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Radiation characteristics of Dipole Antenna with Bended Parasitic Element in the Vicinity of a Lossy medium

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1. Introduction

Built-in antennas of mobile terminals are used in the vicinity of lossy dielectric media such as a user's hand, body or head. It is well known that an antenna performance will deteriorate dramatically due to the lossy media. In addition, there are various relative positions between antenna and lossy media depending on the situation such as when making a call, sending mail or in standby status. In such a situation, the valid radiation characteristic is a unidirectional radiation pattern in a direction opposite to a lossy medium [1]. Optimal performance is required of the built-in antennas in these situations. Tunable antennas capable of tuning their own electrical characteristics have been studied in order to optimize their performance in various situations [2]. However, there are many problems to be solved, for instance, insertion loss of an active device.

In this work, we have assumed that a mobile terminal is put in a user's breast pocket. The mobile terminal put in the pocket has two states of back side or front side. We have conducted a basic study of an antenna capable of improving radiation characteristics in the two states without using active devices. Our proposed antenna is a dipole antenna with a bended parasitic element. The parasitic element acts as director or reflector in the case that the relative positions of antenna and high-permittivity lossy dielectric media change. The simulated results in the case of a thin mobile terminal in proximity to lossy media for both the front and the back sides are shown.

2. Mechanism of the Proposed Antenna

Figure 1 shows the concept of the proposed antenna. Two parallel conductors placed in the vicinity of a dielectric are shown on the left in Fig.1 (A). When a conductor is arranged in proximity to a dielectric with high permittivity, stray capacitance occurring at the end of the conductor becomes larger. And the conductor closer to a dielectric appears to become electrically longer than the other conductor. Our proposed antenna applies this phenomenon to tune the radiation pattern passively. That is, the antenna elements are designed such that a parasitic element acts as a reflector when it is closer to a dielectric and acts as a director when it is farther from a dielectric.

The proposed antenna is a modified Yagi-Uda array consisting of a dipole antenna (radiator) and a parasitic element. The end of one conductor (or both conductors) is bended as shown in Fig.1 (B). Since stray capacitance tends to occur at the end of the conductor we bended only the end of the conductor. And the middle part of the conductor where current is dominant was kept at a distance from the lossy dielectric to prevent deterioration of radiation efficiency. When the bended element is arranged on the dielectric side, state 1 in Fig. 1 (B), the bended part is closer than the center of the element, so that stray capacitance occurring at the end of the conductor becomes larger. On the other hand, when the bended element is arranged on the side opposite to the dielectric, state 2 in Fig. 1 (B), the bended part is farther than the middle part of the element, so that

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the difference in the stray capacitance becomes significant as distances (h_1 and h_2) change between the bended element and the dielectric medium when the antenna is turned upside down on the dielectric.

3. Simulation Model

In this work, we studied one of the proposed antenna structures in which only the radiator is bended. Figure 2 shows the simulation model of the proposed antenna on a rectangular solid lossy dielectric. And Fig.3 shows the cross-sectional view in the thickness direction of the mobile terminal. We refer to the case [a] as reflector mode and the case [b] as director mode. The thickness t of housing is 12mm and the interval d of the two elements is 10mm. h_p is the distance between lossy dielectric and the antenna element closest to the lossy dielectric. The lossy dielectric with the tissue parameter of average muscle at 2GHz [3] is formed by the rectangular solid. It is expected that the radiation characteristic deterioration of the antenna is significant when the radiator is in the lossy dielectric direction. We decided the length of antenna elements such that the parasitic element acts as a director in order to reduce the deterioration. For comparison, we calculated a dipole antenna arranged in the center of the housing (Fig.4). The distance between the dipole antenna and lossy dielectric is h_D.

The housing of the mobile terminal is not considered in the simulation because the scope of this paper is limited to a basic study. For all simulations, 3-D electromagnetic field simulator (CST MW-Studio [4]) based on the finite integration method was used.

4. Simulation Results

Figure 5 shows calculated radiation patterns of dipole antenna in the case of freespace and h_D=6mm at a frequency of 2GHz. Total efficiency including mismatch loss is -9.9dB when h_D=6mm at 2GHz. On the other hand, Fig. 6 shows calculated results of the proposed antenna at 2GHz. The radiation pattern in freespace was calculated when the antenna is arranged in the same direction as the director mode. The total efficiencies of reflector mode and director mode when h_p=1mm at 2GHz are -5.5dB and -7.5dB, respectively. The total efficiencies of both states of the proposed antenna were improved more than 2dB compared to that of the dipole antenna. Figure 7 shows total efficiency vs. h_p. In reflector mode the total efficiencies deteriorate as the distance from lossy dielectric is increasing from h_p=1 to h_p=5 since the state of the antenna is close to the freespace condition. For h_p>5, the radiation efficiency of the antenna dose not deteriorate since the antenna is far from the lossy dielectric. Although the worst total efficiency is when h_p=1mm in director mode, it is still improved more than 2dB compared to the total efficiency of dipole antenna when h_D=6mm.

