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LETTER

A low loss microstrip line on thin flexible substrate film by defected ground structure

Akihisa Tsuchiya [1, a), Yuya Yamaguchi [2], Ryosuke Suga [2, b), Masahiro Takeda [3], Eiji Inami [3], Hideaki Sugama [1], and Osamu Hashimoto [2]

Abstract In this paper, a low loss micro-strip line (MSL) on thin flexible substrate was realized using defected ground structure (DGS). DGS allows thinner MSL than conventional MSL maintaining insertion loss and far-end crosstalk. MSL with DGS on the flexible substrate with a thickness 25 μm was realized the same insertion loss and far-end crosstalk in comparison with conventional MSL on the substrate with a thickness 50 μm while analyzing by 3D electromagnetic simulation. The MSL with DGS was fabricated and evaluated to confirm the simulated results. Excellent agreement with the measurement results was demonstrated over the broad bandwidth of 1-40 GHz.

Keywords: flexible printed circuit, microstrip line, defected ground structure

Classification: Transmission systems and transmission equipment for communications

1. Introduction

High-speed data transmission standards, such as USB4.0 and PCI-express, which achieve a data rate of over 10 GB/s, are widely used for electronic devices. A transmission line, such as Flexible printed circuits (FPCs) and flexible flat cables (FFCs), are required to reduce insertion loss and the thickness of substrate because of the miniaturization of electronic devices. Insertion loss of the transmission line increases dramatically with frequency increased over microwave band. Moreover, when the thickness of the substrate ranges from 25 to 100 μm, the insertion loss of the transmission line increases as well because the set width of the line is narrower for matching the characteristic impedance of the line.

A micro-strip line (MSL) and coplanar waveguide (CPW) are typically used in FPCs and FFCs as transmission lines in microwave and millimeter-wave band [1, 2, 3, 4]. A CPW can achieve low insertion loss requirement because width of the line set to wider than that of MSL. But A CPW could hardly be arranged multiple line in narrowed substrate because the ground plane sets along the line at same planar layer. An MSL fabricated on a mesh-type ground has been proposed to reduce insertion loss [5]. However, it is difficult to match the characteristic impedance of the line on the mesh-type ground.

To effective approach, Defected Ground Structure (DGS) which was used by phase shifter was proposed to reduce insertion loss [6, 7, 8, 9]. Since DGS has defected structure in the ground under the line, width of MSL can be set wider than that of conventional type MSL. In addition, MSL with DGS can be arranged multiple line on same layer conductor and set to characteristic impedance of the line easily. Since DGS has various characteristics depending on the purpose of utilizing, it must be optimized to reduce insertion loss and far-end crosstalk.

In this study, low loss MSL on thin flexible substrate by DGS was proposed. A MSL with DGS on substrate with thickness 25 μm was realized to same insertion loss and far-end crosstalk compared with conventional type MSL with thickness 50 μm. The MSL with DGS was analyzed the transmission characteristics by 3D electromagnetic simulator. The MSL with DGS was fabricated and evaluated to confirm the simulated results.

2. Transmission characteristics analysis

The MSL with DGS was simulated using a 3D electromagnetic simulator and the transmission characteristic was analyzed [10]. Figure 1 depicts schematics of the MSL with DGS. The substrate and line conductors were 25 μm and

