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FD-TD ANALYSIS OF A PLANAR INVERTED-F ANTENNA MOUNTED ON A CONDUCTIVE BOX

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1. Introduction

A planar inverted-F antenna (PIFA) is favorable one to be applied to a compact radio unit like a handheld radio phone, since it is light and small. For expample, this kind of an antenna is widely used as one of the diversity antenna in a handheld radio phone unit in Japan.[1]

Original configuration of PIFA, which is positioned on an infinite conductive plane, seems to be a disk loaded short monopole and it's frequency bandwidth is as narrow as that of a conventional microstrip patch antenna fed by coaxial cable. However, it was found by experiment that it's frequency bandwidth of VSWR became much increased when it was mounted on a rectangular conductive box with dimensions properly chosen.[2,3]

Analysis of the radiation pattern of the PIFA mounted on such a conductive box was carried out and radiation pattern dependence on dimensions of the box were clarified.[2,3] Analysis of the input impedance was also carried out, but large discrepancy between calculated results and measured results exsited.[3] And so, it should be required to analyze input impedance of the PIFA more presisely.

Taga and Tsunoda applied Spatial Network Method (SNM) to analyze the input impedance of the PIFA, successfuly,[4] but their work is limited to the PIFA positioned on an infinite conductive plane. FD-TD methed[5,6] is also effective to analyze a complicated antenna mentioned above, and fundamental analysis of the PIFA with capacitive loading fed by both coaxial cable and electromagnetic coupling was reported [7].

In this paper, FD-TD method is applied to analyze input impedance and radiation pattern of the PIFA. First, analysis model of the PIFA, which is attached on a rectangular conductive box and is fed by a coaxial cable, is presented. Second, influence of the PIFA location on a conductive box to frequency bandwidth and radiation characteristics are described. Finally, enhancement of frequency bandwidth of VSWR is confirmed numerically when the width of the plane, on which the PIFA is mounted, becomes almost equal to that of the antenna element. Agreement between the numerical data by FD-TD and existing experimental data is fairly good and the effectiveness of FD-TD analysis will be shown.

2. Analysis Model of a PIFA

Fig.1 shows the analysis model of a PIFA and its corresponding coordinates. The PIFA is mounted on one plane of the side wall of the box in the X-Z plane. Configuration of the antenna element including feeding cable and shorted bar is illustrated in Fig.2, too.

Total dimension of the spacial domain is $71\Delta \times 71\Delta \times 101\Delta$, where Δ is the space discretization unit and is chosen 3mm in this analysis. Mur's second order absorbing condition[8] is used with ten slightly attenuating layers at the outer region of the analysis domain.

The antenna element is excited through a coaxial cable and its inner conductor is connected to the element as shown in fig.3.[7] Excitation pulse is launched in the coaxial cable by ten cells behind the observation plane, where input and output waves are calculated.

The input impedance can be obtained from the ratio of input and output waves transformed into the freguency domain.[4] Radiation pattern is also obtained from equivalent electric and magnetic sources at the surface which entirely includes the antenna element and the conductive box.[9]

3. Numerical Results

(1) Input Impedance and VSWR

Fig. 3 shows the input impedances of the PIFA on the conductive plate with W=40Δ, L=50Δ and D=0Δ. The dimensions of the antenna element are w=10Δ, l=15Δ and h=4Δ, respectively. Frequency changes from 900MHZ to 1100 MHz and "○" is marked at the freguency of every 20MHz.

Frequency bandwidth, defined by VSWR of less than 2, is increased from 3.8% to 5.5%, when the position of the antenna element moves from the center (S=17Δ) to the top edge, (S=2Δ), respectively. From this result, it is cleared that the frequency bandwidth is affected by the position of the antenna element in the finite size ground plane.

Fig.4 shows the locus of the input impedance expressed in Smith Chart, when the width of the box W is varied. Here, L=50Δ,D=20Δ and S=2Δ are fixed. The antenna element is the same as that in Fig.3. As the width W becomes small and approaches to that of the antenna element, the radius of the locus decreases. This result suggests that the freguency bandwidth becomes wider, as the width of the box W approaches to that of the antenna element.

Input impedances in Fig.4 do not match to the feeding cable whose characteristic impedance is 50 Ω. By adjusting the positions of feeding pin and shorted plate, input impedances in Fig.4 could be almost matched at the frequency points between 900MHz and 1100MHz.

Figure 5 shows FD-TD calculation results of the frequency bandwidth, defined by VSWR of less than 2 with comparing the results presented by Sato et.al [2]. The results obtained by FD-TD are much closer to the experimental results compared to those obtained by Method of Moments using wire grid model, although the length L of the box used in this analysis is slightly longer than the one used in measurement.

