Proposal and investigation of a flat type small volcano smoke antenna

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Abstract

In this paper, a flat type small volcano smoke antenna formed on a PCB (Printed Circuit Board), miniaturizing the well-known volcano smoke antenna with wideband characteristics [2][3], was proposed, and the VSWR, gain and directional characteristics of the proposed antenna were analyzed and measured. As a result, it was confirmed that the flat type small volcano smoke antenna was omnidirectional in the horizontal plane and VSWR ≦ 2.3 in frequency range from 3.1 to 11.5 GHz (bandwidth of 115 %) covering the UWB frequency band. And the radiation patterns for co-polarization were similar to that of a typical dipole antenna. The flat type small volcano smoke antenna proposed in this paper can be easily formed on PCB and fed by the microstrip line, and therefore, it is useful for a wideband and omnidirectional antenna building in mobile and wearable equipments, etc., which requires high speed and high capacity communication.

1. INTRODUCTION

In recent years, wireless communications using UWB (Ultra Wideband) technology are promising in order to materialize the ubiquitous world what is called. Antennas for UWB communications, using a frequency band from 3.1 GHz to 10.6 GHz, require suitable characteristics compared with antennas for conventional wireless communications.

We have been developing a planar type of unbalanced dipole antenna with semicircular and trapezoidal radiators, which has suitable VSWR and omnidirectional characteristics over UWB frequency band [1]. Many UWB antennas have been being developed by several research institutes, however, they are insufficient for practical use in aspects of structure and dimension [4]-[12]. Developing and materializing the miniaturized and thinner antennas is indispensable for building them in mobile equipments and PC peripheral devices.

In this paper, a flat type small volcano smoke antenna, formed on a PCB (Printed Circuit Board), miniaturizing the well-known three dimensional volcano smoke antenna with wideband characteristics [2][3] is proposed. The VSWR, gain and directional characteristics of the proposed antenna are analyzed and measured.

2. SHAPE OF ANTENNA

Figure 1 shows our modification process for miniaturization from the well-known three dimensional volcano smoke antenna to the flat type small volcano smoke antenna formed on a PCB proposed in this paper. The well-known three dimensional volcano smoke antenna is shown in Fig.1 (a). First, as shown in figure (b), In order to make the antenna thinner, a cross-sectional shape of the well-known three dimensional volcano smoke antenna is extracted. Next, as shown in figure (c), In order to miniaturize the antenna, the peripheral regions of the extracted cross-sectional shape are cut off. Finally, as shown in figure (d), a flat type small volcano smoke antenna, proposed in this paper, can be obtained by simplifying the shape and placing a microstrip feeder on the extracted area.

Figure 2 shows the structural details of the flat type small volcano smoke antenna proposed in this paper. Two radiators of the antenna are formed on the top and back layers of a PCB, respectively. The upper radiator formed on the back layer of PCB is shaped by combination of a half ellipse and a circumscribed triangle with it, and a microstrip conductor is connected to the feeding point of the radiator. The lower radiator formed on the top layer of PCB is not only used as a radiator but also used as a ground conductor of the microstrip feeder line, and a part of the lower radiator periphery is shaped by combination of a taper and a part of ellipse for the impedance matching. The geometrical parameters of the proposed flat type small volcano smoke antenna are defined in Fig.2. H is the total length of the antenna, In the upper radiator, r_z and r_x are the major and minor axes of the half ellipse. t_a and t_{ang} are the top position and apical angle of the triangle circumscribed with the half ellipse. And r_a is the height of the upper radiator. In the lower radiator, a and h are the width and height. i_a and i_b are the width and length of the taper. er_z, er_x and (per_x, per_z) are the major and minor axes and the center coordinate of the ellipse. And w is the microstrip width of the feeder line.

