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TECHNICAL REPORT

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Flexible printed circuit boards (FPCBs) – Method to decrease signal loss by using noise suppression materials

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FLEXIBLE PRINTED CIRCUIT BOARDS (FPCBs) – METHOD TO DECREASE SIGNAL LOSS BY USING NOISE SUPPRESSION MATERIALS

FOREWORD

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IEC TR 63018, which is a technical report, has been prepared by IEC technical committee 91: Electronics assembly technology.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
91/1284/DTR	91/1309/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- replaced by a revised edition, or
- amended.

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INTRODUCTION

In recent years, since the use of smart phones, and other mobile and display devices has increased significantly, the supply of FPCBs has also been largely extended. Specifically, since the FPCB devices seek high speed performance, the requirements with respect to electromagnetic interference (EMI) suppression in the devices has also grown in importance. Therefore, FPCBs used inside smart phones employ noise suppression materials (NSMs) to solve EMI problems, as shown in Figure 1.

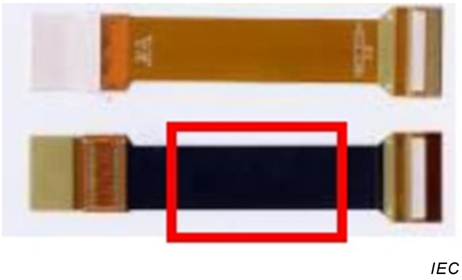

Figure 1 – Bare/shield FPCB

However, an application of noise suppression materials (NSMs) for FPCBs reaches the limit concerning the problem of incrementation of signal loss. Therefore, FPCB and NSMs manufacturers need to analyse signal loss variations of FPCBs shielded by NSMs, as shown in Figure 2.

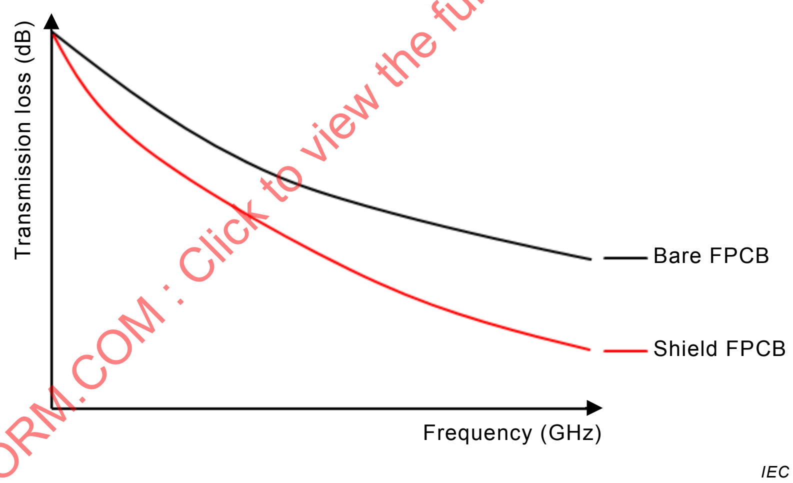

Figure 2 – Increment of signal loss using NSMs

As FPCBs are used with high frequency, the problem of signal loss becomes more significant. As the user of FPCBs has a demand for the lowest value of signal loss by using NSMs, suppliers of FPCBs have to anticipate an appropriate design in order to achieve an adequate signal loss value.

FLEXIBLE PRINTED CIRCUIT BOARDS (FPCBs) – METHOD TO DECREASE SIGNAL LOSS BY USING NOISE SUPPRESSION MATERIALS

1 Scope

This Technical Report specifies a guideline for improvement of signal loss by using noise suppression materials (hereafter referred to as NSMs) for FPCBs.

This Technical Report also indicates a measuring method of signal loss variations of FPCBs using NSMs using network analyzer equipment. In addition, this method only measures the value of the signal loss variation by using NSMs for FPCBs. This report, however, neither determines nor indicates the structure or material of FPCBs.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62333-1:2006, *Noise suppression sheet for digital devices and equipment – Part 1: Definitions and general properties*

3 Test guideline

3.1 Apparatus

3.1.1 Network analyzer

A network analyzer is utilized to identify signal loss data at a specific frequency range of FPCBs.

