Excitation of Dipole Mode in Asymmetrical Ultra Low Profile Dipole Antenna

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Abstract

We have studied characteristics of the ULPD (Ultra low profile dipole) antenna in regard to the mode, the gain and the pattern. There are various problems in designing the ULPD antenna loaded on a satellite. The ULPD antenna is symmetry like a conventional half-wave dipole antenna, and has the vertical part on the center of the horizontal part. Sometimes, this is a serious limitation for the design of a satellite. Therefore, we want to improve the flexibility of the antenna. It is difficult that an asymmetrical ULPD (a-ULPD) antenna is driven a dipole mode only. In this research, by installation of a sperrtopf to vertical part of an a-ULPD antenna, the antenna is driven in a dipole mode only similar to the ULPD antenna. This is because the sperrtopf chokes the current on the vertical part and flow the current only on the horizontal part. The experimental result shows that it is possible to be driven in a dipole mode by the sperrtopf regardless of the location of the vertical part. This a-ULPD antenna with the sperrtopf gives the gain of 7.5～9.1 dBi and the radiation pattern similar to the ULPD antenna.

1. INTRODUCTION

A small antenna is required because satellite equipments require compact size and light weight [1]. In the LGA (Low Gain Antenna), a conventional half wavelength dipole antenna consists of a half-wavelength dipole and a reflector which is set up $\lambda/4$ apart. This antenna is used under more extreme conditions, such as the vibration or pressure change during launch, than ones on the ground. The ULPD (Ultra low profile dipole) antenna has a reflector with short distance which is more stable than a conventional dipole. Therefore, the ULPD antenna is suitable for the antenna loaded on a satellite. However, there are various problems in designing the ULPD antenna loaded on a satellite. The ULPD antenna is symmetry like a conventional half-wave dipole antenna, and has the vertical part on the center of the horizontal part. Sometimes, this is a serious limitation for the design of a satellite. Therefore, we want to improve the flexibility of the antenna.

It was often said that a dipole antenna in proximity to a reflector horizontally can not radiate the electric wave. However, a dipole in proximity to a reflector has the coupling effect and large current is generated and impedance becomes low. Then antenna can radiate forward strongly [2]. Therefore, the ULPD antenna's gain becomes 9 dBi which is 1.5 dB higher than that of a conventional half wavelength dipole. Figure 1 shows the configuration of the ULPD antenna which is T-shaped and symmetry. A coaxial cable is erected from a reflector and bent at the top. The vertical part is set at the center of the horizontal element and is the pole of the antenna. The horizontal part is composed by a coaxial cable and a parasitic element. The parasitic element is a copper wire. The position at the vertical part of the ULPD antenna is fixed at the center of the horizontal part [3].

In this paper, we propose that an asymmetrical ULPD (a-ULPD) antenna with a wave-trap or so-called the sperrtopf. The antenna can be driven only in a dipole mode and has the radiation pattern and gain like the ULPD antenna. Impedance matching is adjusted by the length "x" in the scheme of an offset feed.

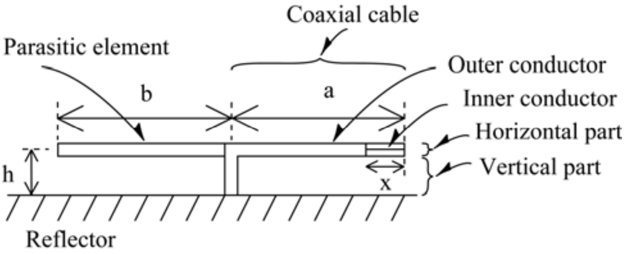


Fig.1: Configuration of an ULPD antenna

2. Theory and Proposal Technique

A. a-ULPD without a sperrtopf

The configuration in Fig. 1 is modified to the one in Fig. 2 as the position of the vertical part is shifted from the center of the horizontal part. It indicates that the ULPD antenna is changed to the asymmetrical ULPD.