3. VSWR CHARACTERISTICS

The VSWR characteristics of the flat type small volcano smoke antenna, with r_z = 12 mm, r_x = 9 mm, t_a = 1.5 mm, t_{ang} = 110.0 °, r_a = 13.5 mm, a = 18 mm, h = 20 mm, i_a = 1.6 mm, i_b = 7.5 mm, er_z = 15 mm, er_x = 10 mm, (per_x, per_z) = (6.0, 15.0) mm and w = 1.15 mm, formed on the dielectric substrate (the thickness t = 0.6 mm and dielectric constant ε_r = 4.2), are shown in Fig.3. In this paper, TLM (Transmission Line Modelling) method was used for the analyses.

Figure 3(a) shows the frequency characteristics of VSWR for several r_x. The parameter t_{ang} also varies with r_x. It is found that the resonance frequency in the range from 8.5 to 11 GHz varies with r_x.

Figure 3(b) shows the frequency characteristics of VSWR for several r_z. The parameter t_{ang} also varies with r_z. It is found that the resonance frequency in the range from 8 to 11 GHz varies with r_z. And as the r_z increases, the lowest resonance frequency in the vicinity of 4 GHz decreases, because the total length of the antenna, H, increases as the r_z increases.

Figure 3(c) shows the frequency characteristics of VSWR for several h. It is found that the resonance frequency in the intermediate range from 5 to 8 GHz varies with h, and the VSWRs at 5.5 and 7.5 GHz improved when $h \geqq 22$ mm and $h \leqq 20$ mm, respectively. However, the lowest resonance frequency hardly changes with h.

Figure 3(d) shows the frequency characteristics of VSWR for several er_x. It is found that the VSWR in the frequency range above 5 GHz improved, and the lowest resonance frequency in the vicinity of 4 GHz increases, as er_x increases.

Figure 3(e) shows the frequency characteristics of VSWR for several er_z. It is found that the VSWR in the frequency range above 5 GHz deteriorated, and the lowest resonance frequency in the vicinity of 4 GHz decreases, as er_z increases.

Figure 3(f) shows the frequency characteristics of VSWR for several per_x. It is found that the antenna has a flat VSWR characteristics in the intermediate frequency range when per_x = 5.0, and that the lowest resonance frequency decreases as per_x increases.

Figure 3(g) shows the frequency characteristics of VSWR for several i_a. As i_a increases, the lowest resonance frequency decreases and the VSWR performs well in the vicinity from 3 to 4 GHz. And in the frequency above 4 GHz, the VSWR characteristics is the best when i_a = 1.6 mm.

Figure 3(h) shows the characteristics of VSWR for several i_b. It is found that as i_b increases, the VSWR characteristics improved, because the impedance matching becomes better.

4. CHARACTERISTICS OF ANTENNA MADE ON AN EXPERIMENTAL BASIS

A picture of the proposed flat type small volcano smoke antenna made on an experimental basis, is shown in Fig.4. In Fig.3, the dimensions of the antennas were decided considering the miniaturization, the lowest resonance frequency as low as possible, and good VSWR characteristics in the UWB frequency band. The dimensions of the antenna made on an experimental basis are r_z = 12.0 mm, r_x = 9.0 mm, t_a = 1.5 mm, t_{ang} = 110.0 °, a = 18.0 mm, h = 21 mm, i_a = 1.7 mm, i_b = 8.0 mm, er_x = 10.0 mm, er_z = 15.0 mm, (per_x, per_z) = (6.0, 15.0) mm and w = 1.15 mm.

The result of VSWR characteristics as a function of frequency, obtained from the measurement, is shown in Fig.5. The result obtained from the analysis is also plotted in Fig.5 for comparison. We found that the measured result agreed well with the analyzed result, and the validity of the analyses was proved. The measured results at frequencies of 4.5, 5.6 and 8.5 GHz were deteriorated, because by inserting the connector for the measurement, the impedance mismatching occurred. As shown in Fig.5, it was confirmed that the proposed flat type small volcano smoke antenna made on an experimental basis, performed well in the range from 3.1 to 11.5 GHz with the result of VSWR $\leqq$ 2.3 and bandwidth of 115 %.

