Knitted Textile Waveguide Bending

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***Abstract*—This paper presents the performance of a knitted textile waveguide under different bending conditions. The waveguide is designed to operate at X-band and consists of a textile sleeve and knitted polyester inside. S21 of the bent knitted waveguide is compared to that of the straight knitted waveguide in both simulation and measurement.**

***Index Terms*—Knitted textile waveguide; Bending; S21**

I. INTRODUCTION

Much research has been done on textile antennas due to the attractive advantages of wearable devices [1]. Waveguide which is used to transmit electromagnetic wave between its endpoints is a basic component in a wireless communications system. However, the knitted waveguide has drawn very limited attention. The authors in [2-4] focused on the design of a textile sheet-shaped waveguide in a wireless on-body communications system, and in [5-7] present research on a textile waveguide integrating wearable antennas. In [8], 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 have been determined. In this paper, the performance of a knitted textile waveguide which is manufactured with the same materials used in [8] is presented under different bending conditions in both simulation and measurement. All the simulation is carried out in CST 2012 Microwave studio and the performance of the knitted waveguide is measured using a Network Analyzer.

II. WAVEGUIDE STRUCTURE AND MEASUREMENT SETUP

The straight knitted waveguide with an elliptical cross-section is shown in Fig.1. It is a conductive textile sleeve filled with knitted polyester. The approximated dimensions and parameters of the knitted waveguide are given in table 1.

Fig.1 . Configuration of a straight knitted waveguide

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

The knitted waveguide performance is studied under principle H-plane and E-plane bending separately. A piece of wooden board served as a base was slotted according to the different bending conditions. The knitted waveguide was then clamped on the wooden board. For both E-plane and H-plane bending, three different conditions are achieved by keeping one end of the knitted waveguide fixed while moving the other end to the different slots.

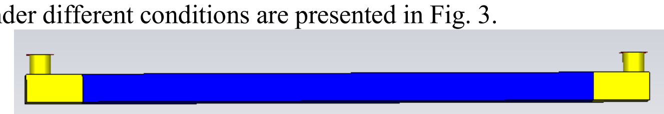
The knitted waveguide is fed by two 50 Ω SMA cables and its forward transmission gain (S21) is measured by a network analyzer.

III. WAVEGUIDE UNDER PRINCIPLE H-PLANE BENDING

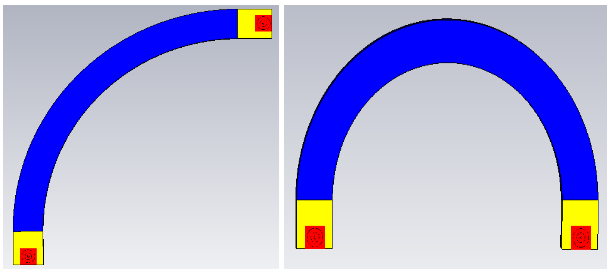
In this section, the effects that principle H-plane bending has on the knitted waveguide performance are studied based on the simulation and measurement. Since CST 2012 cannot support elliptical cylinder bending, a rectangular waveguide (WR-90) which is constructed with the same materials as the elliptical knitted waveguide is modelled instead.

A. Simulation

The waveguide is simulated when it is straight and when it is bent to 90 degree and 180 degree along H-plane as shown in Fig.2 (a,b,c) respectively. The simulated S21 of the waveguide under different conditions are presented in Fig. 3.



