An Investigation of Differential Impedance Controlled Flexible Printed Circuit

Taiji Ogawa,[1] *Hirohito* Watanabe,[1] and *Shinichi* Nikaido[1]

When flexible printed circuit (FPC) is used for a high-frequency signal transmission, it is necessary to adjust the impedance. Moreover, a lot of differential signal transmission methods are adopted for high-speed signal transmission. Therefore, FPC needs the design of the differential signal line. However, it is difficult to design the differential signal line with relatively many design parameters compared with the single-end signal line.

This time, our company has installed a three-dimensional electromagnetic field simulator to address this problem. The purpose of this paper is to report that the actual measurement value of FPC designed with the simulator was in good agreement with the result of the simulation.

1. Introduction

Recently, signal speeds have become increasingly faster, and high-speed serial communications such as IEEE1394 are often carried out between digital equipment. To deal with such circumstances, FPCs used inside a cellular phone, mobile music player, digital still camera, digital video camera, and laptop computer need to be designed considering high-frequency characteristic.

The need for installing the necessary wiring for differential signal transmission has intensified, as differential signal transmission useful in speeding up the transmission is made by specifications, for example, Low Voltage Differential Signaling (LVDS) used for specifications such as Serial Advanced Technology Attachment (SATA) and High-Definition Multimedia Interface (HDMI).

2. An outline of differential impedance

The standards of high-speed data transmission are predicated on connecting to the specified impedance load. We design FPCs considering the impedance matching to prevent waveform distortion caused by reflection of signals at the far end of a transmission line. Moreover, recently high-speed data transmission has generally been carried out by differential signal transmission that is resistant to common mode noise. Differential signal transmission uses two signal lines and transmits opposite phase signals at the same time. The receiver receives data and determines the difference between the two values, as shown in Fig. 1. Now, therefore, when noise is superimposed on signals as shown in Fig. 1 for single-end transmission, the receiver takes the noise that crosses the threshold value of receiver's input level as data. In contrast, differential signal transmission is capable of sending data without being influenced by noise because the receiver receives the difference of values of two signals. As just described, differential signal transmission minimizes the level of the signal because the transmission method is resistant to noise. Consequently, such a characteristic shortens the time to reach maximum ampli-

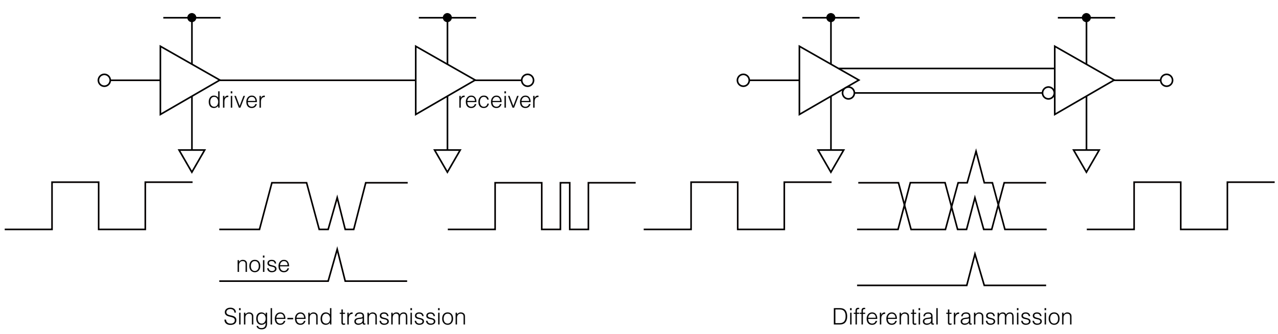


Fig. 1. Influence of common mode noise.

1 FPC Core Technology R&D Department, Electronic Components R&D Center

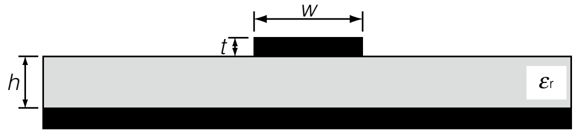
Panel 1. Abbreviations, Acronyms, and Terms.

FPC—Flexible Printed Circuit
LVDS—Low Voltage Differential Signaling
SATA—Serial Advanced Technology Attachment
HDMI—Hign-Definition Multimedia Interface
TDR—Time Domain Reflectometry

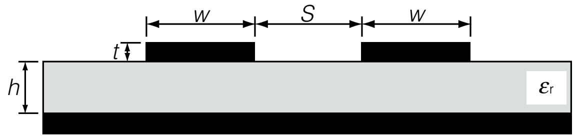
tude and speeds up data transmission.