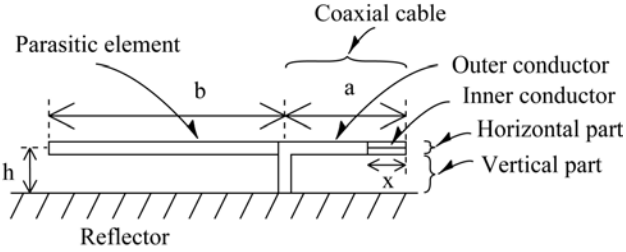


Fig.2: Configuration of an a-ULPD antenna

B. a-ULPD with a sperrtopf

Figure 3 shows configuration of an a-ULPD antenna with a sperrtopf. The sperrtopf is installed at the vertical part of an a-ULPD antenna. Mechanically it requires that the metal sleeve encapsulates the coaxial line, the sleeve length is λ/4, and the edge on the bottom of the sleeve is shorted. Electrically the impedance at the open edge of the sperrtopf will be very large (ideally infinity). By the sperrtopf, an a-ULPD antenna chocks the current on the vertical part of the coaxial cable.

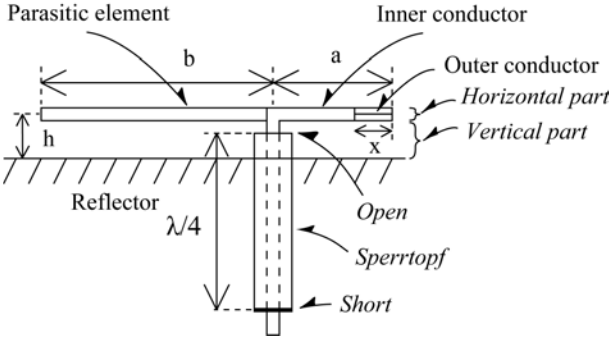


Fig.3: Configuration of an a-ULPD antenna with a sperrtopf

C. Impedance matching

The offset feed is used for the impedance matching. As the ULPD antenna is very close to a reflector, the input impedance is low. We strip off the edge of the outer conductor of the coaxial cable and expose the inner conductor. We shift the feeding point from the center to the edge for increasing input impedance and adjusting impedance matching. It makes the antenna simpler.

3. Composition of Antenna

The effect of the current prevention by a sperrtopf is examined in the case that the length of coaxial cable "a" and the length of parasitic element "b" are changed. The parameter "a" and "b" is shown in Table 1.

TABLE 1: COAXIAL CABLE AND PARASITIC ELEMENT

b/a	a [mm]	b [mm]
1.0	49.5	47.4
1.7	35.8	60.1
2.9	24.85	72
7.2	11.4	81.9

Most portion of "a" is outer conductor except "x". The inner conductor portion "x" is made by stripped off the edge of outer conductor. The other side of the outer conductor on the horizontal part is the parasitic element "b". The parasitic element is made of copper wire. The height "h" is λ/30 (The data measured at height λ/25 is used as the reference value at "a: b=1:1" for data shortage.). The reflector is 450 mm × 450 mm. The length of the sperrtopf is λ/4. The frequency is 1.52 GHz.

4. Experimental Result

A. Case without a sperrtopf

In the case without a sperrtopf, the ratio of "a" and "b" is changed by fixing "a" and changing "b". The frequency is changed, but it is supposed not to affect to the antenna based on similarity theory related to the antenna size and the frequency. It slightly influences on the height in a precise sense, but it seems no matter as long as in the entire tendency. Figure 4 shows return loss in case of the ratio of a: b=1: 2.3. The good resonant appears at 2.06 GHz. There is the other resonant at 2.86 GHz, but it is the second harmonic. The mode in 2.06 GHz is only considered. The good impedance matching is given by adjusting the length "x" when the rate of "a" and "b" is changed. The bandwidth of the ULPD without the sperrtopf is almost the same as a dipole. The bandwidth is 3.6% in evaluated at the return loss 10 dB. The bandwidth is almost the same regardless of the rate of b/a.

