A Multiband Antenna for Mobile Phones

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ABSTRACT Antennas for mobile phone handsets are generally required to have such characteristics as compactness, complete built-in mountability, multiband operation and environmental isolation, as well as broad bandwidth and high efficiency. However, conventional technologies represented by planar inverted-F antenna (PIFA) are reaching their limit of improvement to meet the market requirements. In an effort to better such a situation, we have developed a novel model of antenna --for single band and multiband operation-- best suited for mobile phone handsets through full utilization of electromagnetic simulation techniques. The antenna developed here features the use of a specific radiator pattern and a resin of high dielectric constant, both belonging to Furukawa Electric's proprietary technologies, and it was confirmed that the performance of the antenna is comparable to that of conventional PIFA, whereas its volume is as small as one tenth of its counterparts.

1. INTRODUCTION

The progress of wireless communications equipment including mobile phones is ever accelerating toward implementation of the ubiquitous society, placing more importance to the antenna technologies day by day. As handsets improve in compactness and functions in recent years, the antennas for these equipment have come under the spotlight, transforming their longstanding impression of "an accessory for wireless communications equipment" into "a key device for wireless communication."

Naturally, mobile phone handsets are strongly required to be small in size. But small size is not the only prerequisite. They are required to have not only essential characteristics for antennas such as bandwidth and efficiency, but also the suitability for the environment of use specific to mobile phones.

2. DEVELOPMENTAL TASKS

Four technological tasks to be overcome at the development of antennas for mobile phone handsets are described below.

2.1 Compact Antenna

To efficiently radiate an electromagnetic wave into the free space, the size of an antenna should basically be something in the order of the wavelength radiated, which is inversely proportional to the frequency. For example, the wavelength at 900 MHz that is used in the GSM system is 330 mm, which is much larger than the size of the handsets currently in use. In other words, the frequency used is much lower given the size of the handset. One of the features of modern mobile phone systems is "low carrier frequency and broad bandwidth," which makes a major obstacle in the way of antenna development. It is inevitable in general that the radiation characteristics of an antenna degrade as the antenna size reduces or the frequency becomes lower. In particular, "compact size" and "broad bandwidth" conflict with each other. Thus, how to downsize an antenna without degrading its bandwidth is the design policy of great interest when designing compact antennas.

2.2 Complete Built-in Antenna

As the handsets saturate in their proliferation and they diversify in functions, the design has emerged as a major element of driving the customers to buy. In contrast to whip antennas that protrude from the casing, built-in antennas that are installed within the casing for proper operation can give a high degree of freedom of design. Not only because of this, but also from the standpoints of reinforcing shock resistance, improvement of specific absorption rate (SAR) on the human body, reduction of manufacturing costs, etc., the requirement for complete built-in antennas for handsets is always growing.

Currently planar inverted-F antenna (PIFA) accounts for the mainstream of complete built-in antennas [1)~3)]. PIFA is, like microstrip antenna, a magnetic current antenna featuring low profile necessitating no protrusion into the exterior space. But this type of antenna needs a sufficient volume to secure an appropriate bandwidth of operation, because it basically belongs to the group of narrow bandwidth antennas. It is said that a PIFA of general configuration needs a space of about 5000

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mm^3 to secure a sufficient bandwidth for GSM/DCS operation. This space is a so-called dead space, in which no components are to be allocated. Such a bulky dead space can not be allowed for in today's handset design, in which downsizing and high density implementation of advanced functions are being pursued including the mounting of high-definition-type digital cameras.

2.3 Multiband Operation

With the widespread use of the GSM system which employs the dual frequency bands of 900 and 1800 MHz, multiband operation of mobile phones is advancing rapidly. As things stand today, the application of multiband systems with a variety of frequency band combinations is accelerating, whereby the international roaming is progressing globally, the communications capacity is increasing and new functions are being added including GPS (1.57 GHz) and Bluetooth † (2.4 GHz). It is expected, therefore, that all the handsets will probably become compatible with multibands in the near future. In such multiband systems, a multiband antenna is definitely one of the key devices since it is compatible with all the frequency bands without resort to multiple antennas.

