Moisture Effects on A Knitted Waveguide

X. Jia, A. Tennant, R.J.Langley
Department of Electronic and Electrical Engineering
The University of Sheffield
Sheffield, UK
{xjia1, a.tennant, r.j.langley}@sheffield.ac.uk

W. Hurley and T. Dias
Advanced Textiles Research Group, School of Art and Design
Nottingham Trent University
Nottingham, UK

***Abstract*— Previously, we proposed a knitted textile waveguide working at X-band. Such wearable devices will experience various environmental conditions such as getting wet when applied in practice. In this paper, we have investigated the impact of moisture on the performance of a knitted textile waveguide. The results show that moisture has significant influences on the knitted waveguide's performance. Therefore, the knitted waveguide needs to be water-proofed properly in real-life applications.**

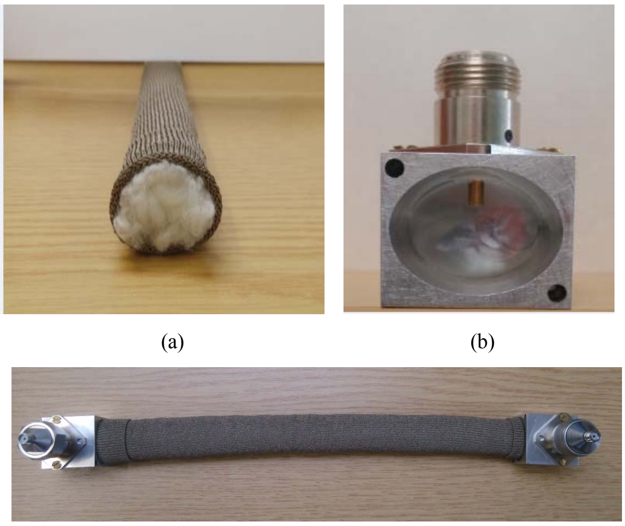
Keywords—Knitted waveguide; Moisture effects; Water-proof

I. Introduction

Due to the advantage of light weight and flexibility, massive research has been done on wearable devices [1]. Authors in [2] have reviewed the development of wearable antennas and authors in [3] mainly focused on the shape distortion study of the textile antenna. In the previous research, we have investigated the performance of a knitted textile waveguide [4]. Moreover, the impact of bending on the performance of the knitted waveguide has also studied [5]. It turns out this knitted waveguide is able to provide a stable transmission under different bending conditions. Therefore, it is possible to not only integrate this knitted waveguide with garments, but also apply it to the conventional communications system. For example, the solid bent waveguide at the corner of radar system can be replaced by this flexible knitted waveguide. However, rain is an inevitable weather factor when dealing with the construction of the outfield communications system. Therefore, the impact of moisture and washing on textile antennas has been investigated in [6-8]. In this paper, the impact of moisture on the performance of a knitted textile waveguide is studied and presented. The knitted waveguide proposed in [2] is employed and measurements carried out with a vector network analyzer in the Communications Group, the University of Sheffield.

II. Waveguide Structure

Fig.1 presents the knitted textile waveguide knitted by a Shima Seiki SWG091N computerized flat-bed knitting machine at Nottingham Trent University. It has an elliptical cross-section and is basically a conductive textile sleeve filled with knitted polyester. The knitted polyester is used to maintain the waveguide shape and two 50Ω transitions are employed to feed the waveguide. The approximate dimensions and parameters of the knitted waveguide are given in table 1.



(a) (b)

(c)

Fig.1. Photographs of a knitted textile waveguide

(a) Cross section, (b) Transition, (c) Knitted waveguide with transitions.

Table 1(a). Dimensions of knitted waveguide

Major Axis	Minor Axis	Whole length	Thickness of Conductive Textile
27 mm	20 mm	320 mm	1 mm

Table 1(b). Parameters of knitted waveguide

ε_r of Knitted Polyester	Tanδ of Knitted Polyester	σ of textile sleeve
1.3	0.001 at 10GHz	4000 S/m

III. Measurement Setup

The reflection coefficient (S11) and forward transmission (S21) of the knitted waveguide are measured by a VNA at room temperature (approximately 20°C). To investigate the impact of moisture on the performance of the knitted waveguide, a complete dry sample is measured at first as shown in Fig.2. Then, 20ml of Evian spring water is poured on the sample as shown in Fig.3 and the wet sample is measured every hour until it is completely dry again as shown in Fig. 4.

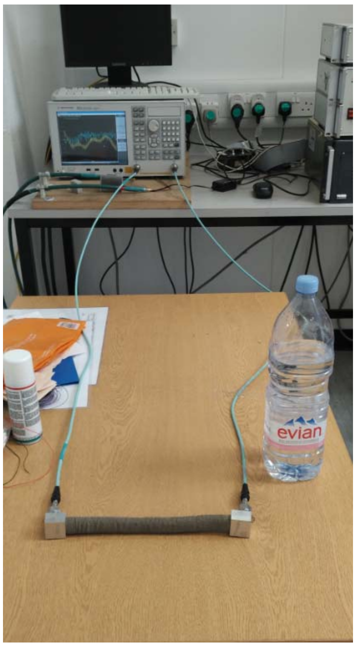


Fig.2 Measure a complete dry sample

Fig.3. Pour 20ml water on the sample then measure

Fig.4 Measure the sample until it is compeletly dry again

IV. RESULTS AND DISCUSSIONS

The measured S-parameter of a dry knitted textile waveguide is shown in Fig.5.

