High-Frequency Characterization of Printed CPW Lines on Textiles using a Custom Test Fixture

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Abstract

A screen printer is used to print conductive inks, loaded with silver particles, on nonwoven textiles substrates. To evaluate this technology for use as flexible interconnects; a custom test fixture was designed to assist in the high frequency characterization of CPW transmission lines. Due to the flexible nature of textile substrates it is necessary to have mechanical support at the points of electrical contact. However, the test fixture must not alter the electrical characteristics of the CPW lines. This test fixture removes the electrical effects of the mechanical support, and provides a simple and repeatable methodology for evaluating various types of textiles substrates, conductive inks, geometrical variations, and other parameters. Time-domain reflectometry (TDR) is used to measure the characteristic impedance of samples across geometrical variations in the 10cm long CPW lines. A comparison showing the effects of the measuring the samples using the test fixture to measuring the samples on a solid acrylic substrate, and a metal plate are presented.

Keywords: wearable electronics, electronic textiles, RF and microwave testing, printed electronics, polymer thick film

Introduction

In this research, we adapt the technologies used in the polymer thick film (PTF) industry and apply them to our nonwoven textiles research effort. Instead of weaving or knitting conductive yarns with fabrics [1], we are screen printing conductive inks on to nonwoven substrates. The goal of this research is to determine if already mature manufacturing methods can be combined to create a new technology that has cost advantages for creating flexible interconnects. This technology could be used for wearable electronics, in biomedical applications, or for traditional flexible interconnection.

Screen printing is the preferred manufacturing process of the PTF industry. This process delivers a thick ink deposit under controlled conditions while maintaining print clarity [2]. In addition, PTF inks can be screen printed onto almost any flexible substrate without resorting to the use of environmentally hazardous and harsh chemicals used in traditional copper circuitry methods. Overall, PTF is a simple and low cost process that has an extremely low impact on environmental issues related to the use of hazardous chemicals for such a manufacturing process [2].

The substrate chosen for the results reported was surface treated Tyvek® and the conductive ink was Creative Material's CMI 112-15. The screen printer used for these experiments was a DeHaart EL-20 flatbed semi-automatic screen printer with a dual squeegee head.

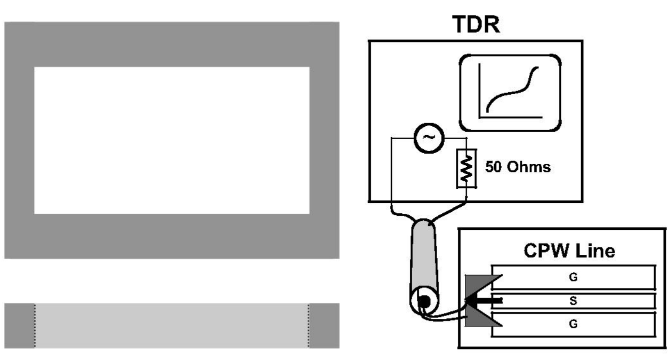
This paper presents the benefits of the developed test fixture for accomplishing TDR measurements on a surface treated Tyvek®. Many other performance metrics are evaluated in this research, but are beyond the scope of this paper.

Test Fixture for High-Frequency Characterization

In order to accurately measure the characteristics of CPW lines printed on textile substrates, we found it was necessary to develop a test fixture to mechanically support the sample and allow for high-frequency probes to be landed in a repeatable manner. This test fixture should not alter the characteristics of the device under test (DUT). The test fixture was made from a 8.3mm thick acrylic substrate that is machined to create a void beneath the CPW lines. The opening or void was machined slightly shorter in length to provide a small region of mechanical support on both ends. This small region also provides a stable region to probe the CPW lines. Figure 1a illustrates the top and side views of the test fixture and the portion of material that was removed to create a void that the textile substrate spans.

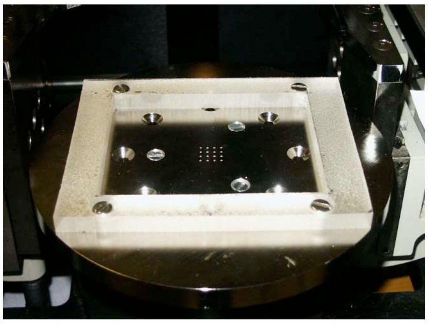
Since any material in close proximity would alter the CPW line's electrical behavior, the removal of the material from beneath the textile is important for the high-frequency characterization of CPW lines. The textile is placed on the test fixture and a light application of a spray adhesive is used to secure the ends of the samples to the test fixture during measurement. Multiple text fixtures with varying void dimension can be made so that thru-reflect-line (TRL) de-embedding can be conducted by measuring S-parameters with a vector network analyzer (VNA).

Time-domain reflectometery measurements of the CPW lines are conducted to determine the characteristic impedance; using a Tektonix 11801B Digital Sampling Oscilloscope in TDR mode and GGB Model 40A GSG Probes with a 1250µm pitch. This configuration minimizes the effects of SMA connections and solder joints [1]; thereby, enabling consistent and repeatable method for characterization. Figure 1b illustrates the test setup used for the reported measurements. In Figure 2a the test fixture is mounted to the probe station chuck. Figure 2b shows a 10cm long set of CPW lines under examination using the custom test setup.

