Microwave Interconnects Between Textile and Rigid Substrates Using Permanent Magnets

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***Abstract*—This paper presents a new approach to the problem of the transition between a textile microwave system and a regular microwave system. A simulated model of a transition between copper conductive line and textile conductive line is presented, with a comparison between simulated and measured results of the same model showing reasonable to good agreement. The work aims to create a full textile remountable and flexible microwave connector.**

***Index Terms*—textile transmission line, textile transition, measurement.**

I. Introduction

In the last decades there has been an increase in the research of textile antennas and transmission lines, from advances in textile antennas [1], [2] and textile transmission lines [3], [4], to advances in the different techniques used to create this systems [5], [6]. There is however, the issue of connecting these textile systems to standard microwave equipment. A connection can be achieved by soldering a connector to a conductive thread but that connection is not flexible.

Some research has been done in this area [7], [8] and this paper will focus on setting the basis for a new approach to this problem. This paper presents a remountable and mechanical robust connection between a rigid substrate and a flexible textile. We consider the use of high performance permanent magnets to apply contact force in such an arrangement and the effect of the magnet placement on the radiofrequency performance.

II. Creating the Simulated Model

To simulate conductive thread embroidered in denim, a textile conductive line was simulated as a block of material in CST® MWS. The values of the Denim permittivity (ε_r) and Loss Tangent ($\tan\delta$) were obtained from [6] and the values used were $\varepsilon_r = 1.8$ and $\tan\delta = 0.07$ with the denim's thickness being approximately $0.43mm$. The magnets are $10 \times 3 \times 2mm$ Neodymium Iron Boron (NdFeB) Nickel coated magnets [9] and are placed directly under the ground plane and on top of the textile conductive line to apply contact force against the copper line. The value of the condutivity used for the magnets is $0.667 \times 10^6 S/m$.

The conductive thread is Liberator™ created by Syscom Advanced Materials and the conductivity value used is $9.47 \times 10^3 S/m$. This value was obtained from [10] and to have a quick prototype simulation it was assumed that the Liberator's™ filament thickness and coating thickness are the same as in Amberstrand®, with the filament thickness at 17μm and coating thickness 1μm. The conductive textile line was modeled with $3mm$ width and $25mm$ length.

The model is a $40mm$ long microstrip line etched in FR4 where the conducting line has a $16mm$ central gap. This model was built in CST® as well as in the lab for comparison. The gap in the microstrip is shown in Figure 1, this gap is then covered with the embroidered conductive thread which is held in place by magnets. The magnets are shown in Figure 2 as light blue blocks, the denim in dark blue and the Liberator™ in orange.

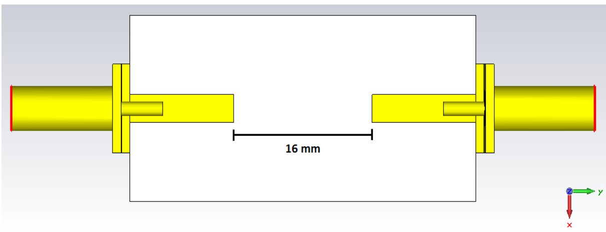

Fig. 1. Top view of the microstrip transition without the textile or magnets

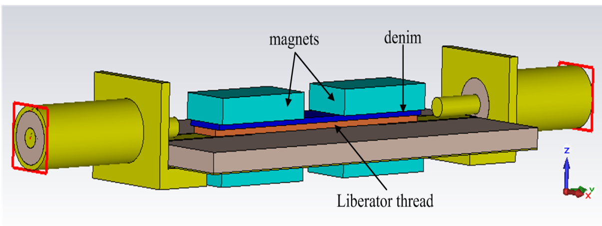

Fig. 2. Perspective view of the microstrip transition with textile line

III. Comparison Between Measured Results and Simulated Results

When performing measurements in the lab using an Anritsu MS4622B VNA, the microstrip gap was covered with either conductive thread in denim, or with a copper line etched in a very thin dieletric. In Figure 3 there are some differences in the S11 results regarding the simulated and the measured model when using the textile conductive line. This can be due to some mismatch in the simulated SMA ports or due to different electrical lengths between the simulated block and the conductive thread due to the embroidery process. The results with the copper line in the thin dielectric have a larger difference because in this setup the rectangular magnets orientation was rotated by 90°.