(2) Radiation pattern

The radiation pattern of the PIFA mounted on a conductive box has already been analyzed and the agreement between calculation and measurement was reported. In this paper, one of the feature of the radiation pattern, which depends on the position of the antenna element and the size of the conductive box.

Fig.6 shows the calculated result of the radiation pattern in the Z-Y plane by using FD-TD. The radiation patterns of the PIFA whose elements are positioned near the edge of the box are similar in E_θ component regardless of the differences in width W nor in depth D. However, if the position of the element is at the center of the box, radiation level toward the ground plane (-Y direction) decreases compared to that toward the antenna element (Y direction). This result suggests that the electric field coupling to the rear surface of the ground plane beyond the top edge is larger than that beyond the side edges of the conductive box.

4. Conclusion

Applying FD-TD method to anayze input impedance characteristies of a planar inverter-F antenna (PIFA) mounted on a conductive box, enhancement of freguency bandwidth of VSWR was clarified by numerical calculation.

It has been confirmed only by experiment that the freguency bandwidh of the PIFA defined by VSWR of less than two, becomes larger than 10%, when the width of the plane of the box, where the PIFA is mounted, get close to that of the PIFA. The numerically calculated result by FD-TD agree well to the measured results, which could not be predicted by Wire Grid Method of Moments. Dependency of the radiation pattern to the dimension of the conductive box was also presented.

References

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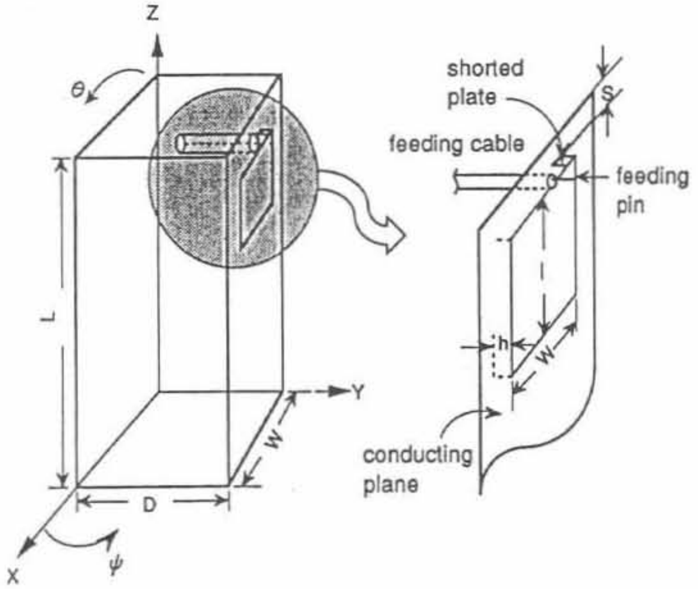


Fig. 1 Planer inverted-F antenna mounted on a conductive box

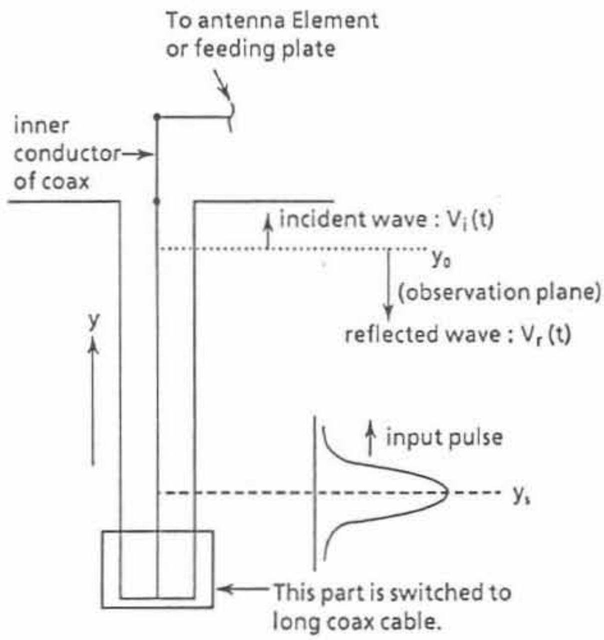
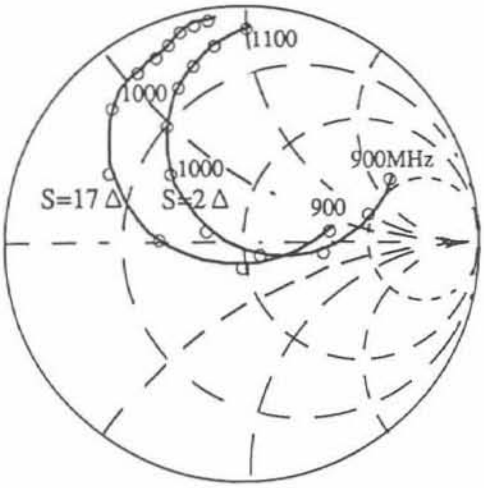
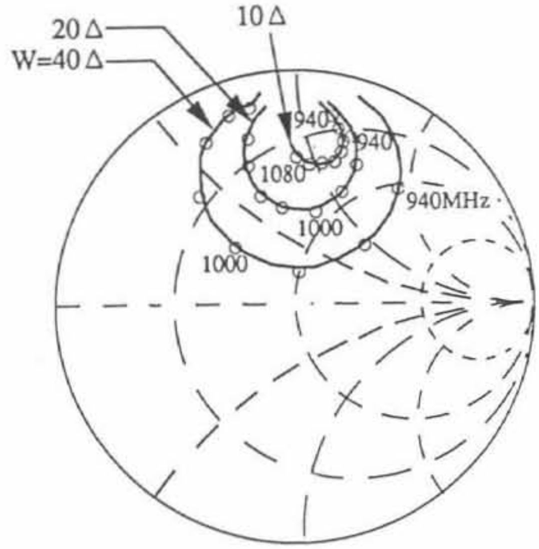