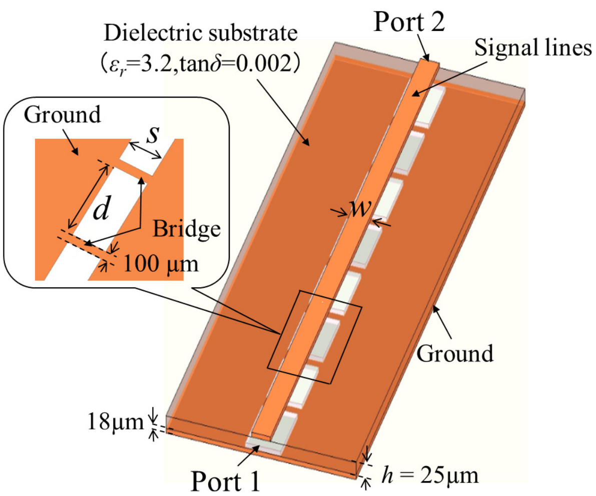

Fig. 1 Schematics of MSL with defected ground structure

[1] Kanagawa Institute of Industrial Science and Technology, 705-1 Shimoimaizumi, Ebina-shi, Kanagawa, 243-0435 Japan.
[2] Department of Electrical and Electronics Engineering, Aoyama Gakuin University, 5-10-1 Fuchinobe, Chuo-ku, Sagamihara-shi, Kanagawa, 252-5258 Japan
[3] Yamashita Materials Corporation, 1-44-12 Komatsubara, Zama-shi, Kanagawa, 252-0002 Japan
a) tsuchiya@kistec.jp
b) rsuga@ee.aoyama.ac.jp

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18 μm for thickness. The signal line and ground plane were made of a copper sheet. The relative permittivity of the substrate, which assumes liquid crystal polymer film, was 3.2 and the dielectric loss tangent δ was 0.002. The width and the length of DGS was set to s and d respectively. The ground planes separated by the structure were connected to the bridges of which the width was set to 100 μm, to decrease the electric potential difference between both sides.

Figure 2 depicts width of the MSL over the width of DGS when characteristic impedance of the line is set to 50 Ω. The width of the line increased as the width of DGS increased. When the width of DGS was 200 μm, the width of the line was 130 μm and 80 μm wider than that of the conventional MSL.

The attenuation constant of MSL with DGS was divided into three components, namely dielectric loss, conduction loss, and radiation loss to investigate the effectiveness of the structure [11]. Figure 3 depicts the three components comprising the attenuation constant of the MSL with DGS over the width of DGS at 40 GHz. In this case, the length d of DGS is set to 400 μm. The total loss was reduced as the width of DGS was increased from 0 to 400 μm. However, the total loss increases from more than 400 μm because the dielectric loss and radiation loss increased to over 200 μm. The conduction loss decreased as the width of DGS increased. The above results show that the attenuation constants can be reduced by using DGS.

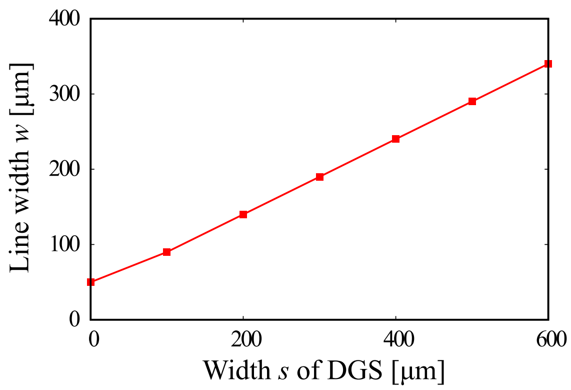

Fig. 2 Width of MSL over width of DGS when characteristic impedance of the line is set to 50 Ω

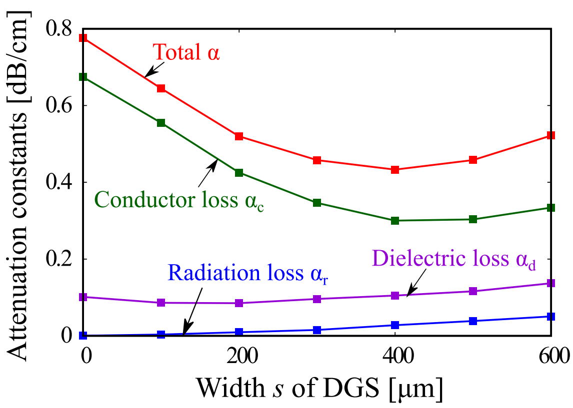

Fig. 3 3 components comprising the attenuation constant of the MSL with DGS over width of DGS

3. Optimization of defected ground structure

The width s and length d of DGS were optimized to realize same insertion loss S_{21} and far-end crosstalk S_{41} as conventional MSL on the substrate with a thickness 50 μm.