(a)



(b) (c)

Fig.2. Waveguide under different conditions in simulation
(a): Straight, (b): Bending angle 90 degree, (c): Bending angle 180 degree

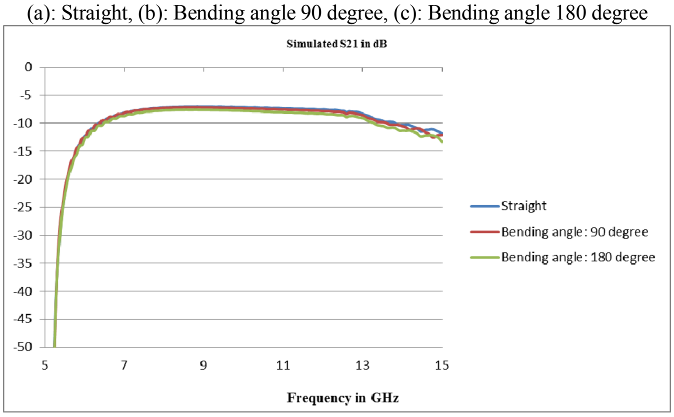
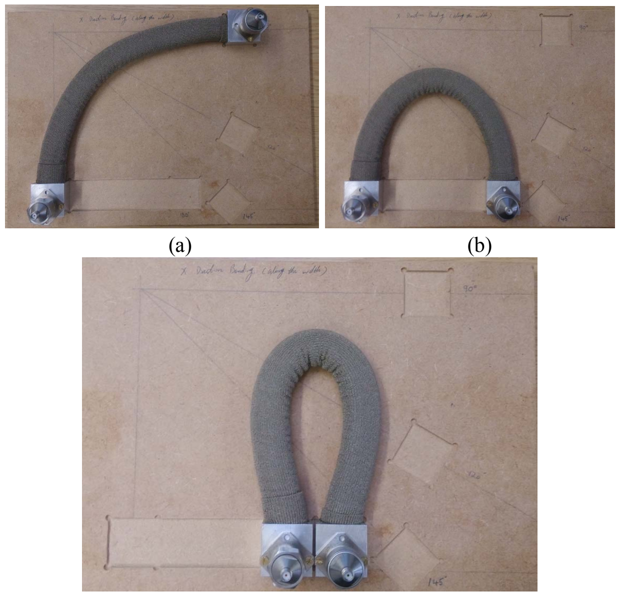


Fig.3. Comparison of simulated S21 of waveguide under different conditions

From the simulated results presented in Fig.3, it can be seen that the waveguide has a similar cut-off frequency under different conditions. Moreover, with the bending angle increase, the average S21 decreases slightly. Therefore, based on the simulation, H-plane bending has little effects on waveguide performance.

B. Measurement

To exam the knitted waveguide performance under H-plane bending in practice, it is measured by a network analyzer under different conditions as shown in Fig.1 and Fig 4. To make the bending condition more severe, two transitions are placed next to each other and a sharp corner occurs in H-plane as shown in Fig.4 (c). The measured S21 of the knitted waveguide under different H-plane conditions are presented in Fig.5. Fig.5 shows that the knitted waveguide works from 8GHz to 10GHz with a S21 gain above -10 dB under different conditions. Additionally, it shows that the cut-off frequency of the knitted waveguide shifts upwards slightly when the bending condition becomes severe. It might be caused by the inevitable compression when the knitted waveguide is bent in practice. The major axis of the knitted waveguide becomes slightly smaller when H-plane bending occurs, which results in a larger cut-off frequency. Fig.5 also shows that the S21 of the straight knitted waveguide remains almost the same within its working frequency under 90 degree and 180 degree bending conditions. However, the average S21 of the knitted waveguide drops by about 1 dB when the bending condition becomes severe. This could be due to the fact that internal tramsmission loss increases when a sharp corner occurs in H-plane of the knitted waveguide. In overall, H-plane bending has slight effects on knitted waveguide performance in practice.



