Knitted Waveguide Antenna

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*— This paper presents the design of a knitted slotted waveguide antenna and its improvement. The antenna is developed originally from a textile elliptical waveguide and it has a resonant frequency at 9.15GHz with 80MHz bandwidth. Then, slight structural adjustments are taken to improve the antenna's performance. Moreover, the measured results show that the optimized slotted waveguide antenna working at 9.18GHz with 170 MHz bandwidth has a more directional radiation pattern with a higher gain. The antenna was designed and simulated in CST Microwave Studio 2012.**

***Index Terms*—Wearable antenna; Slotted antenna; Elliptical waveguide, Improvements**

I. INTRODUCTION

In the previous research, we investigated the performance of a straight knitted textile waveguide. Moreover, the relative permittivity (ε_r) and dielectric loss (tanδ) of the knitted polyester and the conductivity (σ) of the textile sleeve were determined [1]. Additionally, in [2], we proved that the knitted textile waveguide used in [1] was able to provide a stable performance under different bending conditions. Therefore, a wearable slotted waveguide antenna has been developed based on the knitted waveguide. In this paper, a slotted waveguide antenna manufactured with the same textile materials used in [1] is presented. Additionally, structure improvements which will optimize the antenna's performance are discussed. The antenna is designed to work within X-band. All the simulation is carried out in CST Microwave Studio 2012.

II. ANTENNA STRUCTURE

The slotted waveguide antenna shown in Fig.1 is basically a slotted conductive textile sleeve filled with knitted polyester. A metal waveguide transition with an N-type connector is employed to feed this textile antenna. Fig.1 shows that four slits are arranged into two columns to form a 2*2 array. These slits will make the waveguide to radiate if they are placed offset from the center of the waveguide as the current density is zero at the center, i.e. radiation will not occur as there is no current. Moreover, the distance between the slits and the edge of waveguide will determine how much energy the slotted waveguide antenna can radiate as the current distributes sinusoidally on the surface of the waveguide. In this paper, the length of slits is about half of wavelength in the air ($\lambda_0/2$) and space between two adjacent slits is around half of guided wavelength ($\lambda_g/2$). In this case, as the waveguide is filled with dielectric material, the dielectric constant ε_r of the knitted polyester needs to be taken into account to calculate the guided wavelength (λ_g). Furthermore, two columns of slits are placed offset 3.5 mm from the center waveguide. The last slit is a quarter of a guided wavelength ($\lambda_g/4$) away from the end of sleeve to make sure that the transmission line mode of the slotted waveguide antenna is open circuited. All slits were designed to be rectangular. However, in Fig 1, it can be seen that the slits were stretched when the knitted polyester was inserted inside the sleeve. Therefore, all slits were stitched by using non-conductive cotton yarn in order to keep them in a desired shape as shown in Fig.2. The dimensions of the slotted waveguide antenna and the parameters of the textile materials are shown in table1 and table2, respectively.

Fig.1. A slotted waveguide antenna

Fig.2. Slotted waveguide antenna with stitches.

Table.1.Dimensions of a slotted waveguide antenna

Major Axis	Minor Axis	Slit length	Slit width (no stitch)	Slit width (with stitch)	Distance between two slits	Distance between the last slit and end
29mm	21mm	13.4mm	5mm	2mm	30mm	8.7mm

Table.2. 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. Results and Discussions

The slotted waveguide antenna was simulated in CST Microwave Studio 2012 with the dimensions given in section II. Then, it was knitted by a Shima Seiki SWG091N computerized flat-bed knitting machine. The simulated and measured reflection coefficients (S11) of the slotted waveguide antenna are shown in Fig.3.

