Characteristics of a Deformed Antenna Made of Flexible Printed Circuit

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Abstract

In recent years, wireless communications, such as wireless LAN and Bluetooth, are widely spreading. As the antennas used in wireless communications are usually installed in small mobile devices, it is demanded that the volume to be small. To meet the miniaturization demand, we focussed our attention to flexible printed circuits (FPCs). FPCs have some attractive features such as thinness and flexibility. We designed here a PIFA available for IEEE802.11b/g and Bluetooth. The antenna is made of FPC and its radiation pattern does not vary much when the antenna is deformed. We measured the radiation pattern of the antenna when the antenna is successively curved and folded. We analyzed the antenna by using the moment method.

1. INTRODUCTION

In recent years, wireless communications, such as wireless LAN [1] and Bluetooth [2], are widely spreading. Nowadays, we can use wireless LAN in public facilities such as stations and libraries by using notebook PCs, personal digital assistants etc. As the antennas we use in wireless communications are usually installed in small mobile devices, it is demanded that the volume to be small.

Planar inverted F antennas (PIFAs), ceramic antennas, and dielectric chip antennas are widely used in mobile devices (e.g. [3]-[7]). Since they have 3D-structure, it is difficult to install them in the movable part of mobile devices. As the space available for installing the antenna is becoming narrower and narrower, the antennas for wireless communications should become smaller and smaller, accordingly. If we can design an antenna with low profile by utilizing thinness and flexibility, it will be easier to install it in the narrow spaces of small mobile devices.

To meet this demand, we focussed our attention to flexible printed circuits (FPCs) for constructing antennas. FPCs have some attractive features such as thinness and flexibility. FPC antennas can be installed in the movable part of mobile devices provided that the radiation performance of the antenna does not vary so much when the antenna is deformed. We propose here a PIFA made of FPC, which is available for IEEE802.11b/g and Bluetooth. The size of the antenna is reduced by utilizing meander structures. It is designed to minimize the influence on the radiation performance when along a certain direction [8], [9]. The antenna was investigated experimentally and theoretically. A wire-grid model based on the moment method was applied for the numerical simulation.

2. ANTENNA CONFIGURATION AND MEASUREMENT SETUP

Figure 1 shows the configuration of the PIFA. The antenna is made of FPC which consists of a copper film mounted on a polyimide film, where the thickness of the polyimide film and the copper film is 0.05 mm and 0.035 mm, respectively. The permittivity of the polyimide film is 3.0. By use of this material, we can decrease the thickness of the PIFA by about 0.1mm. The antenna is fed by a coaxial cable which has a diameter of 1.13 mm and a length of 200 mm. We connected the central conductor of the cable to the PIFA radiation element and the outer conductor to the ground.

We designed this antenna for Bluetooth and IEEE802.11b/g, which use a band from 2.4000 GHz to 2.4835 GHz. Among many 2D-structure PIFAs, we reduced the size of the PIFA to 30 mm x 14 mm by putting two slits in the ground part. As the current of this antenna mainly concentrates on the feeding point and flows toward the direction of the coaxial cable, it is expected that its radiation characteristics do not vary much when the antenna is curved or folded along the direction of the coaxial cable.

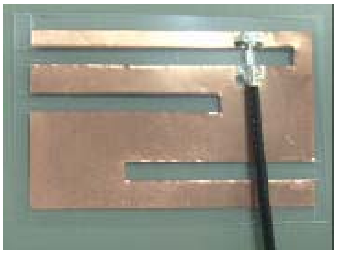

Fig. 1: Configuration of PIFA made of FPC.

In this paper, we carried out two kinds of measurements. First, we measured the antenna characteristics when the antenna is curved along the direction of the coaxial cable. Figure 2 shows the outline of the experiment, where R denotes the radius of curvature. In this experiment, we measured the antenna characteristics when varying the value of R. Next, we measured the antenna characteristics when the antenna is folded along the same direction. Figure 3 shows the outline of the experiment, where *s* denotes the distance between the coaxial cable and the folding position, *f*` the folded angle. We measured the antenna characteristics by varying the values of *s* and *f*`.