Regarding Figure 4 the simulated results are closer to the measured results, which could mean that the simulated characteristics are similar to the real model characteristics. Further improvements will be made to the simulated model as to improve the accuracy of the approximation.

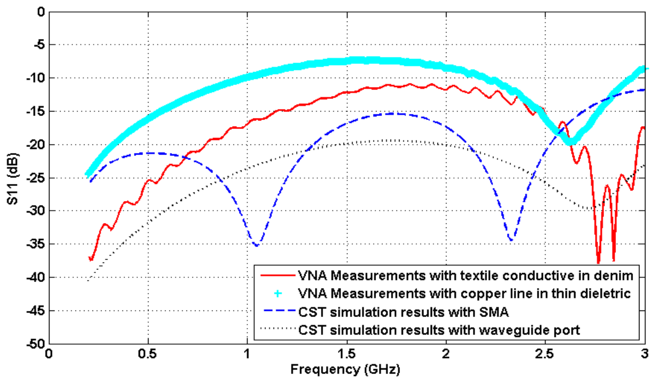

Fig. 3. Comparison between simulated and measured results

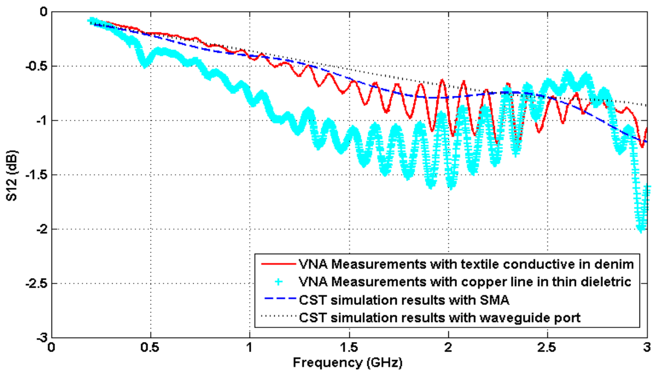

Fig. 4. Comparison between simulated and measured results

A. *Future Work*

The model that was presented in the previous section can not be yet called a full textile transition, since the textile conductive line only covers a microstrip gap etched on FR4. The next step is to do a full transition from a copper line in rigid FR4 dieletric to a textile conductive line in flexible Denim dieletric.

A $25 \times 16mm$ rectangular hole was cut across the FR4 board and through the ground plane which was then filled with 3 layers of denim to be used as a dielectric, on the top and bottom layer of the denim a microstrip and groundplane are designed using the Liberator™ model.

A simulation was ran using the same parameters for the Denim and Liberator™ thread with the simulated S12 result shown in Figure 5. The S12 value is above -1dB until approximately 2.7GHz, this shows that at least 89% of power is transmitted at this frequency.

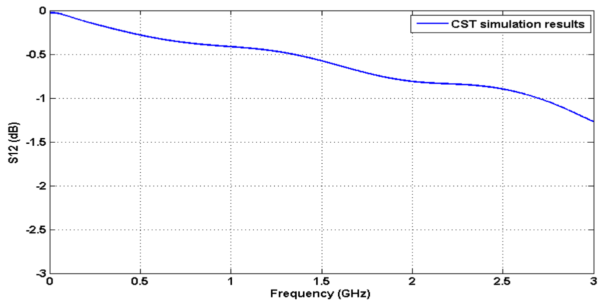

Fig. 5. S12 result of the transition between textile microstrip and FR4 etched copper microstrip

IV. Conclusion

This paper has demonstrated a new approach to the problem of producing a mechanically robust and remountable connection between a flexible textile and a rigid substrate using magnets, and that the contact force that is achieved from the permanent magnets used is suitable for a connection between a rigid substrate and a textile transmission line. The paper also demonstrated that the effect of the magnets in the insertion loss was low enough as to make the connection feasible.

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