The radiation patterns of the antenna at frequencies of 3.1, 5, 8 and 10.6 GHz, shown in Fig.4, are shown in Figs.6 (a)-(*l*), respectively. It is found from Figs.6 (a), (d), (g) and (j) that the radiation patterns in XY plane are sufficiently omnidirectional, although the gains obtained from the measurements in the horizontal plane, from -7 to 0 dBi, are slightly smaller, compared with a typical dipole antenna.

It is found from Figs.6 (b), (e), (h), (k), (c), (f), (i) and (*l*) that the radiation patterns in YZ and ZX planes, at frequencies of 5, 8, 10.6 GHz, for the co-polarization, obtained from the measurements, are similar to that of a typical dipole antenna, although the radiation patterns at a frequency of 3.1 GHz are deteriorated.

In the frequency range from 3.1 to 10.6 GHz, the radiation patterns of cross-polarization obtained from the measurements are different from those obtained from the analyses, and the radiation patterns of co-polarization from the measurements are slightly different from those obtained from the analyses. It is seen that these differences between the measurements and the analyses are caused by the characteristics of the connector, cables and peripheral devices used in the measurements. Therefore, in the co-polarization, it is found that both the measured and the analyzed radiation patterns generally agreed, and it is useful for a wideband and omnidirectional antenna building in mobile equipments.

5. CONCLUSIONS

In this paper, a flat type small volcano smoke antenna formed on a PCB, miniaturizing the well-known three dimensional volcano smoke antenna and making it thinner, was proposed, and investigated. First, the characteristics of VSWR and radiation patterns for several geometrical parameters of the antenna were analyzed using the TLM method. Next, the antennas were made on an experimental basis, and the characteristics of them were measured and evaluated. As a result, it was confirmed that the flat type small volcano smoke antenna, proposed in this paper, was omnidirectional in the horizontal plane, the VSWR $\leqq$ 2.3 in frequency range from 3.1 to 11.5 GHz (a bandwidth of 115 %) covering the UWB frequency band, the radiation patterns for co-polarization were similar to that of a typical dipole antenna.

The flat type small volcano smoke antenna proposed in this paper can be easily formed on PCB and fed by the microstrip line, and therefore, it is useful for a wideband and omnidirectional antenna building in mobile and wearable equipments, etc., which requires high speed and high capacity communication.

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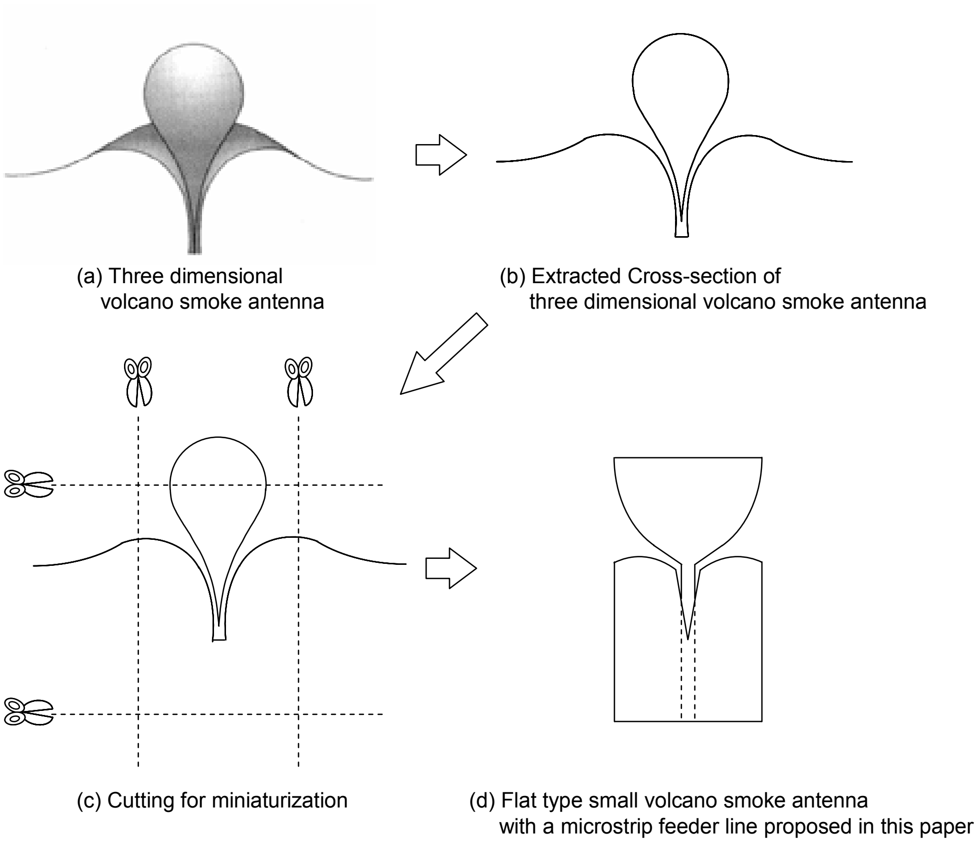