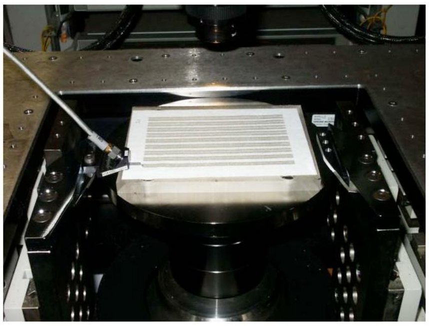


(a) (b)

Figure 1: (a) Top & side views of test fixture, (b) Test setup



(a)



(b)

Figure 2: (a) Test fixture mounted on probe station chuck, (b) 10cm long samples being characterized

CPW Line Characterization: TDR Measurements

CPW lines printed on textiles substrates are measured to determine their characteristic impedance. Shown in Figure 3 is a cross sectional view of a finite ground CPW line structure. The CPW line structures consisted of 10cm long lines having variations in center conductor width (a), with a fixed the gap (W) between the center and ground. The measurements were conducted by placing one GSG probe on the CPW line, while the other end of the line was left open and un-terminated.

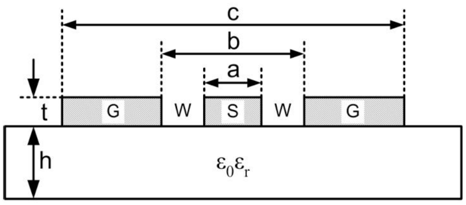
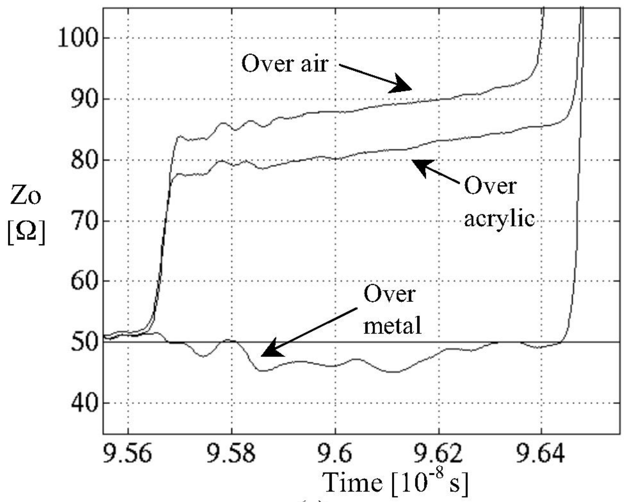
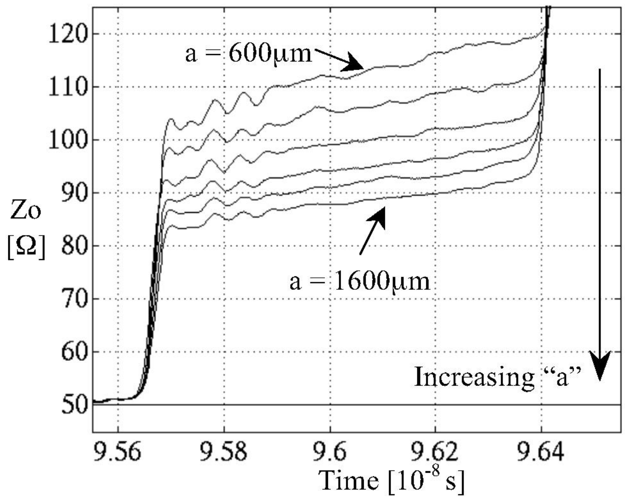


Figure 3: Geometric parameters of CPW line

To illustrate the impact of dielectrics and conductors beneath the surface of the textile substrate being characterized, a comparison of a 10cm CPW line with geometric parameters of G=2000μm, W=300μm, and a=1600μm. As expected, the surrounding material alters the characteristics of the CPW lines. The raw TDR data, figure 4a, shows that the dielectric constant of the solid acrylic substrate reduces the characteristic impedance and the propagation velocity of signals on the CPW line. These results also show that placing a metallic plate beneath the textile drastically alters the behavior of the line. This change occurs because the basic topology of the line has now been modified due to the addition of the underlying conductive plane. Another point of interest is that the propagation velocities of the samples over acrylic and over metal are approximately the same. This similarity is most likely due to the electric field dominating the propagation velocity, which in both causes, is penetrating a material with a similar permittivity (higher than air). Shown in Figure 4b are the raw TDR measurements for lines over air (using the test fixture) for G=2000μm, W=300μm, and the width of the center conductor being swept from a=600-1600μm in 200μm steps, yielding a range of characteristic impedance values from 80-105Ω.



(a)



(b)

Figure 4: TDR measurements: (a) comparing textile over air, acrylic, and metal, (b) over air for variuos line dimensions

Conclusions & Future Work

It has been shown that conductive inks can be printed on textiles substrates to create flexible interconnects. A test fixture was developed for assisting in the high frequency characterization, and its benefits are shown through measurement. Research efforts on various types of textiles, conductive inks, and their durability are currently in progress. These variations will be quantified by TRL de-embedding from VNA measurements, and TDR measurements.

References

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