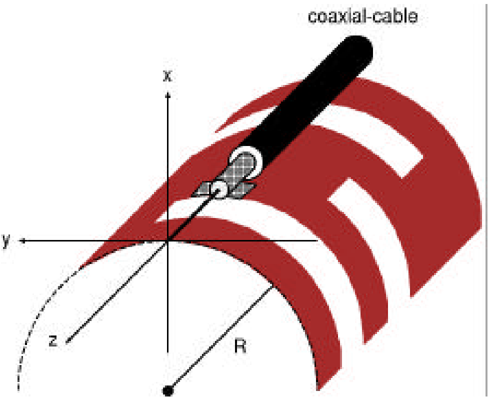

Fig. 2: Curved model.

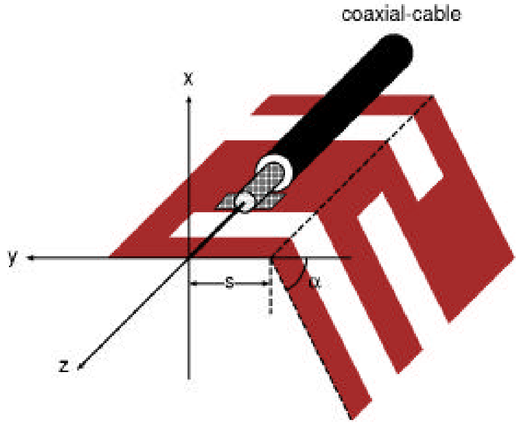

Fig. 3: Folded model.

3. RESULTS

A. Curved model

Figure 4 shows the voltage standing wave ratio (VSWR) when *R* varies from 10 mm to 40 mm. It is shown that while the VSWR shifts to low frequency when *R* is 10 mm, it remains almost unchanged when *R* is more than 20 mm. Figure 5 shows the radiation pattern of E_f on XY-plane at 2.48 GHz. While the radiation pattern changes dramatically and the gain decreases when *R* is 10 mm, the radiation pattern does not vary much when *R* is more than 20 mm. Figure 6 shows the relation between *R* and the average gain for each plane of the main polarized field. It is also shown that the average gain does not vary much when *R* is more than 20 mm.

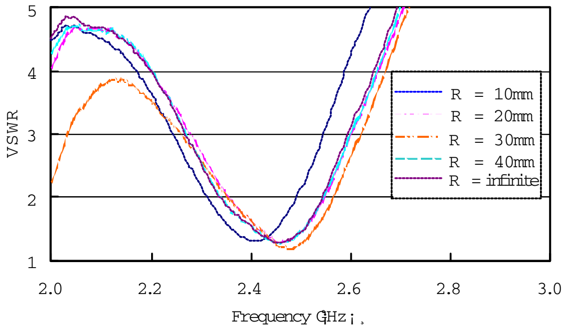

Fig. 4: Measurement of VSWR.

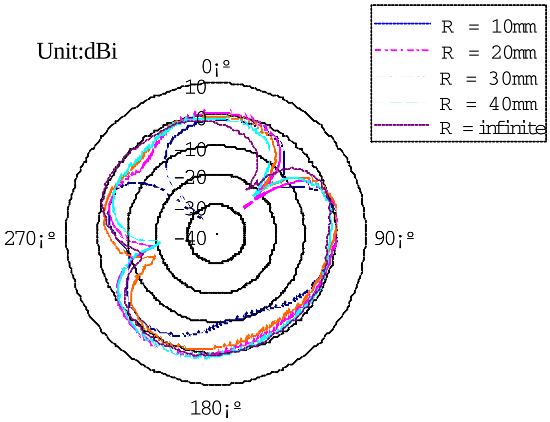

Fig. 5: Radiation pattern on XY-plane at 2.48 GHz.

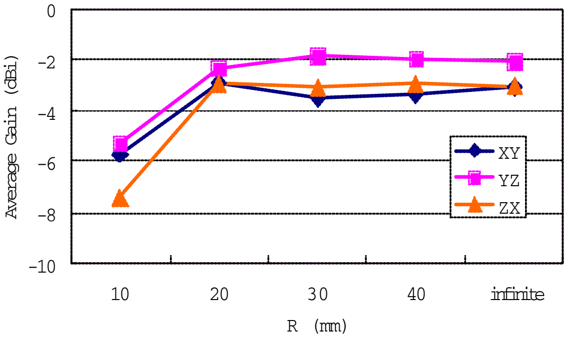

Fig. 6: Relation between *R* and average gain.

