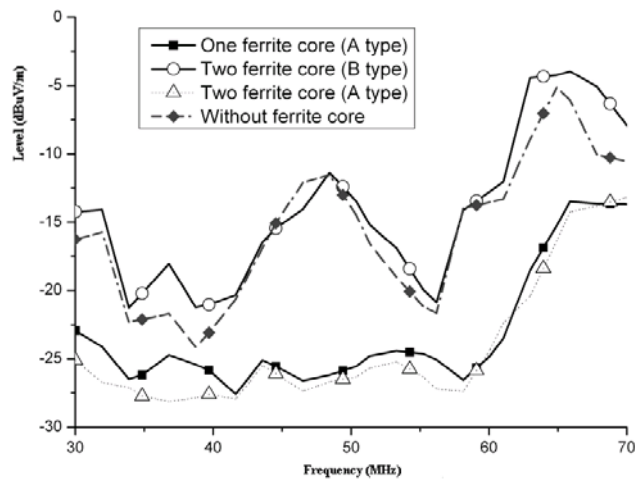


Fig. 7 EMI response of the HDMI cable due to ferrite core.

Ferrite core is most frequently used as two terminal circuit elements, or in groups of two terminal elements. The unique high frequency noise suppression performance of ferrites can be traced to their frequency dependent complex impedance, as shown in Fig.8. When used as EMI filters, ferrite core can thus provide resistive loss to attenuate and dissipate (as minute quantities of heat) high frequency noise while presenting negligible series impedance to lower frequency intended

signal components. When properly selected and implemented, ferrite core can thus provide significant EMI reduction while remaining normal circuit operation. For high frequency applications, ferrite core should be viewed as frequency dependent resistors. [8]

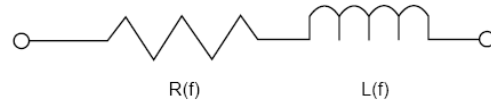


Fig. 8 Simple equivalent circuit model of a two terminal ferrite core

The impedance of ferrite core can be expressed as:

$$Z = R(f) + j\omega L(f) \quad (1)$$

The frequency dependent loss term arises from the loss of energy incurred as a result of oscillation of microscopic magnetic regions (called domains) within the ferrite. The loss and the ferrite impedance can be expressed in terms of a complex permeability as:

$$\begin{aligned} Z &= K \{j\omega\mu_0 [(\mu'(f) - j\mu''(f))] \} \\ &= K\omega\mu_0 \mu''(f) + jK\omega\mu_0 \mu'(f) \\ &= R(f) + j\omega L(f) \end{aligned} \quad (2)$$

Where:

$\mu'(f)$ is the real component of the frequency dependent series complex relative permeability, $\mu''(f)$ is the imaginary component of the frequency dependent series complex relative permeability, K is a constant corresponding to the number of windings and the core dimensions, μ_0 is permeability of free space, and the radian frequency is $\omega = 2\pi f$.

The loss tangent ($\tan d$) of a ferrite material can be defined as the ratio of the imaginary part to the real part of the material's relative permeability

$$\tan d = \mu''(f)/\mu'(f) \quad (3)$$

As is true with the permeability, the loss tangent is frequency dependent. The loss tangent is an intrinsic property of a given ferrite material formulation. Choosing a particular ferrite material corresponds to choosing a particular loss tangent and an associated impedance versus frequency characteristic

Since EMI suppression ferrites are frequently used to filter common mode EMI on conductors carrying DC or AC power, they should be applied so as to encircle pairs or groups of conductors that carry equal and opposite low frequency currents. EMC engineer wishes to reduce the high frequency noise on a HDMI cable, as shown in Fig. 9. Equal and opposite low frequency currents are passed through a single ferrite core. The ferrite core equal and opposite currents and thus the net magnetic flux density is zero. The HDMI simulation for Electric field intensity is shown in Fig. 10 [9,10].

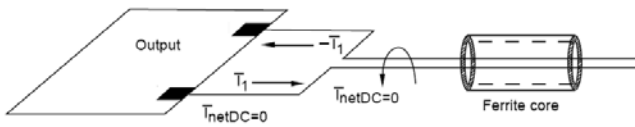


Fig. 9 Equal and opposite low frequency currents are passed through the ferrite core

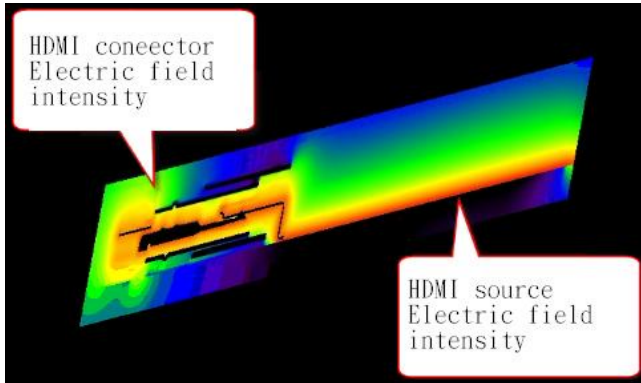


Fig. 10 HDMI simulation for Electric field intensity

V. CONCLUSION

The significant HDMI CTS and EMI effect with ferrite core. HDMI cable with ferrite core is better EMI than HDMI cable without ferrite core. HDMI cable without ferrite core is better HDMI CTS than the other HDMI cable with ferrite core. Hence based on this ferrite core analysis changing the present HDMI cable will result in EMI improvement and pass HDMI CTS. Therefore controlling ferrite core features for HDMI cables could prove valuable for passing FCC and CE EMI regulations and HDMI CTS.

VI. REFERENCES

- [1] High-Definition Multimedia Interface Specification, version 1.3a (www.hdmi.org).
- [2] Tektronix seminar HDMI Measurement Solutions Aug. 2006.
- [3] K. P. Slattery, "A Comparison of the Near Field and Far Field Emissions of a Pentium Clock IC" IEEE International Symposium on Electromagnetic Compatibility, vol. 1, pp. 547-551, Aug. 2001
- [4] C. R. Paul, "A Comparison of The Contributions of Common-mode and Differential-mode Currents in Radiated Emissions", IEEE Trans. Electromagnetic Compatibility, vol. 31, pp. 189-193, May 1989.
- [5] L. A. Hayden, and V. K. Tripathi, "Characterization and Modeling of Multiple Line Interconnections from Time Domain Measurements," IEEE Transactions on Microwave Theory and Techniques, vol. 42, pp. 1737-1743, Sep. 1994.
- [6] [Http://www.complextoreal.com/chapters/eye.pdf](http://www.complextoreal.com/chapters/eye.pdf) , accessed, Jul. 2007.
- [7] A. Tolescu and P. Slvasta, "Characterization of Differential Interconnects from Time Domain.

Reflectometry Measurements" Electronics Technology : Concurrent Engineering in Electronic Packaging, pp. 298 -301, May 2001.

- [8] C. R. PAUL, Introduction to Electromagnetic Compatibility, Wiley Series In, 1992, p299-308.
- [9] Junichiro Urabe, Katahira Fujii, Armad Mukifza Bin Harun" A Study of EMI Suppression Characteristics of Ferrite Core ", 17TH International Zurich Symposium on Electromagnetic Compatibility, pp. 622- 625, Feb. 2006.
- [10] Junichiro Urabe, Katahira Fujii, Yuji Jito" A Method for Measuring the Characteristics of an EMI Suppression Ferrite Core", IEEE Transactions on Electromagnetic Compatibility, Vol.48, No4, pp. 774-780, Nov. 2006.