3.1.2 Block diagram for signal loss measuring

Figure 3 indicates one of the examples of the network analyzer setup.

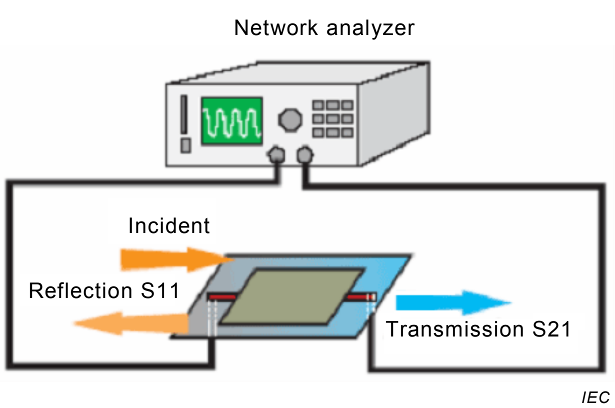

Figure 3 – Signal loss test system

3.2 Test specimen

3.2.1 Structure

Test specimens shall be designed by two structures, i.e. with and without NSMs in one FPCB board. The part without using NSMs is called bare FPCB. The part using NSMs is called shield FPCB, as shown in Figure 4. This test coupon shall also be designed as two types in order to have an object of comparison. The first design shall be composed of one bare FPCB with one shield FPCB. A design of this structure allows to compare the bare FPCB with the shield FPCB, as shown in Figure 4 a. The second design shall be composed of one bare FPCB with two over shield FPCBs. This structure allows to compare the bare FPCB with the two over shield FPCBs, as shown in Figure 4 b.