B. Folded model

Figures 7 and 8 show the VSWR for *s* = 0 and 16 mm, respectively. We measured the radiation patterns by varying *f*` from 0 to 135 degrees and *s* from 0 to 16 mm. In both cases of *s* = 0 and 16 mm, the VSWR does not vary much when *f*` is less than 90 degrees. Figures 9 and 10 show the radiation patterns of E_f on XY-plane at 2.48 GHz for *s*=0 and 16 mm, respectively. We can observe that the radiation pattern does not vary much as *f*` is less than 90 degrees. It is also shown that as *s* is becoming longer, the variation of the radiation pattern is becoming smaller.

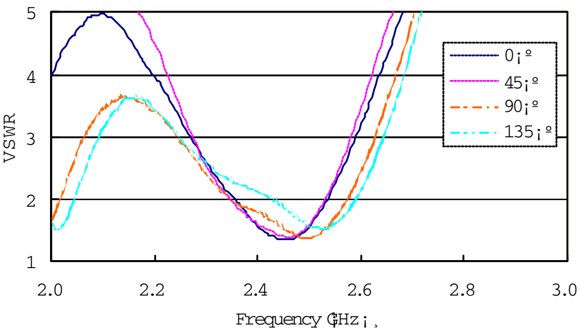

Fig. 7: Measurement of VSWR for *s*=0 mm.

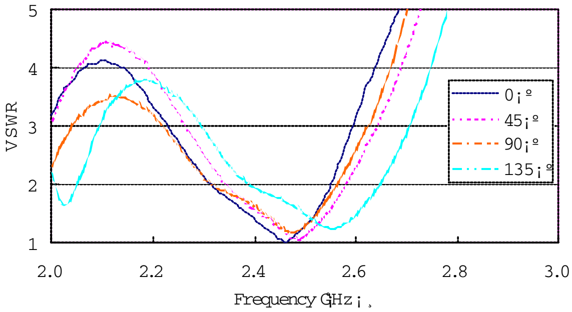

Fig. 8: Measurement of VSWR for *s*=16 mm.

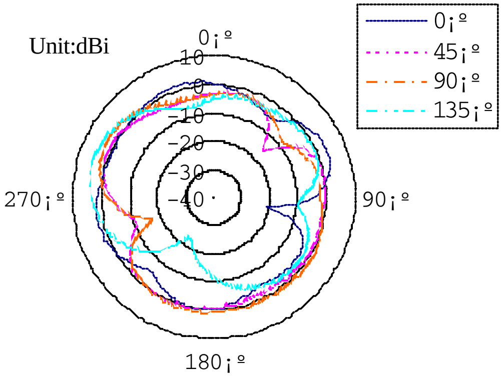

Fig.9: Radiation pattern on XY-plane at 2.48 GHz for *s*=0 mm.

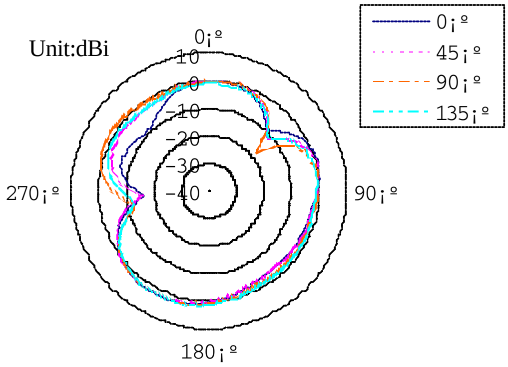

Fig.10: Radiation pattern on XY-plane at 2.48 GHz for *s*=16 mm.

C. Simulation

By using a wire-grid model based on the moment method, we calculated the current distribution at 2.48 GHz when the antenna was deformed. The software Numerical Electromagnetic Code Version 4 [10] is used but the cable influence is not taken into account. Figures 11 and 12 show the current distributions when the antenna is curved along the coaxial cable for *R* (infinite and 10 mm, respectively). From these two figures, it is observed that the current concentrates strongly in the region near the feeding point and the curvature does not influence the current distribution so much. As a result, the VSWR does not vary much when the antenna is curved.