(a) (b) (c)

Fig.4. Knitted waveguide under principle H-plane bending.
(a): Bending angle: 90 degree, (b): Bending angle: 180 degree,
(c): Bending angle: 180 degree with a sharp corner

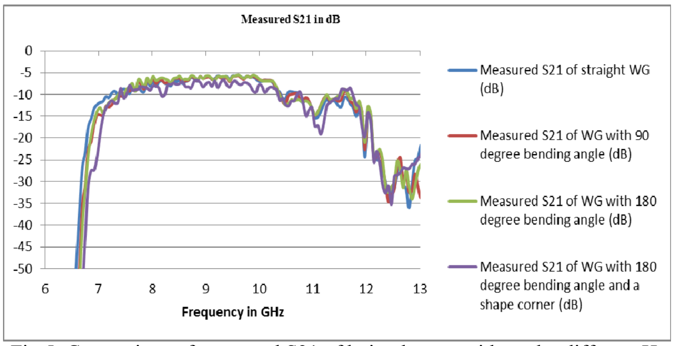


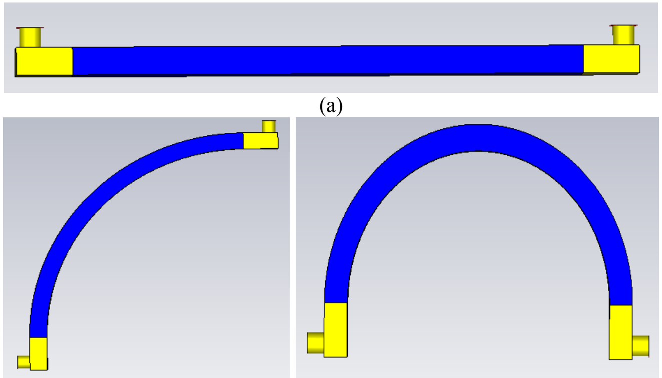
Fig.5. Comparison of measured S21 of knitted waveguide under different H-plane conditions

IV. WAVEGUIDE UNDER PRINCIPLE E-PLANE BENDING

In this section, the effects that principle E-plane bending has on the knitted waveguide performance are studied based on the simulation and measurement. The rectangular waveguide in section III is used again for simulation.

A. Simulation

Similarly, the waveguide is simulated when it is straight and when it is bent to 90 degree and 180 degree along E-plane as shown in Fig.6 (a,b,c) respectively. The simulated S21 of the waveguide under different conditions are presented in Fig. 7



(a)

(b) (c)

Fig.6. Waveguide under different conditions in simulation
(a): Straight, (b): Bending angle 90 degree, (c): Bending angle 180 degree

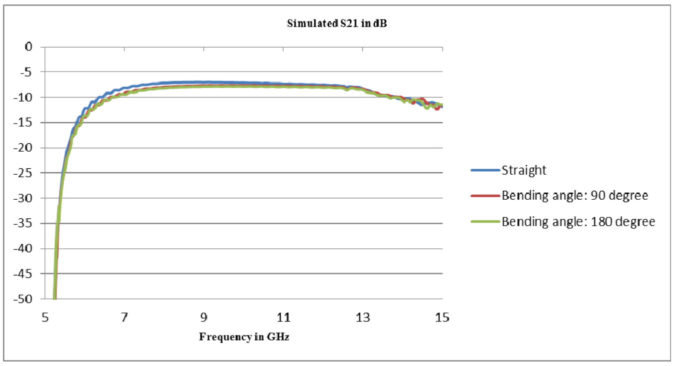


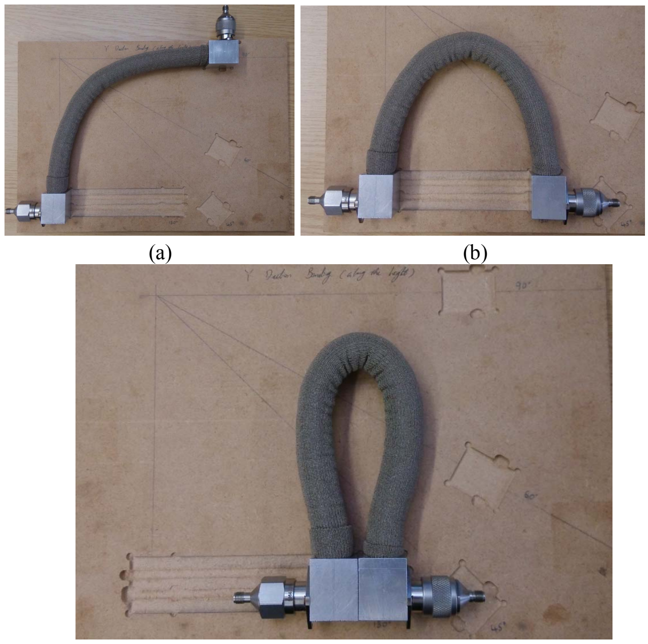
Fig.7. Comparison of simulated S21 of waveguide under different conditions