5. Conclusion

The proposed antenna which is a dipole antenna with bended parasitic element improved the total efficiency when it was in proximity to lossy media for both front back sides compared to the total efficiency of dipole antenna when h_D=6mm. Optimization of the radiation pattern of the antenna for more than two states is a subject for future work.

References

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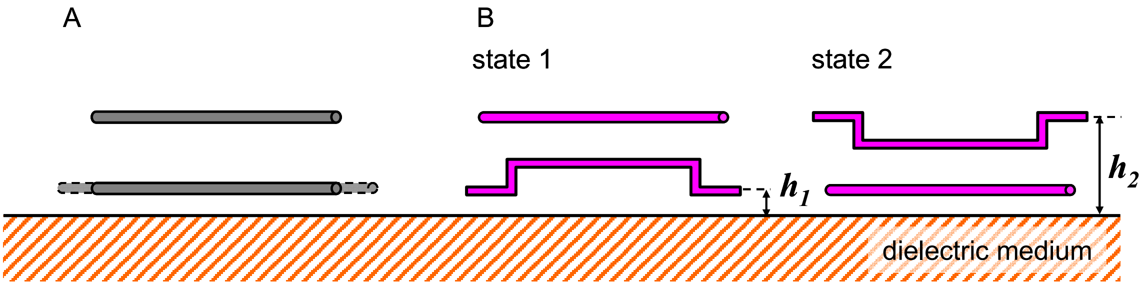

Figure 1: Concept of the proposed antenna
State 1 is an arrangement when bended conductor is close to the dielectric medium.
State 2 is an arrangement when bended conductor is far from the dielectric medium.

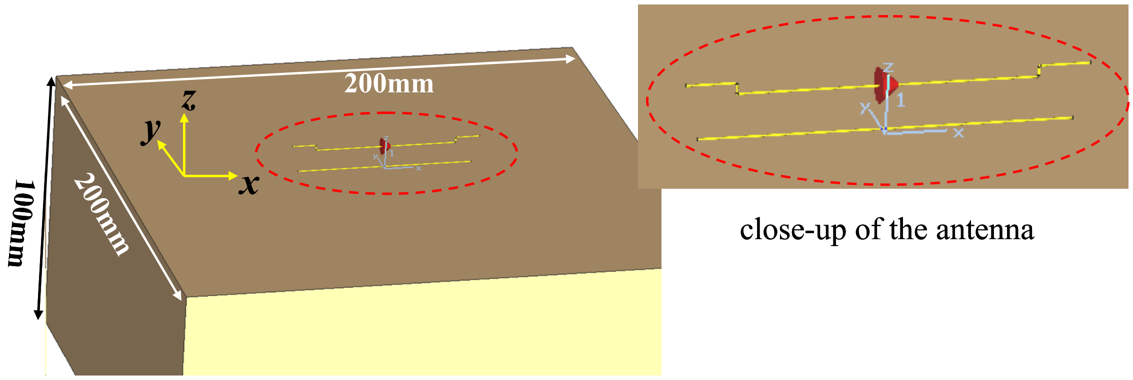

Figure 2: Antenna simulation model on a rectangular solid lossy dielectric (reflector mode)

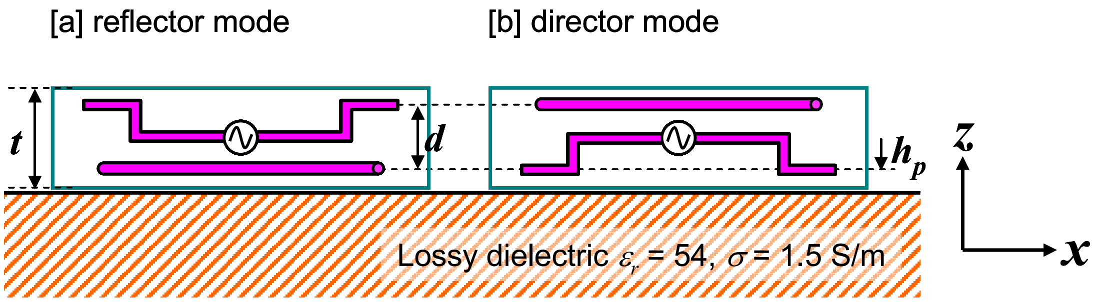

Figure 3: Configuration of simulation model of the proposed antenna
[a] reflector mode, [b] director mode