2.4 Isolation Characteristics

The isolation characteristics of an antenna indicate whether its performance is stabilized or not against the environmental changes. Much importance has been placed on the isolation characteristics of a mobile phone antenna from the two viewpoints as shown below. The first relates to the foldable casing consisting of the main circuit board and display. More specifically, whether or not the same level of communication sensitivity can be maintained between the two conditions where the casing is folded or unfolded. The second is concerned with the performance stability against the influence of the human hand and head. This is a problem specific to handsets, such that the equipment is used near the head while being held by the hand. Since human body is a lossy dielectric, the electromagnetic waves radiated during the communication are absorbed by the human body thus considerably degrading the radiation efficiency. There is a general requirement of improving this efficiency. In response to such a requirement, a design methodology for compact antennas has been suggested to make use of the ground plane or the entire casing as a radiator. But it would be difficult to satisfy the important performance parameter of isolation characteristics by using this design principle.

3. ANTENNA DESIGN

The above-mentioned developmental tasks from 2.1 through 2.5 have to be solved simultaneously, not respectively. Whereas they cannot be solved by extension of the conventional technologies such as PIFA, we have set out to develop an innovative compact antenna most suitable for mobile phone handsets.

3.1 Electromagnetic Simulation

In this development program, we focused on electromagnetic simulation in order to achieve the antenna design and analysis at a low cost and in a short time. IE3D, an electromagnetic fields simulator based on the method of moment from Zeland Co. was used together with Fidelity, a simulator based on the finite difference time domain method from the same company.

3.2 Basic Design of Single-band Antenna

Figure 1 is a schematic of the antenna developed here, consisting of two line conductors disposed in a high-dielectric material. This antenna structure is placed on an L-shaped ground plane, a part of which is removed from just underneath the antenna, with one of the conductors fed while the other grounded. Figure 2 shows the result of near-field analysis by Fidelity. It can be seen that a fringing electric field is formed between the edge of the ground plane and the surface of the antenna dielectric, leading to a prediction that the magnetic current thus generated acts as a major radiation source for the antenna. Thus there is the possibility that the antenna developed here performs as a complete built-in antenna like PIFA.

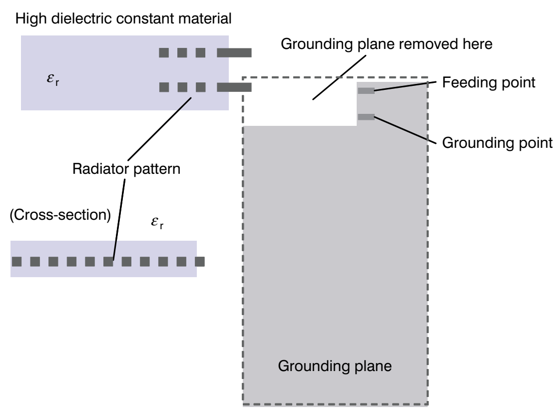


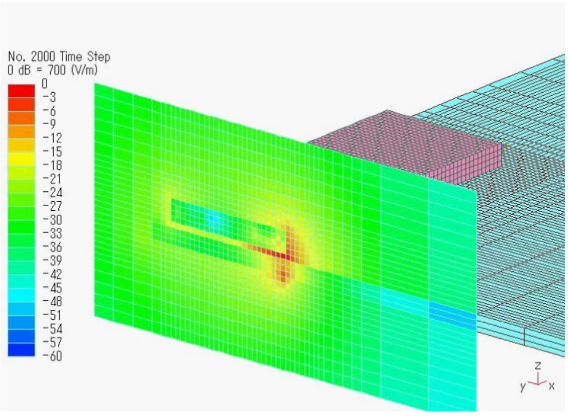
Figure 1 Schematic of the developed antenna for single-band operation.

Furthermore, downsizing of such an antenna structure was studied. Figure 3 shows comparisons of bandwidth characteristics obtained by simulation between the developed antenna and PIFA. It can be seen that the antenna developed here is basically broad banded, and is suitable for downsizing as well.

