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Self-balanced and Wideband Characteristics of Improved Built-in Folded Dipole Antenna for Handsets

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1. Introduction

In conventional antennas, such as a monopole antenna and a planar inverted-F antenna (PIFA) for handsets, some gain degradation has been often observed when the operator holds the handsets at a talk position. This is caused by the variation of the current on the conducting box used in the handset due to human body effect. Because of this point, we have to consider reducing the current flow on the ground plane (GP). In the previous paper [1], Built-in Folded Dipole Antenna (BFDA) for handsets having a one-wavelength loop structure was introduced and analyzed. BFDA consists of a folded loop element placed horizontally on the top of GP so that the height of an antenna is reduced up to 20% in comparison with a folded loop antenna and it can place very close to the rectangular GP, which represents a shielding plate used in the handset unit. In addition, it has been shown that this antenna has a self-balanced structure not to produce unbalanced current on the feed line and is useful to reduce the current flow on the GP.

Furthermore, the services (IMT-2000, Bluetooh, W-LAN, WiMAX) for the cellular phone and PHS are recently increasing. So the wider bandwidth antenna for handsets is required. The relative bandwidths of BFDA which is fed by coaxial cable was reported approximately 400 MHz (13.0%) at the center frequency 2,900 MHz.

In this paper, the parameters related to the feed structure are optimized in order to obtain a wider bandwidth for the BFDA system, and the fundamental performances are analyzed in both theoretically and experimentally.

2. Antenna structure

Fig.1 shows configuration of the antennas. A folded dipole is essentially a two-wire transmission line, folded at about a quarter-wavelength to foam an equivalent half-wave folded dipole. Otherwise it consists of two parallel dipoles connected at the ends forming a narrow wire loop. The folded strip element forms a very thin ($d \ll \lambda$) rectangular loop is considered as a folded dipole as shown in Fig.1. The feed point is at the center of one side. Its operation is analyzed by considering the current to be composed of two modes: the transmission line mode and the antenna mode. The currents in the transmission line mode have fields that tend to cancel in the far field since d is small. In the antenna mode, the fields from the currents in each parallel section reinforce in the far field since they are similarly directed. In this mode the charges "go around the corner" at the end, instead of being reflected back toward the input as in an ordinary dipole, which leads to a doubling of the input current for resonant lengths. The result of this is that the antenna mode has an input current that is half that of dipole of resonant length. On the other hand, by using the two-wire transmission, a reactance component of the antenna impedance can be adjusted flexibly by selecting the length and the width of the strips and the distance of the two strips. This is an important feature of this antenna, which is contributed by applying the integration technology.

Fig.2 shows the structure of BFDA. The parameters of the antenna element are a=16 mm, b=1.5 mm, c=45 mm, d=1 mm, $w1$=$w2$=h=7 mm, g=10 mm, and p=7 mm. The antenna element has been installed on the rectangular GP, which represents a shielding plate used in the handset unit and the

ISBN: 978-4-88552-223-9 C3055©IEICE

overall length of GP is 45 mm × 120 mm. BFDA has a folded dipole element bended into U-shape and placed along the upper end of GP. The lower antenna element has a gap of 1.0mm (*d*) at the center of it. The antenna element is fed by a coaxial cable at the feed strip and connected to GP at the short strip. The antenna element and GP are made of copper plates with thickness of 0.2mm and 0.5mm, respectively. In the experiment, a semi-rigid coaxial cable with a diameter of 2 mm is used and the simulator IE3D, which is based on the MoM, is used in the calculation.

3. Results

Fig.3 shows the calculated input impedance of BFDA using smith chart. Fig.3 plot the impedance variations for the spacing of the feed and short strips (g), where a=16 mm, b=1.5 mm, c=45 mm, d=1 mm, p=7 mm and $w1$=$w2$=h=7 mm. From the results, the desired input impedance characteristics are achieved when g = 10 mm.

Fig.4 shows the VSWR characteristics in the calculation and measurement. As can be seen in the figure, the wideband characteristics of both calculated and measured results agree well each other and BFDA has three-resonance modes. The calculated and measured bandwidths (VSWR≤2) are approximately 940MHz (39.3%) at the center frequency of 2,390MHz and 1,120MHz (45.2%) at the center frequency of 2,480MHz, respectively.

