High Frequency Attenuation Characterization of Knitted E-Textile Structures

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Abstract In this research study, knitted fabrics were produced on an E=12 gauge electronic flat bed knitting machine for the High frequency attenuation characterization in the frequency range of 1 GHz -1.5 GHz. Conductive yarns with different linear resistances were knitted into non-conductive base fabrics made from double covered PA 6.6 core spun lycra yarns. Two different design approaches have been applied for manufacturing of samples. In the first approach, conductive yarn has been knitted in plain arrangement into elastomeric interlock base fabric. In latter case, the base fabric was produced with elastomeric yarns in an interlock arrangement and a conductive yarn was embedded in this substrate to create a series of single loop structures. Effect of design approaches and conductive yarn linear resistance on high frequency attenuation properties of conductive knitted samples was investigated. It was observed while design differences have more effect on attenuation characteristics of samples, linear resistance values of conductive yarns have also slightly affected the properties of samples.

Keywords— Attenuation, Conductive Knits, E-Textiles, High Frequency, Conductive Yarns

I. INTRODUCTION

INTEGRATION of conductive materials into textiles is promoting a new range of functional textile materials over traditional textile applications, which are woven [1], knitted [2], and embroidered [3] to produce fabric for both structural and aesthetic purposes. Conductive materials, i.e., conductive yarns [4], conductive coating [5] or printing materials [6], can be used for creation of textile-based sensors [7], transmission lines [8] or textile-based antennas [9] within the electronic textile structures. Since electromagnetic waves radiates from electronic devices threats to human health, one specific application area of conductive textiles is creation of textile structures with electromagnetic shielding properties and there are many studies shows that harmful effect of electromagnetic field [10-12]. These harmful effects include but not limited to increase the chance of developing a brain tumor, cancers and problems associated with nervous system. Thus, conductive textile structures are suitable candidates due their lightweight, flexibility, as well as ease of manufacturing of desired products for wide range applications thanks to the developments in textile machinery and technology.

There are a few studies that investigate electromagnetic shielding properties of conductive textile structures. Coating of textile structures with conductive materials is one way to produce these structures and metal deposition on textile surfaces can be used to generate electromagnetic shielding. Kardarian et al. created silver coated textile structures by in situ synthesis of silver particles on textile surface combination with sintering process and they concluded that sintering process increased the shielding effectiveness of the structures [13]. Electroless plating is also widely preferred method to produce metal-coated electromagnetic shielding fabrics [14]. Inherently conducting polymers, i.e., polypyrrole, polyaniline can also be applied on textile surfaces to develop shielding fabrics [15]. Another main approach for the creation of textile-based electromagnetic shielding structures is the embedding of conductive yarns into knitted or woven structures [16]. As a distinction from the coated structures, they offer an integration of the conductive part during the manufacturing stage of the fabric. Thus, this approach reduces the production stage to one step. In addition to this, since conductive materials relatively more expensive, processing of conductive yarns along with nonconductive yarns to form textile structures is desirable in terms of cost issues.

The main purpose of this research was to investigate high frequency characterization of various knitted textile structures. One of the structures has been successfully employed as a strain sensor in our previous study [7]. Thus, this study will also reveal possible usage of same design for different application areas. The following section describes production of knitted strain samples followed by the measurement method for the high frequency
attenuation characterization in the range of 1 GHz and 1.5 GHz. The third part reports the results obtained from the experimental procedure and discussion of the electromagnetic shielding properties of the knitted structures.

II. MATERIALS AND METHODS

A. Materials

In this study, in order to do the high frequency attenuation characterization of e-fabrics, two silver conductive yarns with linear resistances of 50 ohm/m and 235 ohm/m were used to form electrical circuits in knitted fabric samples. The linear resistance of the conductive yarns was measured in ohm per meter (ohm/m) using a TTI 1906 computing multimeter. Polyamide covered lycra yarn with a yarn density of 800dtex was used to form an insulating area in the structure. The samples were produced by Shima Seiki SES124-S 12GG flat knitting machine. Two different knitting design were used to test the fabrics. The knitted designs of the samples with their original images are shown in Fig.1. The grey colored area shows the conductive zones which are designed using silver plated PA yarns.

![Fig. 1. Knitted sample designs](image_url)

B. Measurement method

In order to measure the high frequency attenuation of the samples, a straight wave guide with its two coaxial to waveguide converter, WR650 was used. Signals generated from port of the vector network analyser (VNA- Rohde & Schwarz ZVA24) were sent to waveguide and then, the signals passing through the waveguide are transmitted via knitted samples to the input port of VNA. The measurement set up is shown in Fig.2. As seen in the figure, during the measurements all the fabric samples were placed in vertical position inside the waveguide.

![Fig. 2. Measurement set-up and placement of the fabric inside the waveguide](image_url)

III. RESULTS AND DISCUSSION

Using the measurement setup of Figure 2 the attenuation through the waveguide is measured by the vector network analyser (VNA). The spectrum of the guided wave that is excited by the VNA’s generator and which propagates through the waveguide at the TE10 polarization mode, is analyzed by the instrument. The attenuation due to the inserted yarn is derived as the difference between the reference response and the sample’s response at each frequency point of the two curves. Using this procedure the spectral attenuation of each sample of design 2 in the range of 1.1 to 1.7GHz is depicted in Figure 3.
In particular, the higher conductive sample exhibits a higher attenuation in the upper part of the examined frequency band. Although this is justified partially by the increased reflectivity of the lower resistive yarn, the dimensions and the shape of the specific design are also critical. In particular, the attenuation increases in the lower band due to the small separation between the conductive lines in comparison with the wavelength at low frequencies. As a result, both samples react as a solid reflector with the same attenuation. On the other hand, at the upper frequency band, the wavelength decreases and the pattern of the conductive yarn design is more recognizable by the electromagnetic wave. As a result, the conductivity of the yarn of each sample is crucial and justifies both, the higher attenuation of the lower resistive yarn and the overall lower attenuation at the upper band.

Furthermore, a ripple is also evident for both samples throughout the spectrum. This ripple is caused by the expected interference phenomena caused by the interaction of the waveguided field with the textile obstacle. It should be also noted that the interference phenomena are weaker for the lower conductive sample due to the decreased reflectivity through the sample, which is mainly evident at the upper frequency band.

In Figure 4 the sample with the conductive area is examined (design 1). The position and the area of the conductive sample, explains the reduced attenuation in comparison with the samples of the design 2.

The spectral response of the attenuation is rather similar to the one discussed before with the difference of a lower attenuation throughout the spectrum. This is an anticipated result for two reasons: first, due to smaller effective reflection area in comparison with the previous samples, and second because the reflection area is not distributed deeply inside the waveguide, therefore, it has a small impact on the field profile of the wave guided mode.

ACKNOWLEDGMENT

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant agreement no. 644268.

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