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Crumpled Textile Antennas

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Abstract - This letter describes the performance of a dual band textile antenna under two dimensional crumpling conditions. Both input impedance and radiation patterns are investigated based on numerical and experimental methods at 2.45 GHz and 5.8 GHz. The return loss for the coplanar antenna is affected by the most severe crumpling at the higher frequency band while the radiation patterns remain acceptable at both bands.

Introduction: Recently, there has much interest in body worn communication systems and consequently textile antennas. Several authors have described the use of flexible materials to integrate antennas into clothing [1, 2] while in [3] a dual band antenna integrated with a high impedance surface was presented. However, under an on-body environment it is difficult to keep the antenna flat all of the time especially for elements made of textile materials. Therefore, it is necessary to evaluate an antenna's performance under bending and crumpling conditions. Previous research has mainly concentrated on the measurement of wearable antenna bending effects [4-7]. In this paper, we present the measured effects of multiple bending or crumpling in two dimensions under controlled conditions for a dual-band coplanar textile antenna covering the 2.45 GHz and the 5.8 GHz wireless networking bands. Simulations were also carried out and found to be in good agreement with the measurements although these are not presented here due to space restrictions and for clarity.

Fig. 1 presents the geometry of the dual-band coplanar waveguide fed (CPW) antenna used in the study, which operates at 2.4GHz and 5.8GHz. The antenna is a coplanar design consisting of an inner patch, operating at the high frequency band, surrounded by a parasitic rectangular ring element resonating at 2.45 GHz with another outer rectangular ring connected as the ground [3]. The antenna measured 55mm x 55mm and was manufactured on a flexible felt substrate with a dielectric constant ε_r = 1.38 and conducting "Zelt" fabric was used for the conductors.

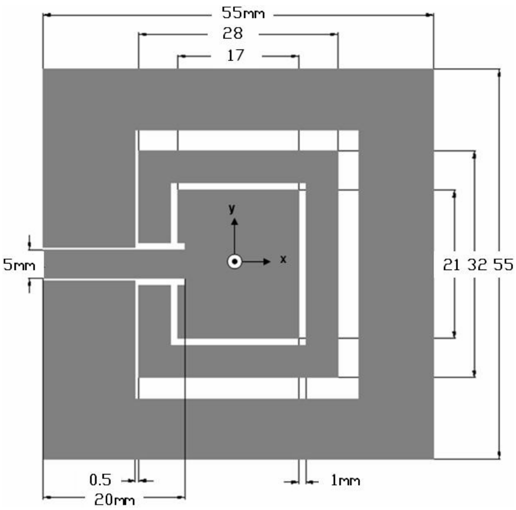

Fig. 1 Geometry of the dual-band CPW antenna

Crumpling: In practical situations for a textile antenna integrated into clothing on the human body the antenna may be located in a variety of places, perhaps the main torso or on an arm or leg. As the person takes up various positions the garment and potentially the antenna will be crumpled particularly near the joints. Under these conditions the type of crumpling shown in Fig.2 may take place. The two crumpled cases represent a typical bending/crumpling pattern caused when the arm is bent at the elbow. In Fig.2 the flat antenna measuring 55mm x 55mm is shown together with the antenna which has been initially crumpled so that the antenna aperture measured 37mm x 55mm and the crumpling depth was 5mm. A very severe case is also shown where the aperture is reduced in one plane to just 22.0 mm and the crumpling depth was 10mm. In order to measure the resulting reflection loss and radiation patterns two pairs of formers/moulds were made 20mm thick from Rhocell foam with ε_r = 1.06. The antenna was sandwiched between the two moulds to crumple the antennas in a fixed and controllable manner.