Fig.7 shows that in the simulation, the knitted waveguide has a similar cut-off frequency when it is straight and when it is bent to 90 degree and 180 degree along E-plane. Moreover, with the bending angle increase, the average S21 decreases slightly. Therefore, based on the simulation, E-plane bending has little effects on waveguide performance

B. Measurement

To exam the knitted waveguide performance under E-plane bending in practice, it is measured by a network analyzer under different conditions as shown in Fig.1 and Fig 8. Similarly, to make the bending condition more severe, two transitions are placed next to each other and a sharp corner occurs in E-plane as shown in Fig.8 (c). The measured S21 of the knitted waveguide under different E-plane conditions are presented in Fig.9. Fig.9 shows that the knitted waveguide works from 8GHz to 10GHz with a S21 gain above -10 dB under different conditions. It also shows that the cut-off frequency of the knitted waveguide approximately remains the same when the bending angle increases even a sharp corner occurs. The slight cut-off frequency shfit might be caused by the inevitable compression when the knitted waveguide is bent in practice. Moreover, Fig.9 shows that the S21 of a straight knitted waveguide remains almost the same within its working frequency under 90 degree and 180 degree bending conditions. However, the average S21 of the knitted waveguide drops by about 1 dB when the bending condition becomes severe. This could be due to the fact that internal tramsmission loss increases when a sharp corner occurs in E-plane of the knitted waveguide.

In overall, E-plane bending also has slight effects on knitted waveguide performance in practice. Compared with H-plane bending, E-plane bending has less effect on the cut-off frequency of a knitted waveguide and both E-plane and H-plane bending have little effects on the S21. However, when the bending condition becomes severe and a sharp corner occurs in either E-plane or H-plane, it will cause approximately 1 dB drop for the average S21 of a knitted waveguide within it working frequency.



(a) (b)

(c)

Fig.8. Knitted waveguide under principle E-plane bending.
(a): Bending angle: 90 degree, (b): Bending angle: 180 degree,
(c): Bending angle: 180 degree with a sharp corner

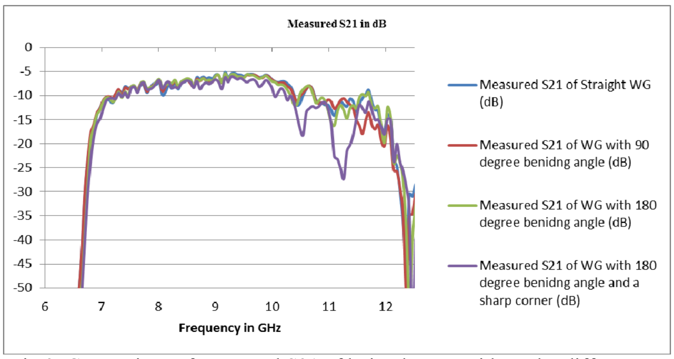


Fig.9. Comparison of measured S21 of knitted waveguide under different E-plane conditions

V. Conclusions

In this paper, the performance of an X-band knitted textile waveguide manufactured with the same materials used in [8] is investigated under different bending conditions. The measured results generally agree with simulated results and it can be concluded that the knitted waveguide can obtain a stable performance when E-plane or H-plane bending occurs. However, when the bending condition becomes severe and a sharp corner occurs in either E-plane or H-plane, it will cause approximately 1 dB drop for the average S21 of a knitted waveguide within it working frequency. Therefore, a sharp corner needs to be avoided to maintain a high transmission performance of a knitted waveguide.

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