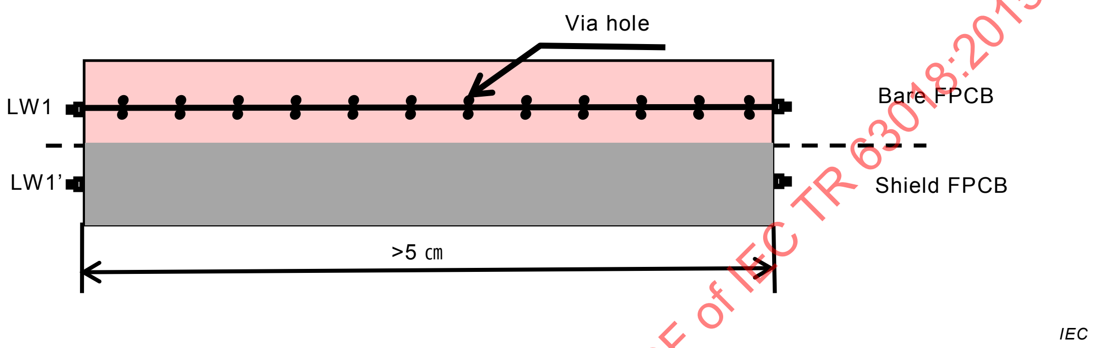

Figure 4 a – Test specimen for comparing one bare FPCB with another shield FPCB

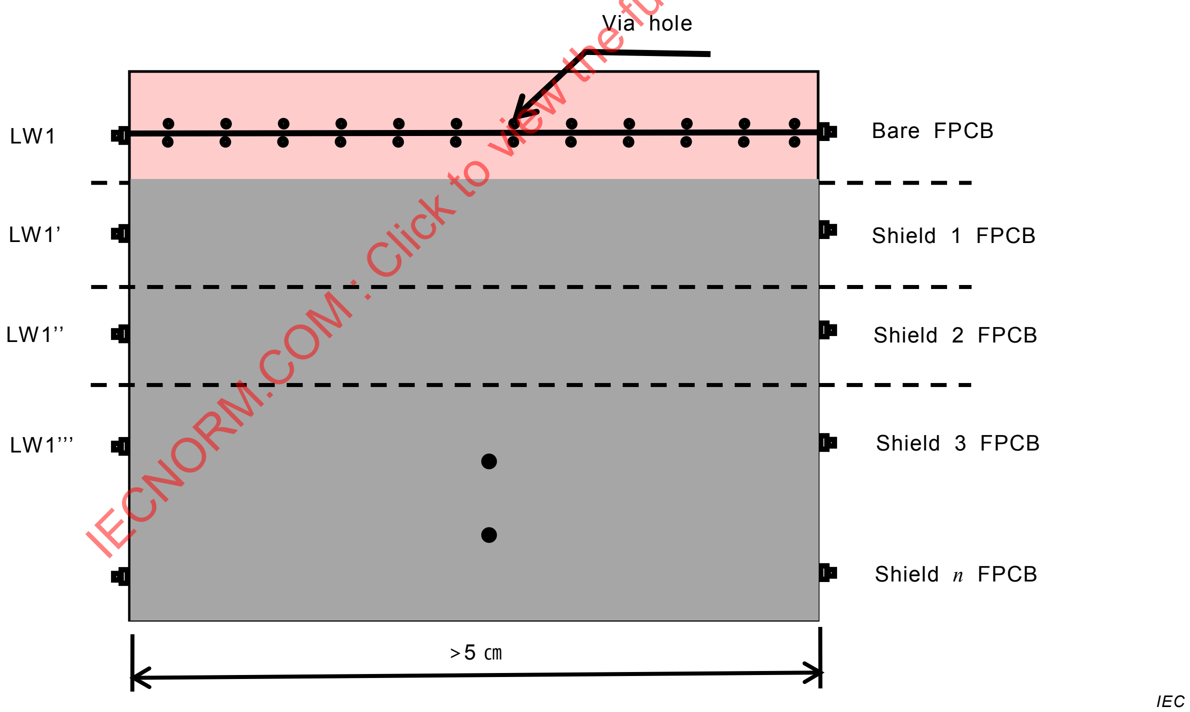

Figure 4 b – Test specimen for comparing one bare FPCB with two over shield FPCBs

Figure 4 – Schematic diagram for two type of test specimen

The test specimen shall be divided into two halves with one board (bare FPCB and shield FPCB) for equitable estimation with the same Cu line (LW1, LW1'...). This structure has the merit of uniformly measuring at once a bare and a shield FPCB under the same conditions.

The Cu line is formed with a linear distance of direction, because the variation of shield effect is very weak for the curved line. The width of Cu line shall be chosen freely in the allowance range of a manufacturing process. The size and spacing of via holes shall not be limited. Especially, via holes offer an important role to contact the NSMs with the ground plan of shield FPCB, as shown in Figure 2. However, the size, spacing and amount of via holes shall be as agreed between user and supplier (AABUS).

The length of test specimens shall be over 5 cm in order to obtain stable values from measuring equipment. The width and thickness of test specimens shall be in accordance with the needs of the end user.

Figure 5 indicates one of the examples of a cross-section of a shield FPCB, where the shield region shall be formed just above the bare FPCB. The shield region contains the shield insulation layer, the shield conductive layer and the shield conductive adhesive layer. Where the shield conductive layer plays a role in an EMI absorber, the shield conductive adhesive layer plays a role for electric interconnection between the shield conductive layer with the ground layer, and the shield insulation layer plays a role to protect the shield conductive layer from direct contact with the external device.

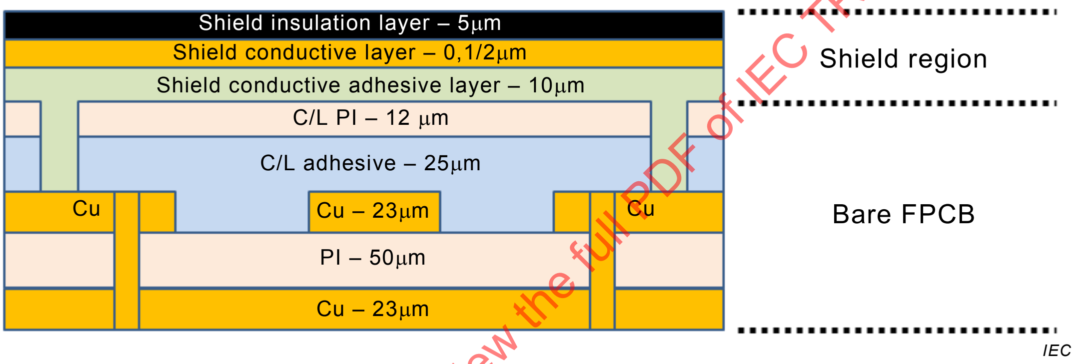

Figure 5 – Cross-section of shield FPCB

However, generally the structure of a test coupon shall also be as agreed upon between user and supplier (hereafter referred to as AABUS). The structure and materials of the test specimens is required depending on the user's sample specifications. But the variation of these test specimens is not important, because the user for FPCBs shall check only the signal loss variation effect by using NSMs.