Figure 4 depicts the schematic of MSL with DGS to evaluate transmission characteristics. Length of transmission line was set to be 100 mm. Two lines were placed with 580 μm on distance and input ports were set at the lines respectively to investigate transmission characteristics between both lines. The far-end crosstalk was considered to interference between both lines.

Figure 5 depicts the insertion loss S_{21} and far-end crosstalk S_{41} of the MSL with DGS over the width of the slot at 40 GHz. Insertion loss and far-end crosstalk of conventional MSL of which substrate was 50 μm for thickness were shown as dash line on the graph. The insertion loss reached the peak at s=200 μm, while the far-end crosstalk increased with width of slot increased. The far-end crosstalk of MSL with DGS reached over that of MSL at 300 μm for width of slot. Width of DGS was fixed at 200 μm to became same transmission characteristics as the MSL.

Figure 6 depicts insertion loss and far-end crosstalk of the MSL with DGS over the length of the slot at 40 GHz. When the length of DGS was increasing, the insertion loss decreased gradually, but far-end cross talk has peak at 100 μm and decreased from 200 μm. Insertion loss of MSL

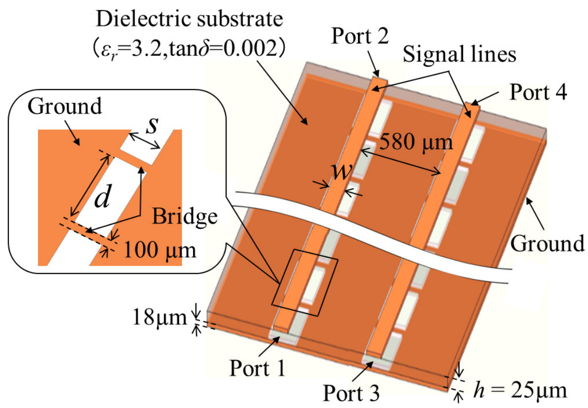

Fig. 4 Schematics of MSL with DGS to evaluate transmission characteristics

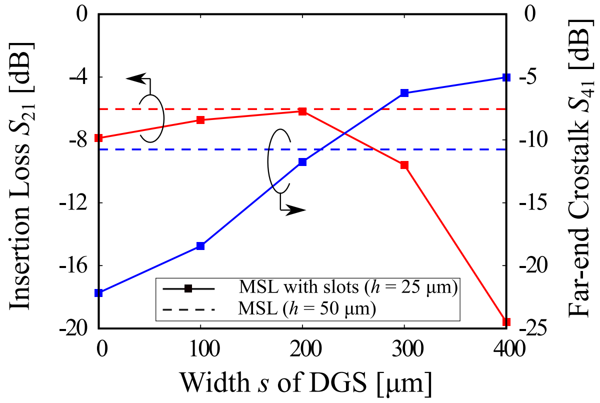

Fig. 5 The insertion loss and far-end crosstalk over the width of DGS.

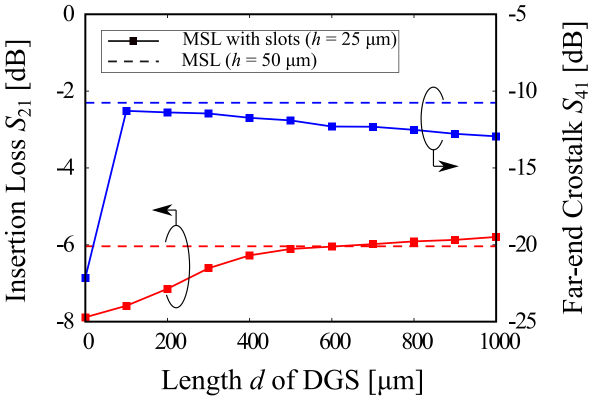

Fig. 6 The insertion loss and far-end crosstalk over the length of DGS.