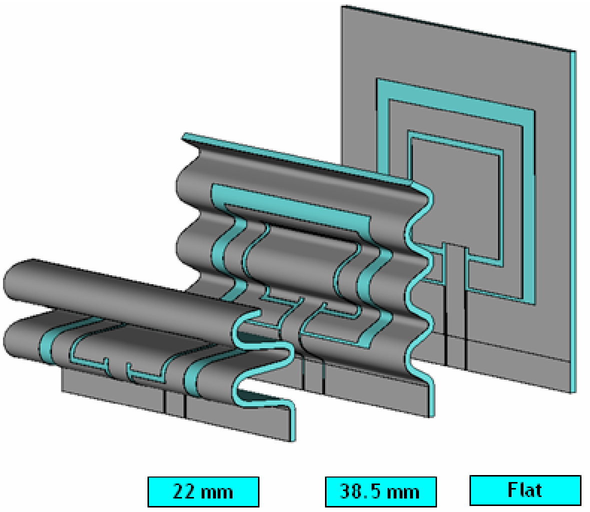

Fig. 2 Coplanar antenna 55mm x 55mm flat (plane), crumpled to a depth of 5mm with 38.5mm aperture, and crumpled to a depth of 10mm with a 22.0mm aperture.

The measured antenna reflection coefficient results for the three cases shown in Fig.2 are plotted in Fig.3. Comparing the antenna under flat conditions and under crumpled conditions, both the resonant bands of the antenna were affected to some degree. At the lower frequency band the resonance remains very close to 2.4 GHz in all three cases but the reflection coefficient reduces with crumpling depth from -25 dB for the flat antenna to -14 dB for the worst crumpled case (22mm aperture) with a corresponding reduction in the bandwidth from 400 MHz to 250 MHz at the -10 dB points. At the upper band crumpling the antenna by 5mm (37.5mm aperture) only affects the resonant frequency by about 100 MHz but for the 10mm crumple the best reflection coefficient is seen at 3.8 GHz and the reflection coefficient reduces to -7 dB at 5.8 GHz. Nevertheless the antenna's performance would still be acceptable for many applications.