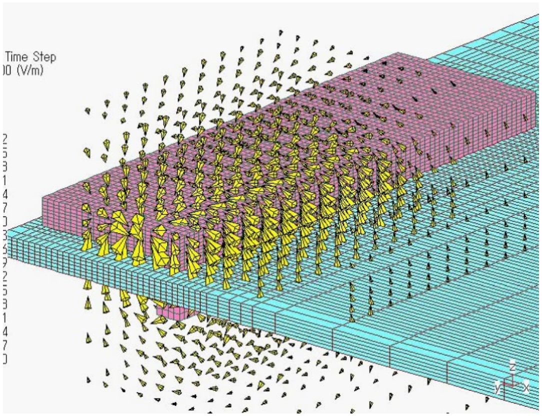
3.3 Prototyping and Evaluation of Single-band Antenna

The prototype antenna for 1.8 GHz band (PCS system) was fabricated based on the antenna structure above mentioned. The antenna size was decided to 18 mm x 6 mm x 1 mm, a resin with a dielectric constant of 5.7 was used, and the inner line conductors were constructed

† Bluetooth is a trademark of The Bluetooth SIG In.

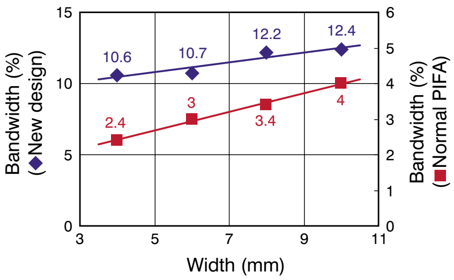


(a) Electric field intensity distribution

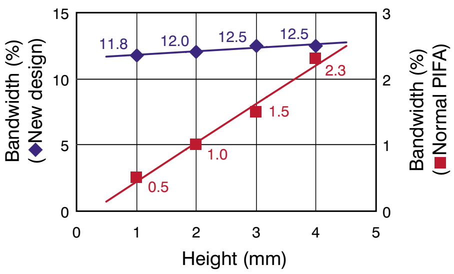


(b) Electric field vector distribution

Figure 2 Result of electromagnetic near-field analysis by Fidelity.



(a) Antenna width dependence



(b) Antenna height dependence

Figure 3 Comparisons of bandwidth characteristics between the developed antenna and PIFA.

with the meander line for the sake of downsizing, whereby the conductor pattern fabricated by etching was sealed into the resin by insertion molding. The antenna thus fabricated is surface mountable onto the main circuit board.

The prototype antenna was installed on an actual fold-type handset, and their characteristics were evaluated. The resonant frequencies were fine tuned for the operation band of 1.75~1.87 GHz, and the evaluation was carried out under three conditions of: with folded casing; with unfolded casing and with body phantom having head and hand in simulation of an actual use situation. Figure 4 shows the VSWR characteristics under these three conditions, indicating that virtually no changes in the center frequency can be seen among the three conditions, and that the antenna characteristics are much stabilized. Figure 5 shows the radiation characteristics at the center frequency in a major radiation plane.

Radiation characteristics of helical and small monopole antennas were evaluated in a similar way, and the results are compared in Table 1. Because their characteristics significantly depend on their locations, the values in the table are representative ones. It can be seen that both the helical and small monopole antennas have difference in the average gain between the folded and unfolded conditions, and that their gains appreciably degrade in the condition with phantom. The antenna developed here, on the other hand, maintains the comparatively stable characteristics, demonstrating that the antenna has better isolation characteristics in comparison to the other two antennas.

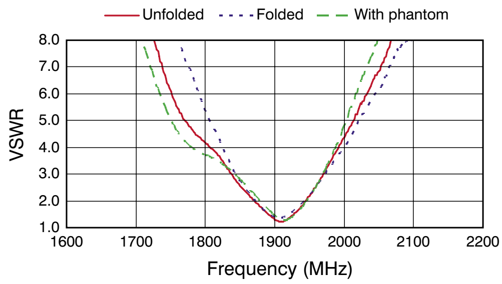


Figure 4 VSWR characteristics under the three conditions of folded casing, unfolded casing and with phantom.

3.4 Multiband Antenna

As described above, it was demonstrated that the antenna structure developed here has superior characteristics for mobile phone handsets. The antenna development was promoted further to achieve multiband performance, targeting at a triple band antenna compatible with the GSM/DCS/PCS systems.