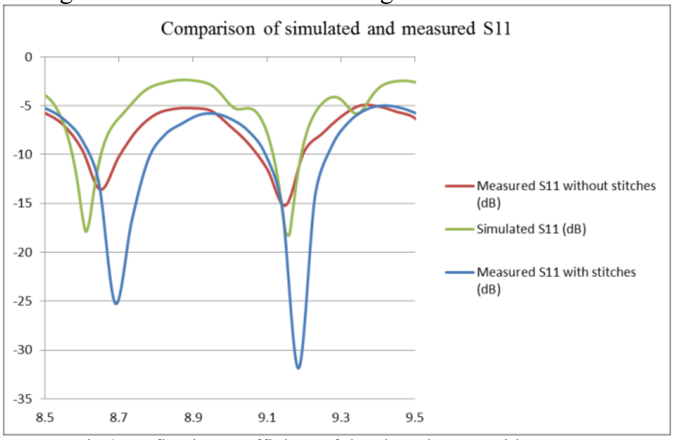

Fig.3. Reflection coefficient of the slotted waveguide antenna

Fig.3 shows that an agreement has been achieved between the simulated and measured reflection coefficient. The simulation shows that the antenna has a resonant frequency at 9.16GHz and the slotted waveguide antenna without stitches has a measured resonant frequency at 9.15GHz with an 80MHz bandwidth. However, the knitted sample with stitches has a resonant frequency at 9.18GHz with about a 170 MHz bandwidth. Although the stitched slits results in a slight higher resonant frequency, the antenna's bandwidth has been doubled and impedance matches better than the sample without stitches. The tiny difference between the simulation and measurements may be caused by the flexible nature of the textile materials as the antenna can not be knitted in exactly the same size as simulated model and the stitches may shorten the slits slightly.

Fig 4 shows the comparisons of measured radiation patterns between samples without and with stitches.

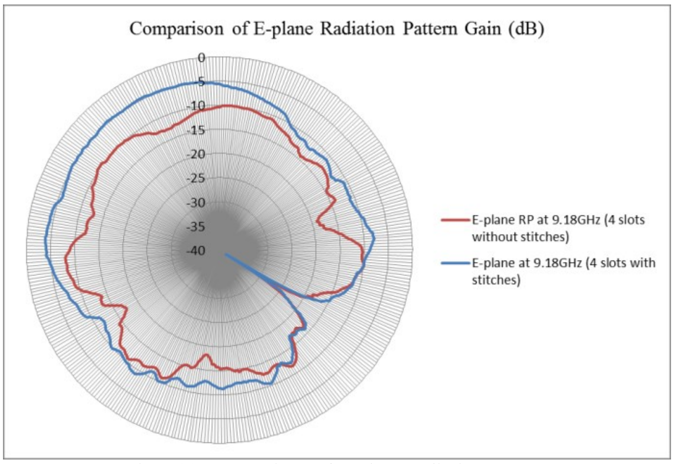

Fig.4.(a) Comparison of E-plane radiation pattern

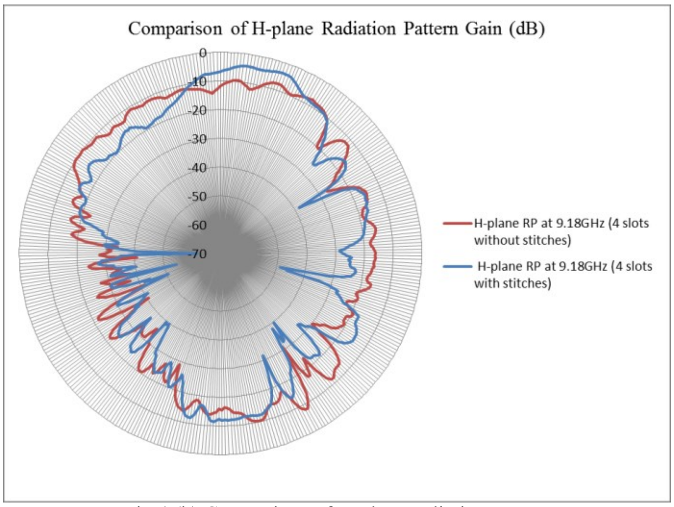

Fig.4.(b) Comparison of H-plane radiation pattern

From Fig.4, it can be seen that the slotted waveguide antenna has a directional radiation pattern in practice. In Fig.4 (b), the antenna without stitch has a 3dB beam width of 34 degree in H-plane and the antenna with stitches has a 3dB beam width of 26 degree in H-plane. Additionally, Fig.4 (a) and (b) shows that the stitched antenna has a maximum gain of -3.64dB at 9.18GHz in the measurement, which is about 3dB higher than the unstitched sample.

To sum up, the stitched slits can not only increase the antenna's bandwidth, but also make the antenna more directional with a higher gain. Theoretically, the actual gain of slotted waveguide antenna can be increased further by adding more stitched slits on the antenna.

IV. Conclusion

In this paper, a knitted slotted waveguide antenna working at 9.18GHz has been designed and tested. There are good agreements between the simulation and measurement. The stitched slits have been tested to be able to improve the antenna's performance significantly. The next step is to increase the number of slits on the slotted waveguide antenna.

References

[1] X.Jia and A.Tennant, "A Knitted Textile Waveguide", *Antennas and Propagation Conference (LAPC)*, Loughborough, IEEE, pp: 679-682 Nov 2014.

[2] X.Jia and A.Tennant, "Knitted Textile Waveguide Bending", *Antennas and Propagation (EUCAP)*, Portugal, 9 th European Conference, IEEE, pp: 1-4, April 2015.