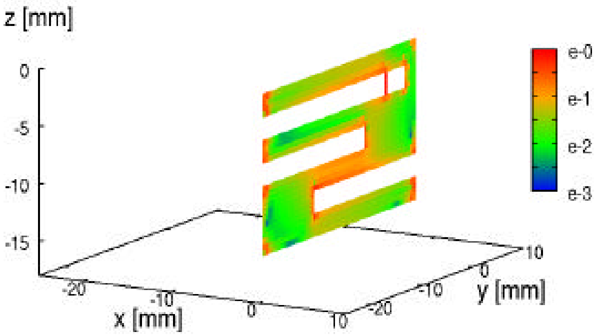

Fig. 11: Current distribution at 2.48 GHz for *R*=infinite.

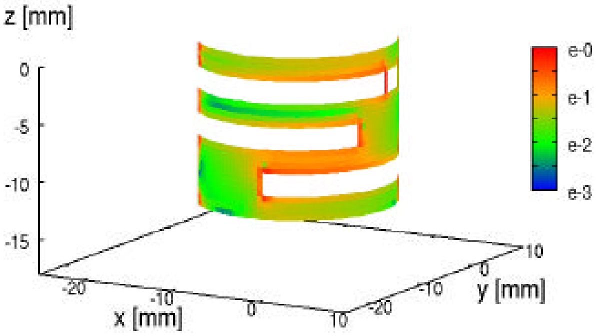

Fig.12: Current distribution at 2.48 GHz for *R*=10 mm.

Next, we calculated the current distribution at 2.48 GHz when the antenna is folded along the direction of the coaxial cable for *s*=0 mm of 45 and 90 degrees as shown in Figs. 13 and 14, respectively. As for the curved model, the current also concentrates strongly in the region near the feeding point and the folding does not influence the current distribution so much. In addition, the current also concentrates on the folded part due to the sharp edge, but for the influence on the radiation is not significant. As a result, the VSWR does not vary much, either.

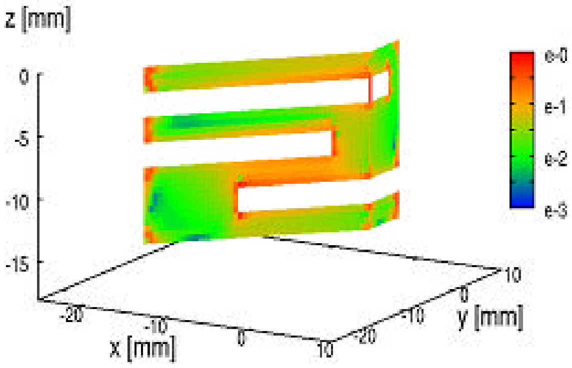

Fig. 13: Calculation of current distribution at 2.48 GHz. (f`=45 deg and s=0)

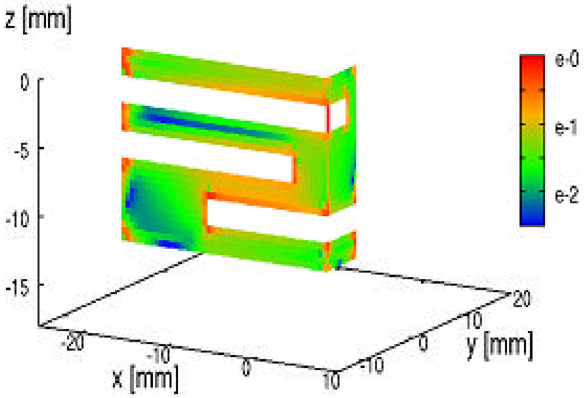

Fig.14: Calculation of current distribution at 2.48 GHz. (f` =90 deg and s=0)

4. CONCLUSION

We designed a PIFA available for Bluetooth and IEEE802.11b/g, which is made of FPC. We measured the antenna characteristics when the antenna is curved and folded along the direction of the coaxial cable. When the antenna is curved, the antenna characteristics do not vary much when the radius of curvature is more than 20 mm. When the antenna is folded, the antenna characteristic does not vary much when the folded angle is less than 90 degrees. As the distance between the coaxial cable and the folding position is becoming longer, the radiation pattern remains unchanged. We confirmed by numerical simulation based on the moment method that the variation of the radiation characteristics is small when the antenna is deformed because the deformation does not influence dramatically the current distribution. This antenna is expected to be installed in the moving part of mobile terminals. As a further study from the practical point of view, we need to further reduce the size of the antenna and to design the antenna when it is installed in a real terminal of mobile devices.

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