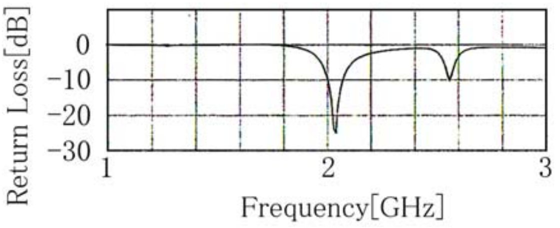
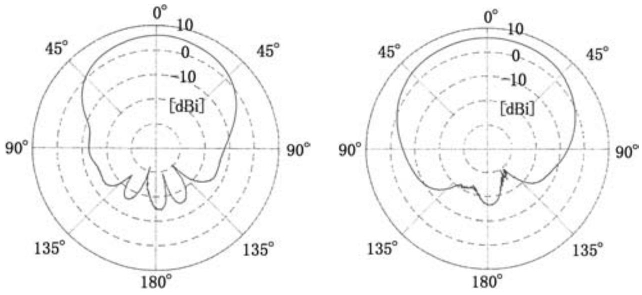


Fig.4: Return loss without a sperrtopf

Figure 5 shows the radiation pattern of ULPD antenna in case of the ratio of a: b = 1:1. The direction of the pattern of ULPD antenna is forward. The half power beam width is 58.5° in the E-plane and 87° in the H-plane [3]. In this paper, our purpose is to get the pattern and the gain of 9 dBi such as Fig.5 in the any rate of b/a.



(a) E-plane (b) H-plane

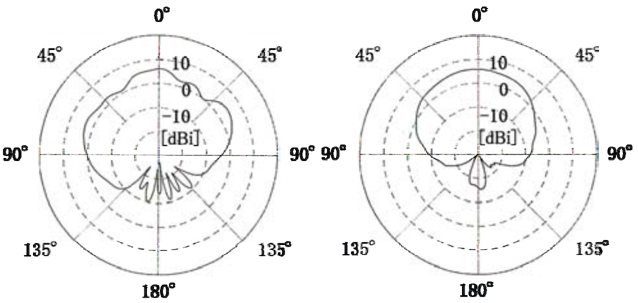
Fig.5: Radiation pattern of the ULPD antenna

Figure 6 shows the radiation pattern of an a-ULPD antenna in case of the ratio of a: b = 1: 2.3 at 1.52 GHz. The gain is 6 dBi which is lower than the ULPD antenna. The beam is wider, and has dips around ± 30°.This tendency is regardless of the relation to the rate of b/a.

There are mainly two reasons why the current doesn't flow on the vertical part of the ULPD antenna. First, the vertical part is located on the middle of the horizontal part. Second, the horizontal part of the antenna is very close to a reflector. These make the voltage potential of the middle of the horizontal part nearly 0 (shown in Fig.1).

However, in the case of an a-ULPD antenna, voltage potential is not 0 at the junction of the vertical part and the horizontal part (shown in Fig.2). Therefore, the current flows not only on the horizontal part but also on the vertical part of the antenna.

This a-ULPD antenna excites the combined mode which includes both a dipole mode and a monopole mode. It radiates from not only the horizontal part but also the vertical part. Then the beam width expands. Therefore, an a-ULPD antenna has a lower gain than the ULPD antenna [4].



(a) E-plane (b) H-plane

Fig.6: Radiation pattern of an a-ULPD antenna without a sperrtopf

B. Case with a sperrtopf

Figure 7 shows the return loss in the case "a: b=1: 1.7". The good resonant appears at 1.52 GHz and the return loss is 18 dB. There are the other resonant at 0.78 GHz and 2.4 GHz. In this research, a mode of dipole is considered and 1.52 GHz is used. The good impedance matching is given by adjusting the length "x" when the ratio of "a" and "b" is changed. The bandwidth of an a-ULPD antenna with a sperrtopf is 0.8% regardless of the rate of b/a. The bandwidth of an a-ULPD antenna with the sperrtopf narrows compared to any ULPD antenna without the sperrtopf.