Fig. 1: Process of modification

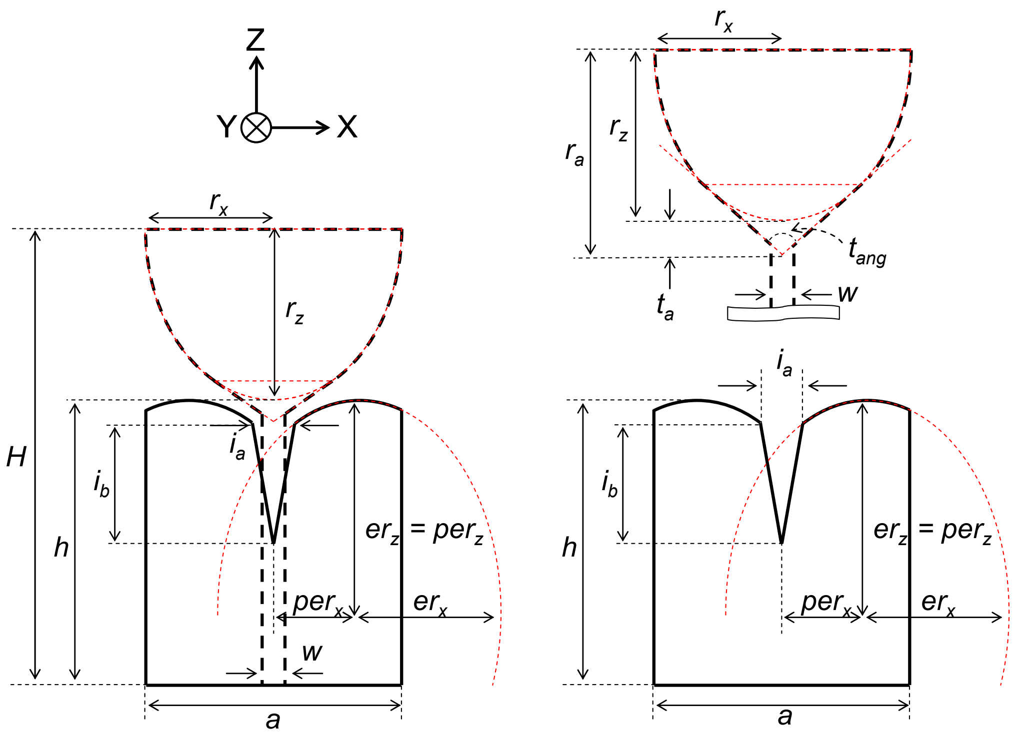
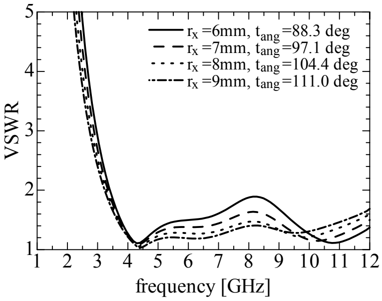
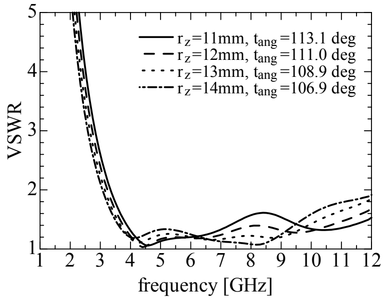