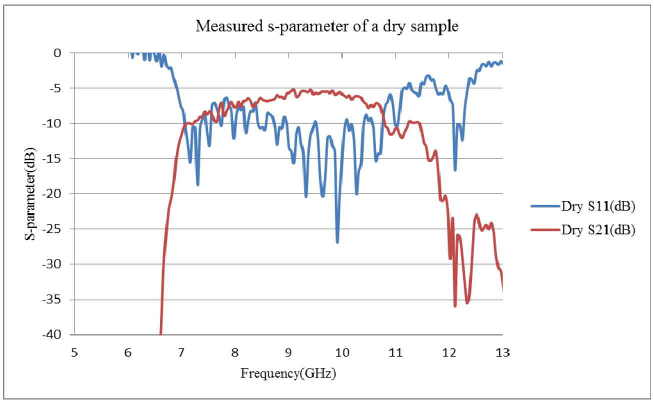


Fig.5 Measured S-parameter of a dry sample

Fig.5 shows that the knitted waveguide has a distinct cutoff frequency at about 7GHz and approximately -6dB transmission gain within its working frequency band. Then, 20ml water is poured on the knitted waveguide and its S-parameter is measured after the water is totally absorbed by the knitted sample. Fig.6 shows the measured S-parameter of the wet sample. From Fig.6, it can be seen that there is no significant transmission (S21) and impedance is mismatched when the sample is completely wet.

The knitted waveguide stops working when it absorbs 20ml of water. It may be due to the fact that water has a high dielectric constant of 80 and it totally reflects the signal when the inner knitted polyester is completely wet. After that, the wet sample is drying at room temperature, and measurement is taken hourly. It turns out the knitted waveguide does not have a significant S21 until after 24 hours.

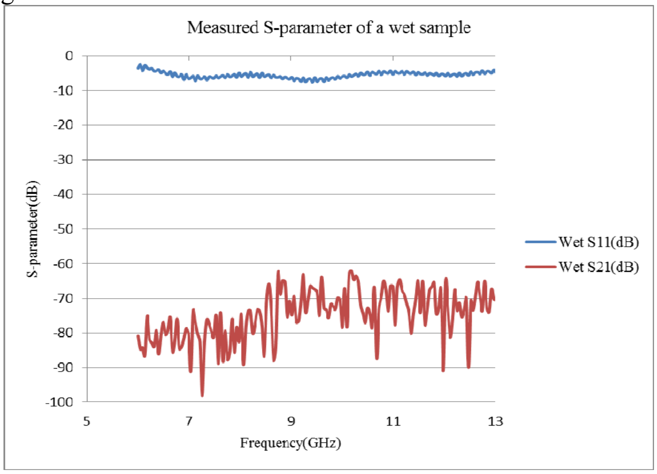


Fig.6 Measured S-parameter of a wet sample

Fig. 7 shows the measured S21 of the wet sample at different time intervals after drying 24 hours. From Fig. 7, it can be seen that the S21 reaches -20 dB and the knitted waveguide start to have a typical transmission characteristic after 24 hours drying. Moreover, the half-wet sample has the same cutoff frequency as the dry sample while the S21 level is much lower than the dry sample. This is because water in the knitted waveguide is evaporating and after 24 hour, the remaining water in the sample is not enough to totally reflect the signal and it only increases the dielectric loss of the knitted polyester and attenuates the transmission. Fig.7 also shows that the transmission gain level of the knitted waveguide increases as time passes. This is due to the fact that with less water in the sample, the internal loss of the knitted waveguide is lower, which will result in a higher S21. After 51 hours, the S21 of the knitted waveguide almost returns to its original value which means that water does not damage the sample and the knitted waveguide is able to provide the same performance after completely drying.

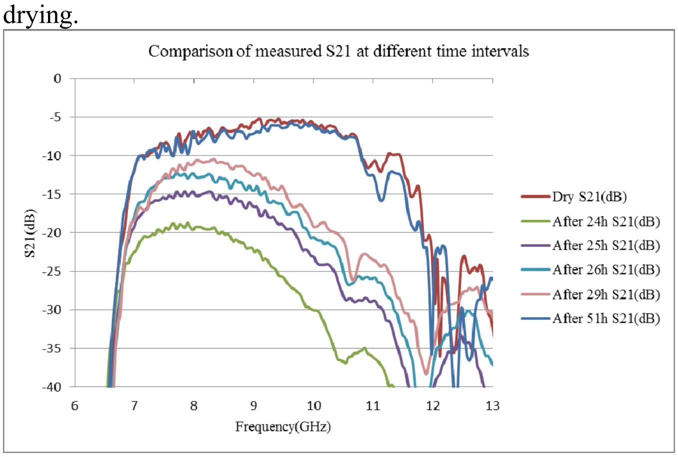


Fig.7 Comparison of measured S21 of a dry sample and drying sample at different time intevals

V. CONCLUSIONS

In this paper, the impact of moisture on the performance of the knitted waveguide has been investigated. The results show that when the sample is completely wet, the knitted waveguide stops working due to short circuit. The knitted waveguide starts to work with a low transmission gain after drying 24 hours at room temperature and returns to its original performance when it is completely dry. Therefore, the knitted textile waveguide needs to be water-proofed thoroughly in real-life applications.

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