3. Design of differential impedance controlled FPC

We described in our company's report No. 109 "An investigation of impedance controlled flexible printed circuit" [1] that the parameter of design for making impedance controlled transmission lines was calculated by a two-dimensional electromagnetic field simulator and reported in our company's report No. 110 "An investigation of FPCs high frequency characteristics" [2] that we are capable of designing thinner impedance controlled FPCs to control the impedance by using mesh in the GND layer without changing the signal line. The GND structure with mesh is also necessary to design differential impedance controlled FPCs because of the need for satisfying both low-profile and impedance control conditions/requirements.



$$Z_0 = \frac{60}{\sqrt{0.475\varepsilon_r + 0.67}} \ln\left(\frac{5.98h}{0.8w+t}\right) \quad (1)$$



$$Z_{diff} = 2Z_0\left\{1 - 0.48\exp\left(-0.98\frac{S}{h}\right)\right\} \quad (2)$$

Fig. 2. Impedance calculation expression.

We manufactured FPCs based on several different designs of differential signal lines. We also measured the differential impedance by Time Domain Reflectometry (TDR). The following is the example of the measurement results of differential impedance. FPC's materials and structures remained the same in order to define the correlation between the widths of a signal line and characteristic impedance.

Figure 2 (1) shows a formula to calculate the characteristic impedance and Fig. 2 (2) shows a formula to calculate the differential impedance.

As shown in Fig. 3, when the signal line width changes, the differential impedance changes. It is because the characteristic impedance is calculated by formula (1) in Fig. 2, which includes the line width. For differential impedance, the value changes as Fig. 4 by the change in the distance, *S*, between signal lines, which is included in formula (2). As just described, designing an FPC that has differential transmission lines and mesh GND structure takes time because many parameters need to be considered.

Given this factor, our company installed a three-dimensional electromagnetic field simulator. The three-dimensional electromagnetic field simulator can simulate the mesh GND structure of an FPC that cannot be calculated by the two-dimensional electromagnetic field simulator that our company has. For new design, this simulator enables us to design an FPC that has transmission lines that controls the impedance to achieve a target value and has a mesh GND structure.

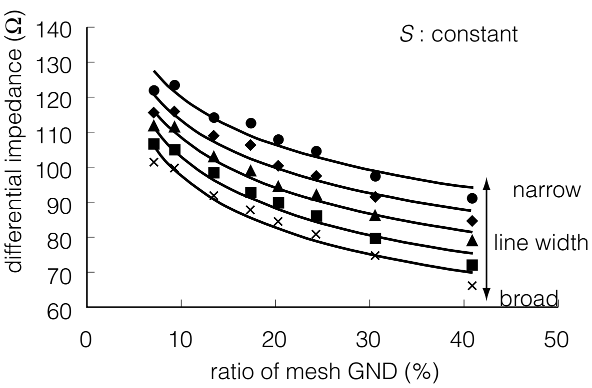


Fig. 3. Differential impedance of FPC designed by meshed GND.

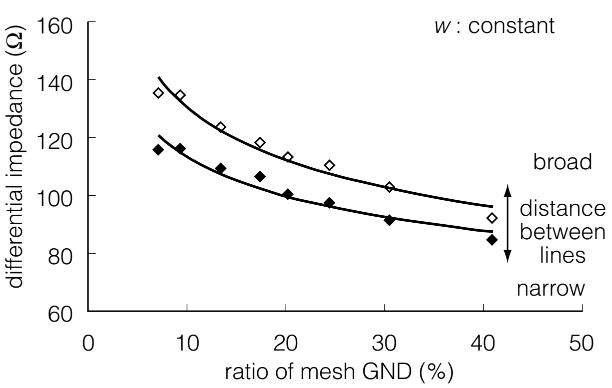


Fig. 4. Differential impedance of FPC designed by meshed GND.

4. Matching of measurement value and simulation value

If we calculate impedance by the three-dimensional electromagnetic field simulator, modeling is important in matching the measurement value and simulation value (Fig. 5). We need to define the conditions that adjust to every design of FPCs because the results of simulation change by the size of the divided calculation area. If the size of the divided calculation area of the model is inadequate, the calculation value is not in good agreement with the measurement value as the calculation value A in Fig. 6. Considering this, we used an adequate simulation model and reached a good agreement between the calculation value and the measurement value as calculation value B in Fig. 6. Figures 7 and 8 show the chart of comparison between the calculation value simulated by an adequate model and the measurement value of characteristic and the differential impedance. As just described, we attained good agreement between the values.