3.2.2 Preparation

The following steps are needed to prepare the test.

a) First, prepare a 5 cm over length for a bare FPCB. Then, apply NSMs lamination to half of the FPCB.

b) Each end of the test specimen shall consist of SMA (subminiature A) connectors.

c) To designate the Cu line width, write the number (or symbol) to the bare side end (or shield side end) of test specimen near the SMA connector.

3.2.3 Test method

In order to measure the proper signal loss value, the following procedures shall be respected.

a) The signal loss values of the test specimen shall be measured by composition of a network analyzer, a test specimen and a coaxial cable.

b) The measurement conditions shall be set in the network analyzer, such as the frequency range, dielectric constant, measurement point, etc.

c) Coaxial connectors (SMA) of test specimens shall be connected with coaxial cables.
d) Measure the signal loss value of the test specimen for bare FPCBs.
e) Repeat a measurement of above for shield FPCBs.
f) In order to obtain the correct data, a direct hand contact to the specimen should be avoided as the electrostatic capacity varies.

3.2.4 Calculation

The following applies to the calculation of the loss values.

a) Calculate the difference of the signal loss value between bare FPCBs and shield FPCBs according to an S-parameter analysis, as shown in Figure 6.
b) Estimate the shield effect of NSMs according to frequency. The signal loss (transmission loss, S21) shall be increased by the shield effect of NSMs. The difference (ΔTL) of the signal loss value between bare FPCBs and shield FPCBs shall be gradually increased by a higher frequency.
c) Re-design a signal loss margin of the bare FPCB to predict an application of shield materials (NSMs).

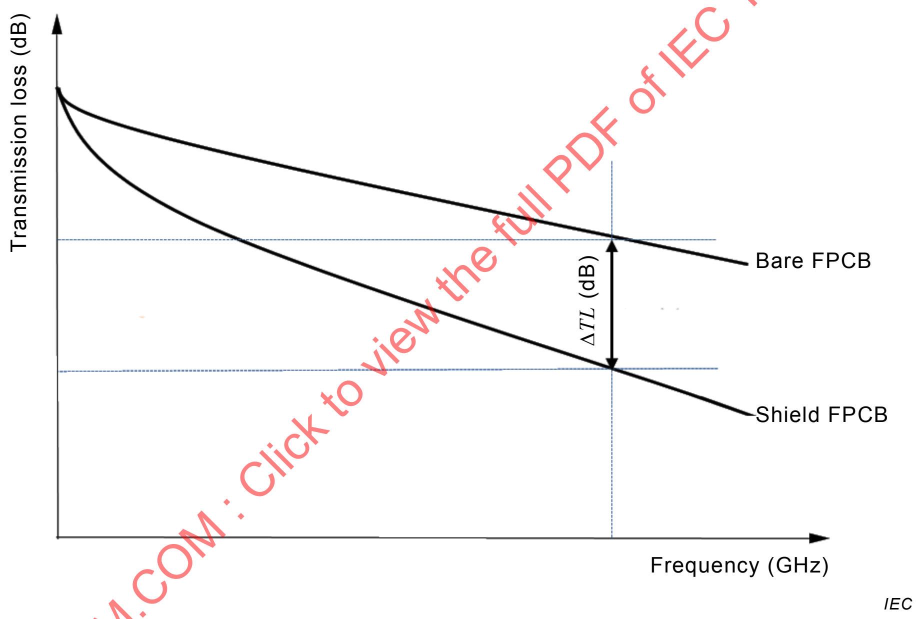

Figure 6 – Difference of signal loss between bare and shield FPCBs

3.2.5 Test result

3.2.5.1 Comparison of signal loss between bare and shield FPCBs

Figure 7 indicates an example of the signal loss value of a bare FPCB and a shield FPCB. Signal loss (S21) of a shield FPCB (at Cu signal line width 40 μm) has been additionally increased by 2 dB ~ 7 dB as compared with a bare FPCB at 10 GHz frequency. In addition, a signal loss of a shield 2 FPCB with a thin Cu/Ag conductive layer (0,1 μm) has been increased to 5 dB as compared to a shield 1 FPCB with a thick Cu conductive layer (2 μm).