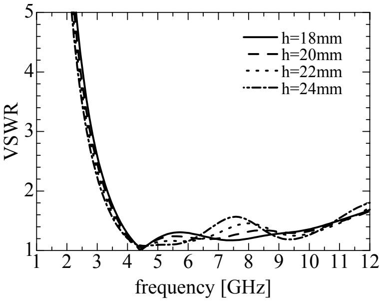
Fig. 2: Flat type small volcano smoke antenna proposed in this paper and definition of geometrical parameters



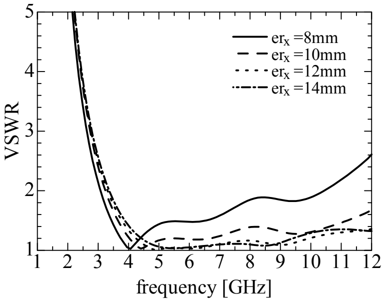
(a) VSWR characteristics for several r_x



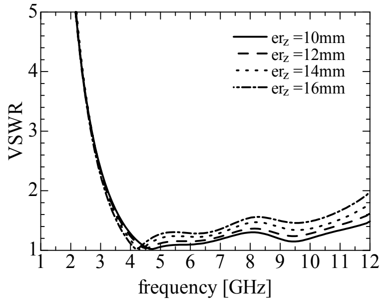
(b) VSWR characteristics for several r_z



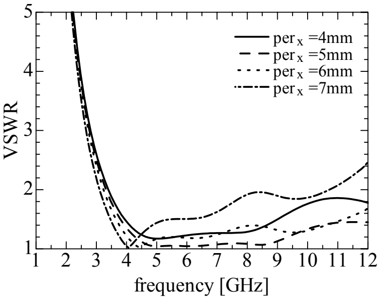
(c) VSWR characteristics for several h



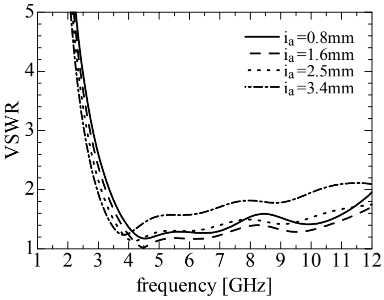
(d) VSWR characteristics for several er_x



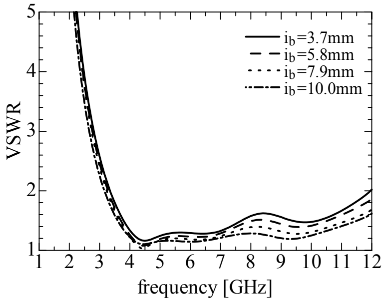
(e) VSWR characteristics for several er_z



(f) VSWR characteristics for several per_x



(g) VSWR characteristics for several i_a



(h) VSWR characteristics for several i_b

Fig. 3: VSWR characteristics as a function of frequency of proposed antenna

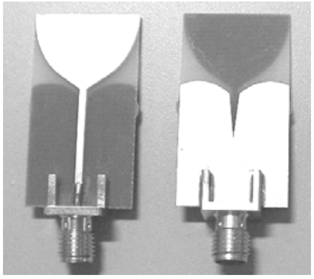


Fig. 4: A picture of the flat type small volcano smoke antenna proposed in this paper

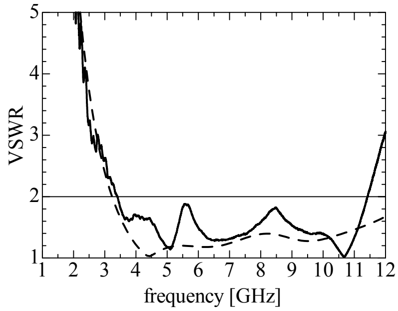


Fig. 5: Comparison of VSWR characteristics obtained from analysis and measurement as a function of frequency