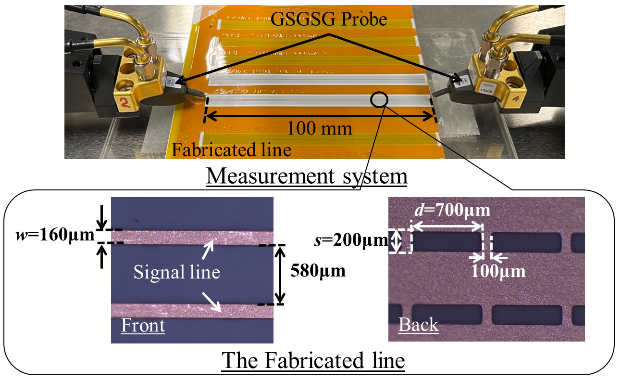

Fig. 7 The fabricated line and the measurement system

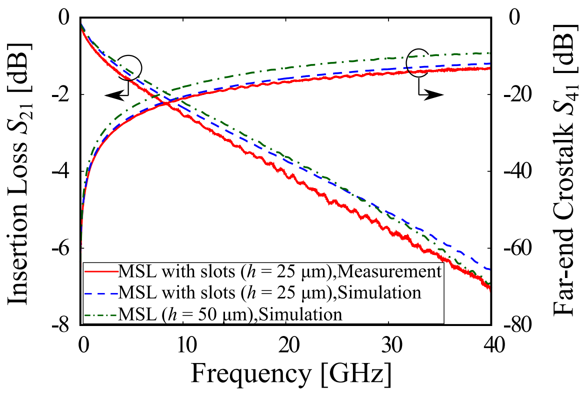

Fig. 8 Frequency dependence of measured and simulated insertion loss and far-end crosstalk of the MSL with DGS

with DGS reached over that of the MSL at 700 μm. As a results, length of DGS was decided to set 700 μm to provide transmission characteristics equivalent to that of the MSL.

4. Measurements

The transmission characteristics of the MSL with DGS were measured in the frequency range from 10 MHz to 40 GHz to confirm the simulated results.

Figure 7 illustrates a photograph of the fabricated line and the measurement system. MSL with DGS was fabricated on LCP film with thickness 25 μm having flexibility. DGS was set as 200 μm for width and 700 μm for length. The transmission characteristics of the lines was measured by using a 4-port vector network analyzer (VNA) with a probe station. Ground-signal-ground-signal-ground (GSGSG) probes connected with 4 ports of the VNA were set on probing pads on which a conductor-backed coplanar waveguide was formed.

Figure 8 depicts frequency dependence of measured and simulated insertion loss and far-end crosstalk of the MSL with DGS. The simulated results of the MSL with thickness 50 μm were shown on the graph. Frequency dependence of the measured results was roughly consistent with simulated results. The insertion loss of measured results increased by 0.42 dB for maximum compared to that of simulated results.

The difference of insertion loss between measured and simulated results is due to surface roughness of conductor because surface roughness is not considered on the simulation [10]. the far-end crosstalk of measured results is also consistent with the simulated results. As shown on above the measurements, the MSL with DGS was confirmed to have effective to fabricate thinner FPCs and FFCs.

5. Conclusion

The MSL with DGS which was fabricated on the substrate with 25 μm for thickness was aimed at the same transmission characteristics in comparison with that of a conventional MSL on the substrate with 50 μm. The proposed line was confirmed to realize a low insertion loss on thin flexible substrate by 3D electromagnetic simulation analysis. The decrease in the insertion loss of the proposed line was due to the decrease in conduction loss. Transmission characteristics of the proposed line fabricated on thin flexible substrate were measured to confirm the simulated results. The measured results of the lines were consistent with the simulated results for all frequencies. the proposed line has effective for thinning FPCs and FFCs to compare with MSL.

Acknowledgments

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