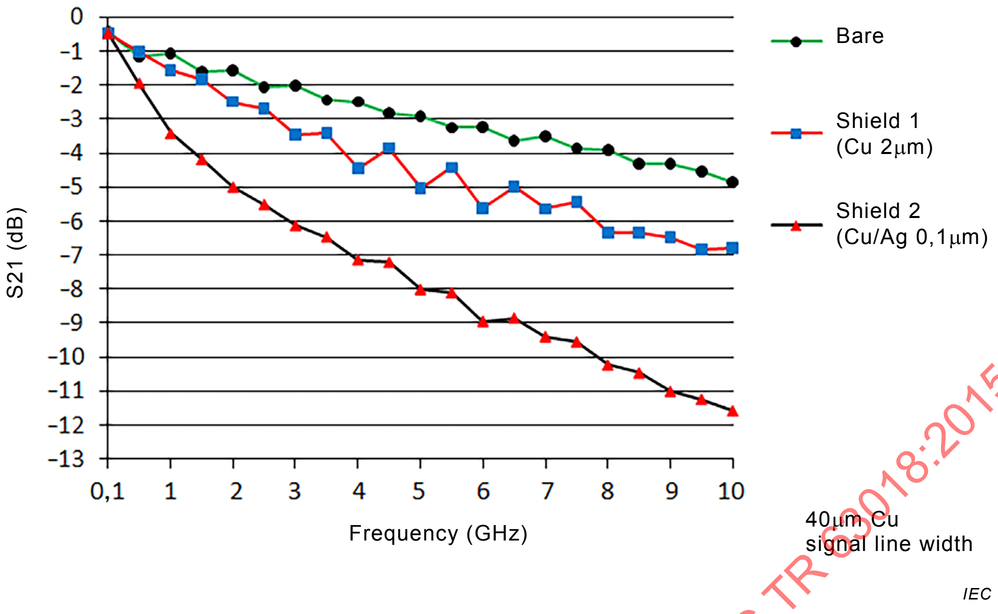

Figure 7 – Signal loss value of the bare and shield FPCB

3.2.5.2 Comparison of cut-off frequency between bare and shield FPCB

Table 1 presents a comparison of cut-off frequency between a bare FPCB and a shield FPC, whose shield FPCB has been divided into two types of shield film. The 3 dB cut-off frequency in Figure 7 is 5,15 GHz in the case of a bare FPCB, 2,71 GHz in the case of a shield 1 FPCB and 0,87 GHz in the case of a shield 2 FPCB. Therefore, a bare FPCB can be applicable for a 5 GHz frequency range, but a shield 1 FPCB cannot be applicable for an over 3 GHz frequency range. Especially, a shield 2 FPCB cannot be applicable for an over 1 GHz frequency range.

Table 1 – Comparison of cut-off frequency with bare/shild FPCB

Classification	Structure		
	Bare	**Shield 1** (Cu 2 µm)	**Shield 2** (Cu/Ag 0,1 µm)
Cut-off frequency (at 3 dB)	5,15 GHz	2,71 GHz	0,87 GHz

3.2.5.3 Effect of the Cu conductive layer thickness

The shield region shall be included in the Cu conductive layer, as shown in Figure 5. Figure 8 presents a comparison of signal loss variation (S11, S21) according to the thickness of the Cu conductive layer. Variation of signal loss according to the Cu conductive layer thickness (2 µm 6 µm, 12 µm) of a shield FPCB (at Cu signal line width 40 µm) is within the small range of 1 dB.