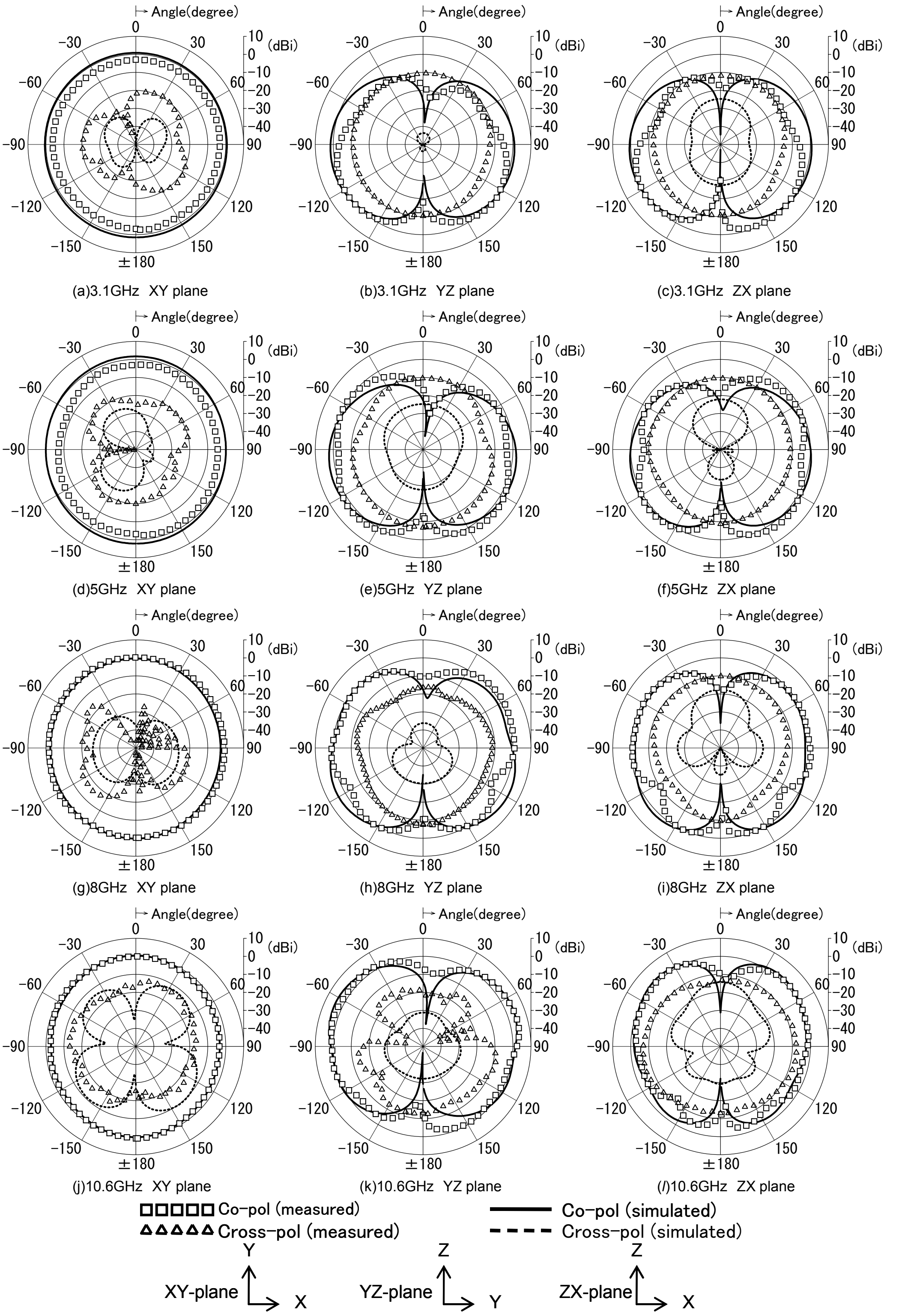


Fig. 6: Comparison of radiation patterns obtained from analyses and measurements