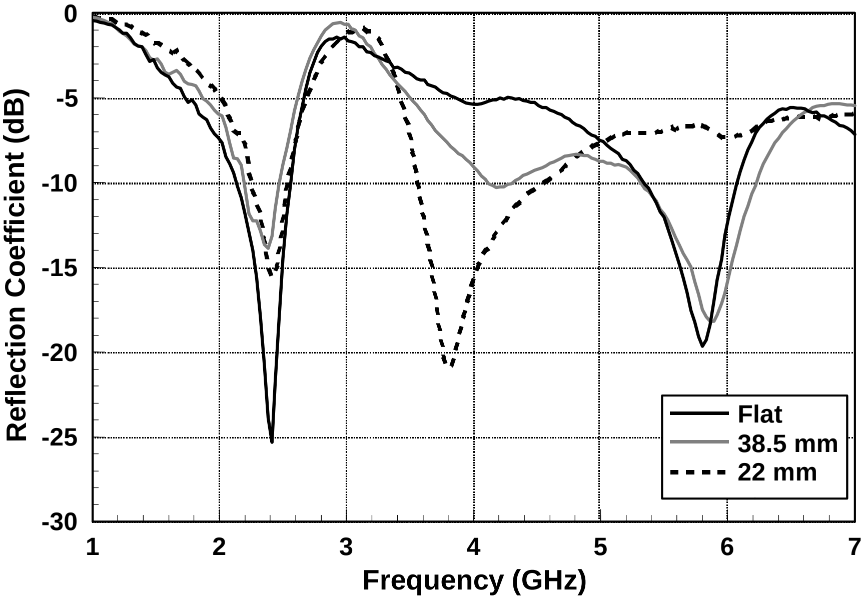

Fig. 3 Crumpled antenna reflection coefficient comparison

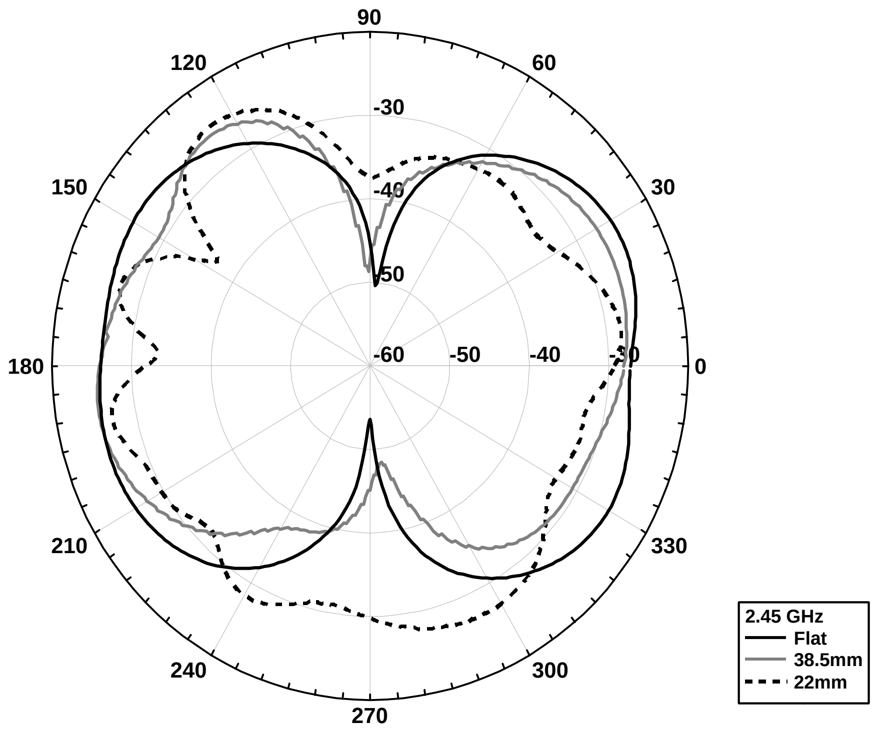

Fig. 4 Measured radiation patterns in E-plane at 2.45 GHz
Flat, 38.5 mm and 22.0 mm crumpled antennas

Finally the E-plane radiation patterns measured in our anechoic chamber for the three cases are plotted in Fig.4 for the lower frequency band at 2.45 GHz where the antenna is physically largest. For the flat antenna the radiation pattern was as expected with nulls near +/- 90°. Crumpling the antenna in the 38.5mm case maintains the overall shape of the pattern with little change in the gain. As the crumpling becomes severe the side nulls fill in and the pattern is more omni-directional with some distortion and loss of gain in the forward and reverse directions. However, overall the radiation patterns remain fairly robust to the severe crumpling. The performance at 5.8 GHz was not affected as much as at the lower band perhaps because the main inner radiating part of the antenna was much smaller electrically at this higher frequency.

Conclusions: The paper has presented the performance of a wearable coplanar antenna under realistic two dimensional crumpling conditions at 2.45 GHz and 5.8 GHz. The resonant frequencies of the dual band antenna changed little with crumpling at the low frequency band although the measured reflection coefficient reduced in the worst case with a loss in bandwidth from 400 MHz for the flat antenna to 250 MHz for the most severely crumpled case. At the high band the reflection coefficient for the most severely crumpled antenna reduced to -7 dB but this would still be acceptable for many applications. The measured radiation patterns showed that overall the performance of the coplanar antenna under crumpling conditions remained robust.

References

1. Salonen, P., Rahmat-Samii, Y., Schaffrath, M. and Kivikoski, M.: "Effect of Textile Materials on Wearable Antenna Performance: A Case Study of GPS Antennas," in Proc. IEEE AP-S, 2004, Vol.1, pp.459-462.
2. Liu, L., Zhu, S. and Langley, R.J.: "Dual-band Triangular Patch Antenna with Modified Ground Plane," IET Electronics Letters, Vol.43, pp140-141, Feb. 2007.
3. Zhu, S. and Langley, R.J.: "Dual-band Wearable Textile Antennas on an EBG Substrate," tbp in IEEE Transactions on Antenna and Propagation, March 2009
4. Locher, M. Klemm, T., Kirstein, T. and Troster, G.:"Design and Characterization of Purely Textile Patch Antennas," IEEE Transactions on Advanced Packaging, Vol.29, No.4, pp.777-788, Nov. 2006.
5. Tanaka, M.and Jang, J.: "Wearable Microstrip Antenna," in Proc. IEEE AP-S, 2003, Vol.2, pp.704-707.
6. Kellomaki, T., Heikkinen, J. and Kivikoski, M.: "Effects of Bending GPS Antennas," in Proc. Asia-Pacific Microwave Conference, 2006, pp. 1597-1600.
7. Salonen, P. and Rahmat-Samii, Y.: "Textile Antennas: Effects of Antenna Bending on Input Matching and Impedance Bandwidth," IEEE Aerospace and Electronic Systems Magazine, Vol. 22, Issue 12, pp. 18 – 22, Dec. 2007.