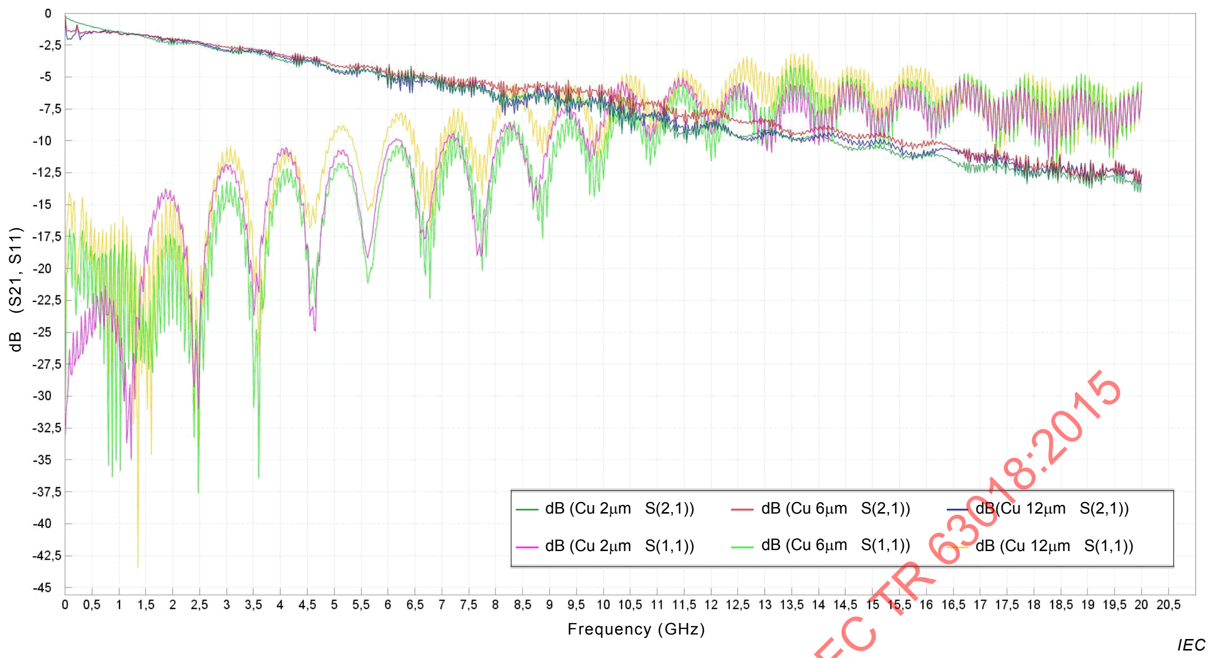

Figure 8 – Signal loss variation according to the Cu conductive layer thickness

3.2.5.4 Effect of the Cu signal line width

Figure 9 presents a comparison of signal loss variation according to the width of the Cu signal line. Variation of the signal loss according to the width (40 µm, 60 µm, 80 µm) of a Cu signal line (at Cu conductive layer thickness of 2 µm) is within the small range of 1 dB.