Since BFDA has a self-balanced effect, it can be considered that there is no effect of the GP on the antenna performance. For the purpose to analyze the effects of the GP on BFDA, the VSWR characteristics for different lengths of GP are shown in Fig.5. As can be seen in the figure, the first-resonance mode (approximately 2GHz) has not been resonated by changing the length of GP. But the second (approximately 2.4GHz) and third-resonance mode (approximately 2.8GHz) has been resonated by changing the length of GP.

The calculated current distributions on the antenna elements, GPs of PIFA that resonated 2GHz and BFDA are shown in Fig.6. Each three frequencies of BFDA are adopted from frequency range in which the antennas resonate. As can be seen in the Fig.6, (a) and (b) have the current distribution appears on the GP and (c) has the asymmetric current distribution appears on the GP, but the amplitude is little as to be neglected. (d) has the asymmetric current distribution appears on the GP, but the one side amplitude is little as to be neglected. From those results, it can be seen as was confirmed in Fig.5 that self-balance effect is still maintained and hence the unbalanced current was reduced.

Fig.7 shows the calculated and measured radiation patterns in the z-y plane of BFDA. Fig.5 (a), (b) and (c) plot the power gain (dBi) at the frequency of f = 2.0 GHz, 2.4 GHz and 2.8 GHz, respectively. As can be seen in these figures, the calculated radiation patterns are similar to the measured results.

From those results, it can be seen as were confirmed in Fig.5 and Fig.6 that BFDA operation is analyzed by considering the current to be composed of three modes. The first mode is the transmission mode. The second mode is the antenna mode. The third mode is the feeble-antenna mode. Fig.8 shows each current mode of BFDA.

4. Conclusion

In this paper, as one of the antennas for handsets with which enhanced bandwidth and input-impedance adjustment can be obtained, BFDA is introduced and its characteristics is analyzed. BFDA fed by unbalanced coaxial cable still has a self-balanced effect and the improved wideband characteristics are achieved. More detailed analysis for this antenna is continuous subjects to be studied

References

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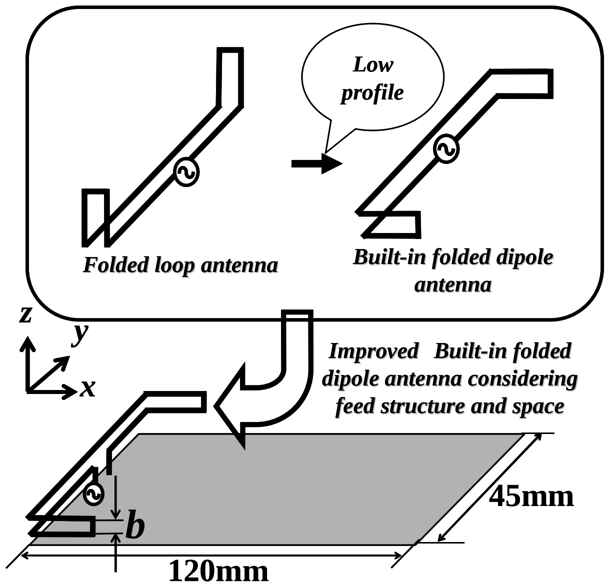