Fig.2 Antenna Excitation through COAX cable



L=50 Δ , W=40 Δ , D=0 Δ
l=15 Δ , w=10 Δ , h=4 Δ

Fig.3 Input impedance of PIFA on a flat plate



L=50 Δ , D=20 Δ , S=2 Δ ,
l=15 Δ , w=10 Δ , h=4 Δ

Fig.4 Impedance of PIFA mounted on a conductive box when changing width W

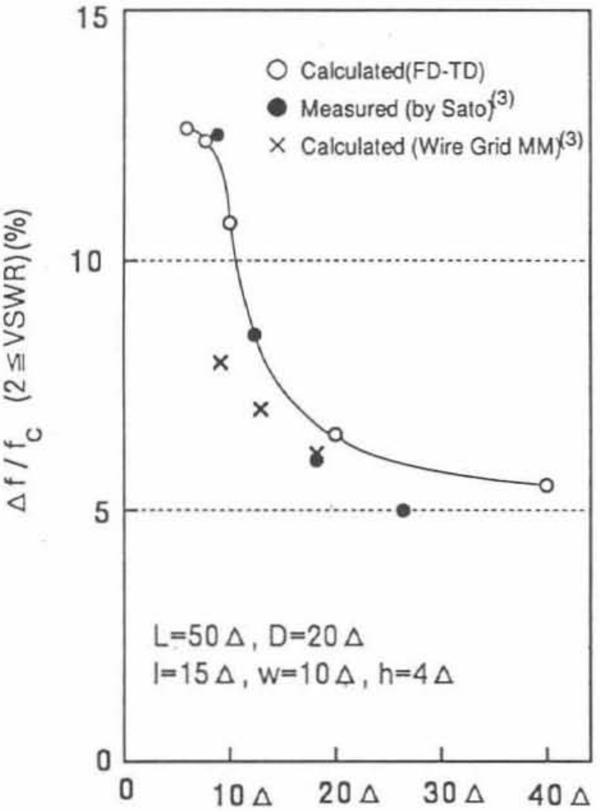


Fig.5 Frequency bandwidth of PIFA on a box. Comparison between FD-TD and measurement and between FD-TD and MM

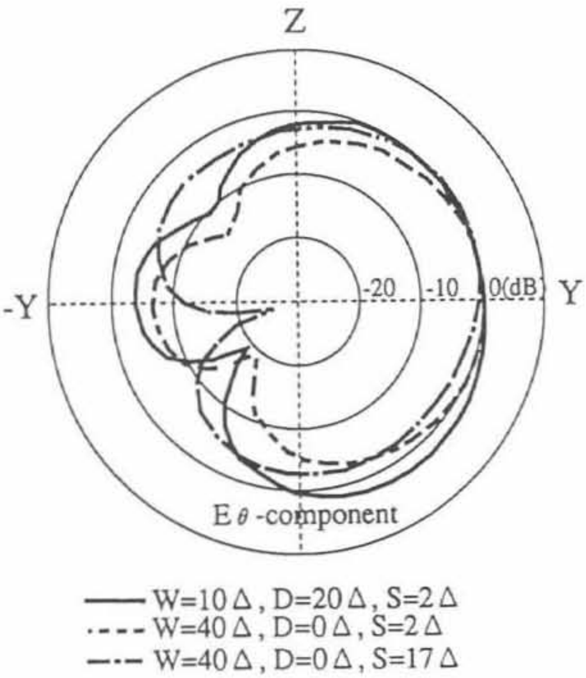


Fig.6 Comparison of radiation pattern of PIFA on a conductive box (L=50 Δ)