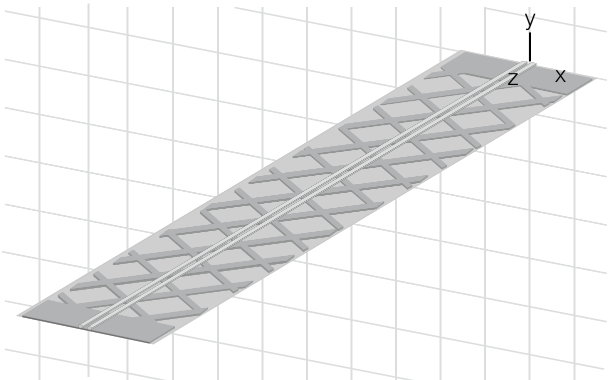


Fig. 5. Simulation model.

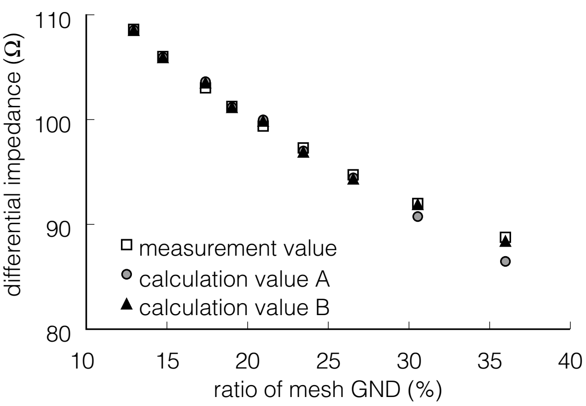


Fig. 6. Difference of simulation model.

5. Conclusion

We manufactured FPCs with transmission lines and measured the differential impedance by TDR to control FPCs' differential impedance. Also, we simulated transmission lines by the three-dimensional electromagnetic simulator installed recently in our company. We accomplished to design FPCs that control the target characteristic and differential impedance in mesh GND structure by introducing simulator's calculation.

Finally, we wish to express our gratitude to all the people concerned for their guidance and cooperation.

References

1) Y. Sakaguchi, et al.: "An Investigation of Impedance Controlled Flexible Printed Circuit", Fujikura Technical Journal No.109, pp.27-30, 2005

2) H. Watanabe, at al.: "An Investigation of FPCs High Frequency Characteristics", Fujikura Technical Journal No.110, pp.19-22, 2006

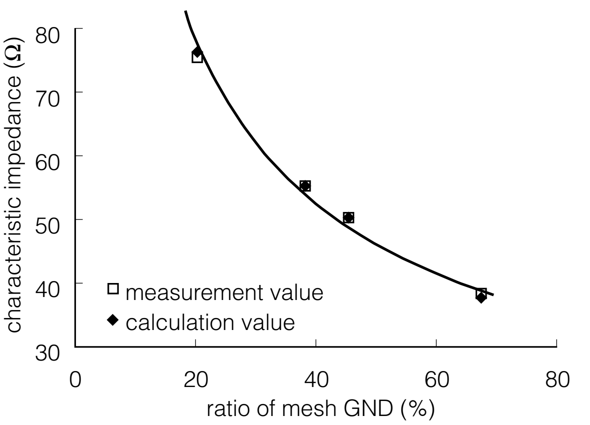


Fig. 7. Comparison between measurement value and calculation value of characteristic impedance.

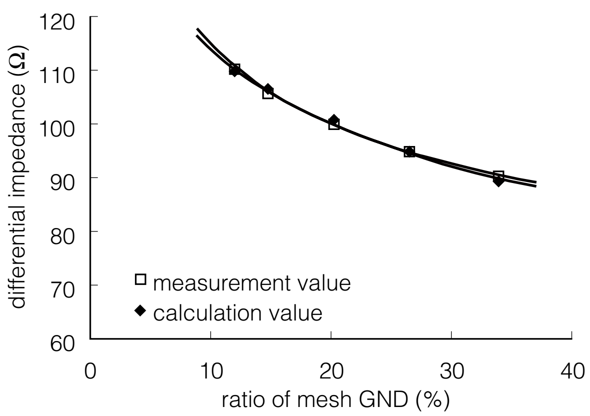


Fig. 8. Comparison between measurement value and calculation value of differential impedance.