Fig1. Antenna configuration

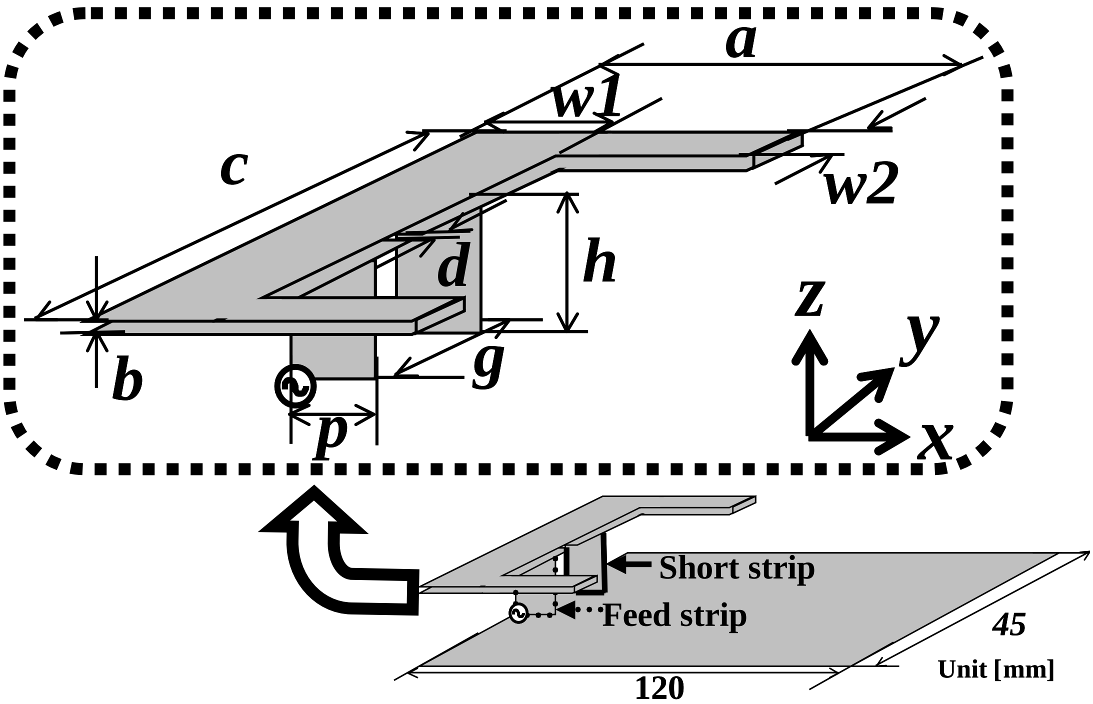
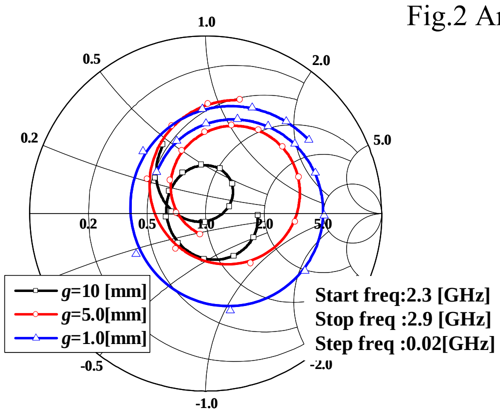


Fig.2 Antenna structure



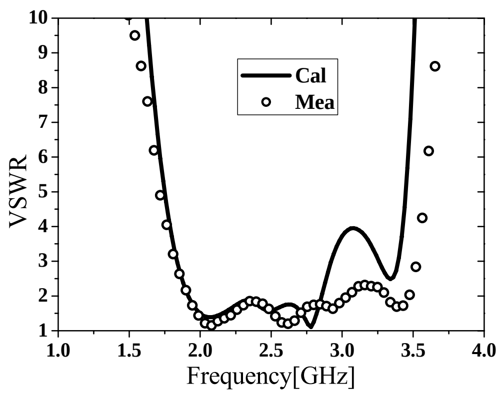


Fig.3 Input impedance of BFDA

Fig.4 VSWR characteristics vs. frequency of BFDA

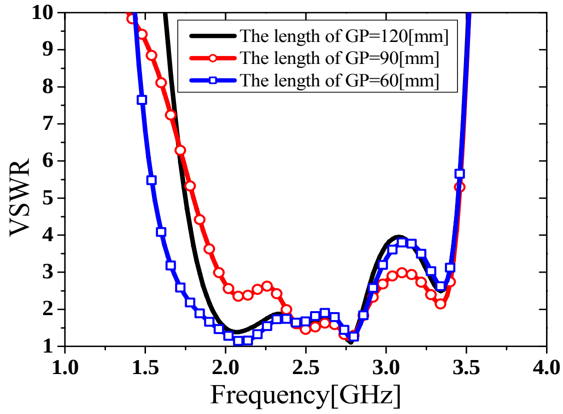
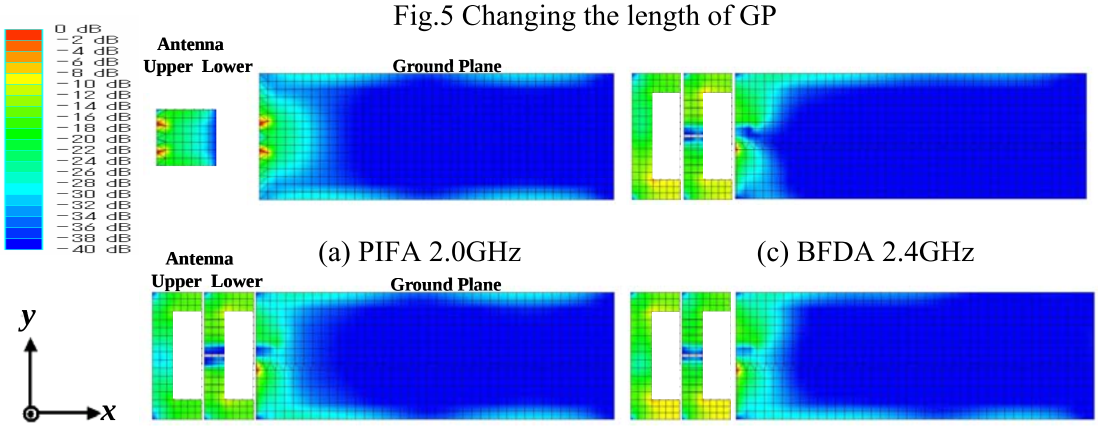