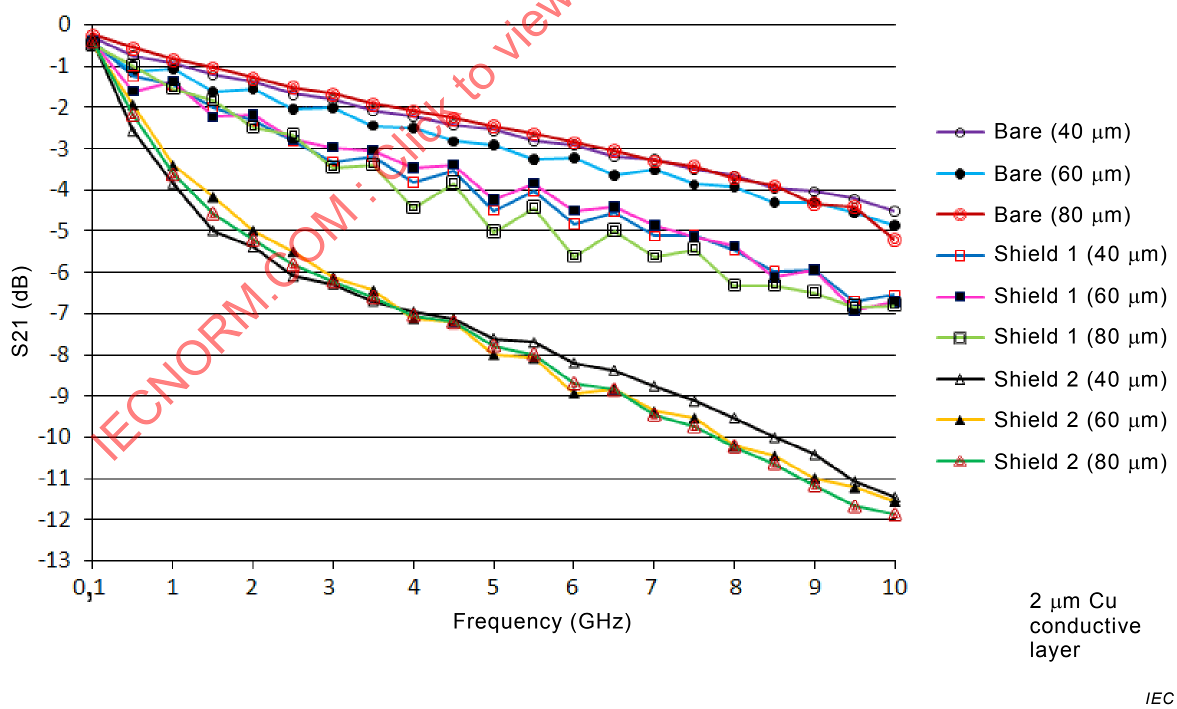

Figure 9 – Signal loss variation according to the Cu signal line width

3.2.6 Analysis

3.2.6.1 A cause of the signal loss difference between bare and shield FPCBs

Figure 10 presents examples of two types of FPCB structure. The major cause of the signal loss increment between bare FPCBs and shield FPCBs is the structure variation from the micro-strip line without using NSMs to strip line using NSMs.

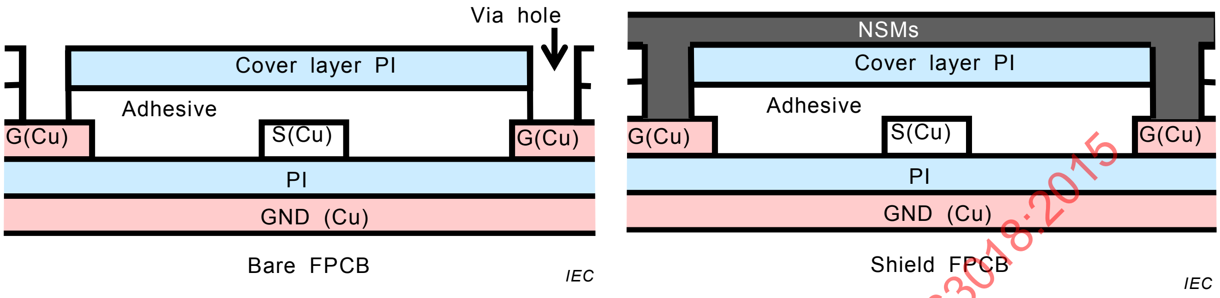

Figure 10 a – <FPCB of micro strip line structure> **Figure 10 b – <FPCB of strip line structure>**

Figure 10 – Two types of structure for FPCB

Generally, the transmission line of a bare FPCB in its first stage shall be designed by a micro-strip line structure in order to achieve the lowest signal loss. But, after an application of NSMs to a bare FPCB, the transmission line shall be changed at the strip line structure and then the signal loss increased.

3.2.6.2 A cause of the signal loss difference between shield films

In Figure 7, signal loss of a shield 2 FPCB has been increased to compare it with a shield 1 FPCB. A signal loss difference between shield 1 FPCB and shield 2 FPCB shall be analysed as follows. Figure 11 shows the distribution diagram of an electric field of two types of shield FPCBs. Shield 1 FPCB is composed of a 2 μm thickness of Cu conductive layer, the electric field around the Cu signal line shall be uniform. But, on the other hand, a shield 2 FPCB is composed of 0,1 μm thickness of a Cu/Ag conductive layer, therefore the electric field around a Cu signal line shall be non-uniform by the cause of incomplete electric conduction with a too thin film. To simplify the illustration, the ground interconnection line has been omitted in Figure 11.

A major cause of the signal loss variation according to the type of shield films is the formation of an unbalanced electric field by using low conductive NSMs. In the case of the shield 2 FPCB, a possibility of high resistance between a Cu conductive layer and a ground layer shall exist. The high resistance shall be caused by a thin Cu conductive layer and/or poor via-hole connection.