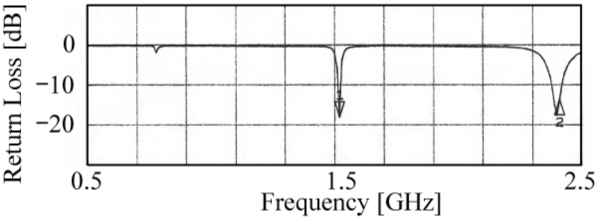
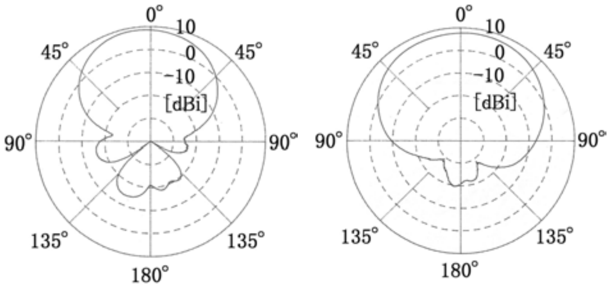


Fig.7: Return loss with a sperrtopf

Figure 8 shows the radiation pattern of an a-ULPD antenna in case of the ratio of a: b = 1: 1.7. The half power beam width is 60° in the E-plane and 91° in the H-plane.



(a) E-plane (b) H-plane

Fig.8: Radiation pattern of the ULPD antenna with a sperrtopf

There is the difference of 1.5° ～ 4° for the half power beam width between the case, a: b = 1: 1.7 with a sperrtopf, and the case, a: b = 1: 1 without the sperrtopf, but the difference is little. Moreover, the radiation pattern in Fig.8 is almost the same as Fig.9. It's apparent that the sperrtopf can choke the current on the vertical part and flow the current on the horizontal part. Thus this antenna becomes only a dipole mode. The current flows on the horizontal part only. The antenna is driven only a dipole mode like the ULPD antenna.

C. Effect of changing the rate of b/a in an a-ULPD antenna with a sperrtopf

In this section, we change the rate of b/a and pay attention to gain. Figure 9 shows the gain related to the rate of coaxial cable "a" and parasitic element "b". The gain between 7.5～9.1 dBi is observed and the radiation pattern is almost the same as the one in Fig. 8. This experiment indicates that the sperrtopf can choke the current on the vertical part and flow on the horizontal part and this antenna is driven only a dipole mode without relation to the rate of b/a. The gains are nearly 9 dBi and it is instability. However, it occurs not related to the rate of b/a, thus it turns out that there is the effect of choking current by the sperrtopf. The stabilization is a future work.

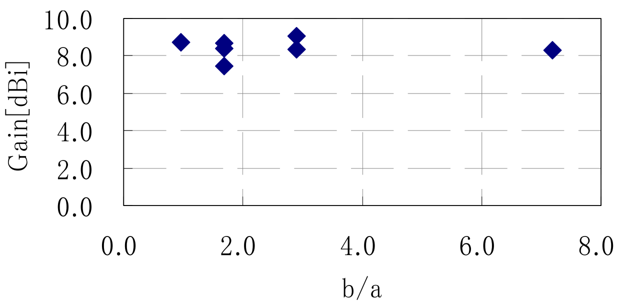


Fig.9: Gain in relation to ratio of coaxial cable "a" and parasitic element "b" in an a-ULPD antenna with a sperrtopf

5. Conclusions

(1) By the sperrtopf, an a-ULPD antenna can be driven only a dipole mode.
(2) Smooth radiation pattern and the gain of approximately 9 dBi are obtained. This result is almost the same as the ULPD antenna.
(3) Almost the same results are given for the length rate of the coaxial cable part and the parasitic part of the horizontal part.
(4) The offset feed can adjust the impedance matching.
(5) The bandwidth is narrower than the ULPD antenna.

Acknowledgement

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