Fig.5 Changing the length of GP



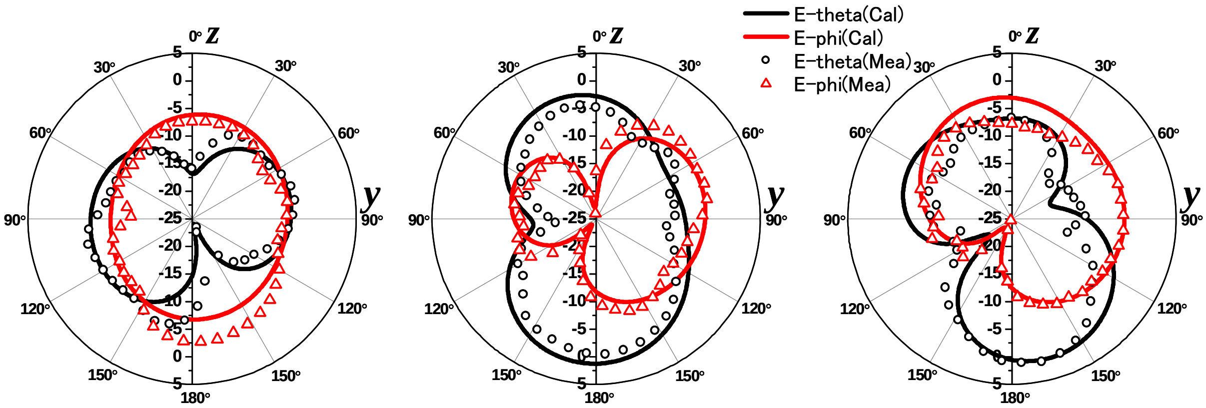
(a) PIFA 2.0GHz

(c) BFDA 2.4GHz

(b) BFDA 2.0GHz

(d) BFDA 2.8GHz

Fig.6 Current Distribution of BFDA

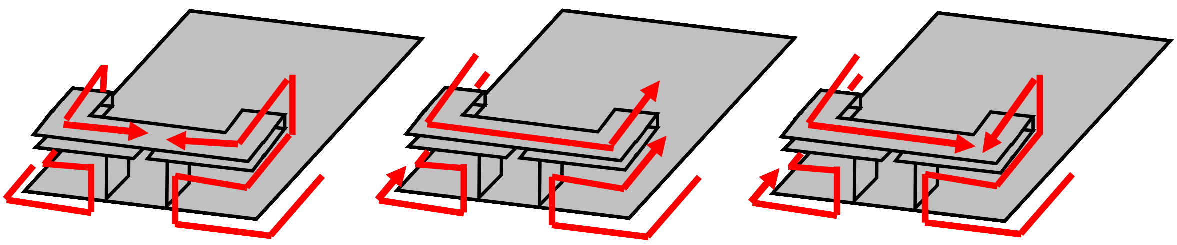


(a) 2.0GHz

(b) 2.4GHz

(c) 2.8GHz

Fig.7 Radiation patterns of BFDA



(a) The first mode

(b) The second mode

(c) The third mode

Fig.8 The current mode of BFDA