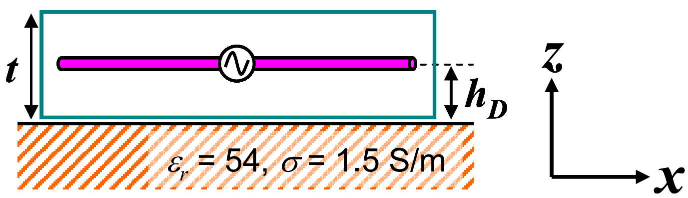

Figure 4: Configuration of simulation model of dipole antenna, for comparison

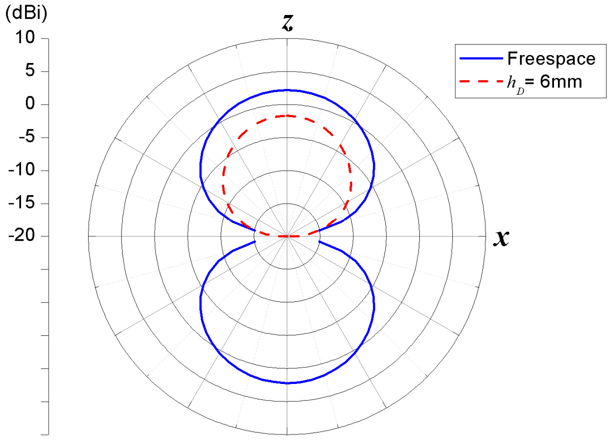

Figure 5: Radiation pattern of the dipole antenna when h_D=6mm at 2GHz

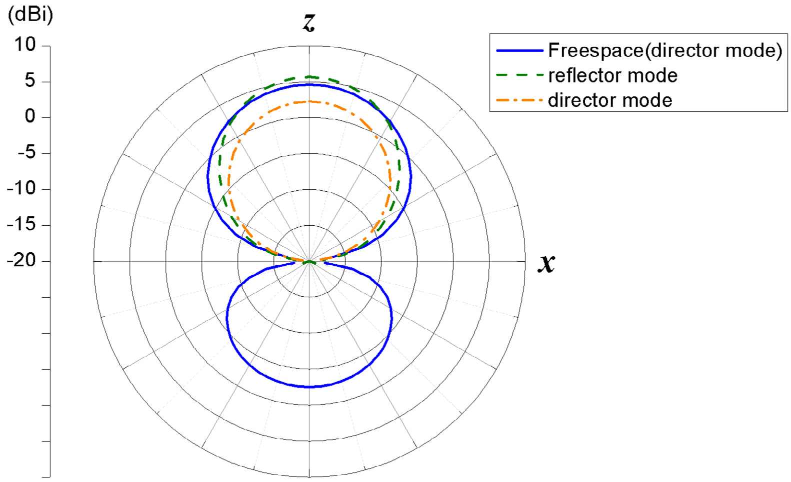

Figure 6: Radiation pattern of the proposed antenna when h_p=1mm at 2GHz

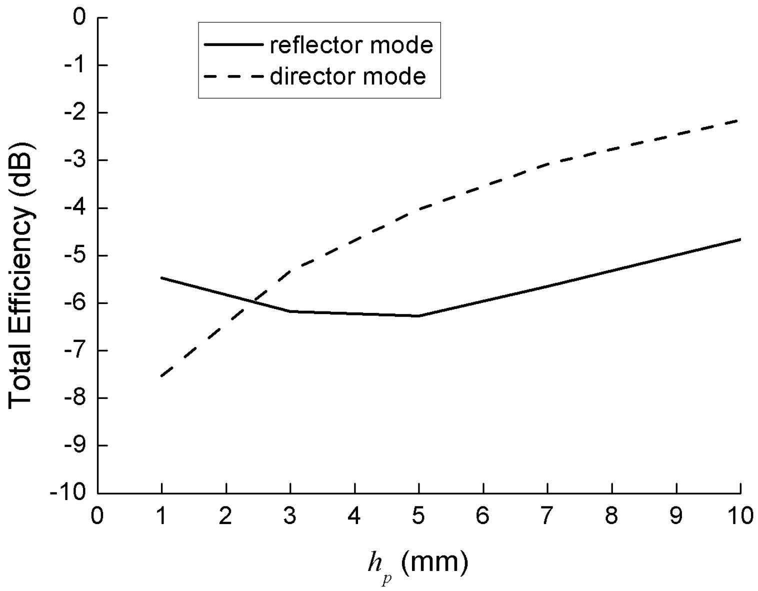

Figure 7: Total efficiency vs. h_p at 2GHz