A design method of bandwidth multiplexing occupying a minimum space was selected, whereby multiple resonance points were provided on one branch of the electric currents. Moreover, the design concept of stacked planar antenna was introduced to enable independent adjustment of resonance frequencies, while keeping balance among these frequencies. Because

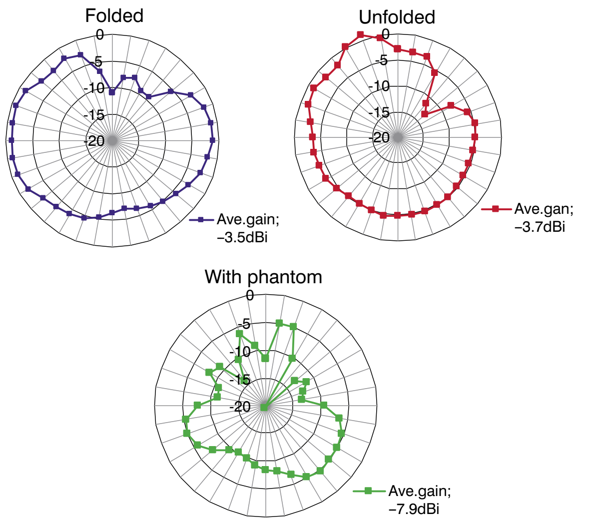


Figure 5 Radiation characteristics at the center frequency in the major radiation plane.

Table 1 Comparison of radiation gains of three types of antennas under different conditions.

	Folded casing (dBi)	Unfolded casing (dBi)	With phantom (dBi)
Helical antenna	−7	−5	−14
Small monopole antenna	−6	−3	−13
Developed antenna	−3.5	−3.7	−7.9

multiple antennas coexist in a small volume, multiband antennas tend to have a problem of interference among the operating frequencies. In an effort to prevent this problem of interference, near-field analysis inside the antenna was carried out by simulation, thereby searching for a structure such that the interference effects are minimized. Resin materials with a high dielectric constant were appropriately employed to downsize the antenna structure.

Figure 6 is a photo of the developed antenna. The antenna measures 28.5 mm in length, 3.0 mm in width and 5.5 mm in height raising a volume of 427 mm^3, and is installed on a 40 mm x 85 mm test board that simulates the main circuit board for a fold-type handset. Although a part of the ground plane must be removed from just underneath the antenna, components mounting is basically allowed for other areas. Accordingly, the space needed for antenna accommodation is just the volume of the antenna itself, which is one tenth the volume required for conventional PIFAs.

Figure 7 shows the VSWR characteristics of the developed antenna measured on a test board. The frequency ranges for VSWR not larger than 3 are 876~972 MHz (10.4 % relative bandwidth) for the lower band and 1616~2003 MHZ (21.4 % relative bandwidth) for the higher band, satisfying the operation bandwidth requirement for the GSM/DCS/PCS systems. With respect to the radiation characteristics, it has been confirmed in the laboratory that the radiation efficiency of the antenna at both bandwidths are satisfactory. For the future, the antenna has to pass, after being installed into actual handsets, various practical performance tests including low electric field test and the like.

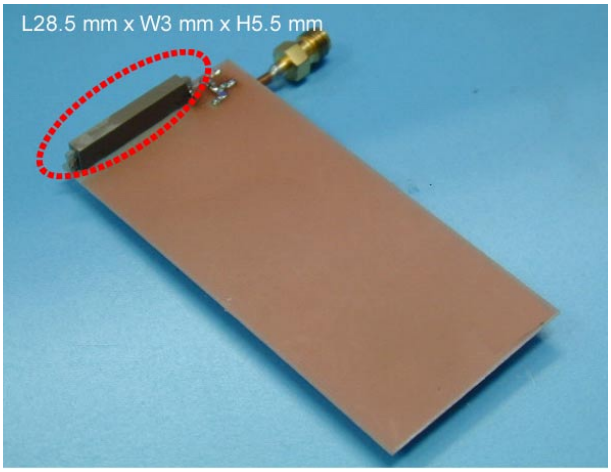


Figure 6 Photo of the developed multiband antenna, encircled with the dotted line.

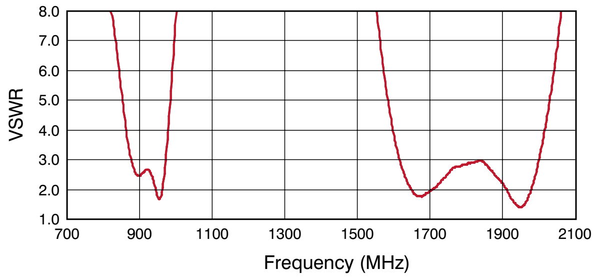


Figure 7 VSWR characteristics of the developed multiband antenna for the GSM/DCS/PCS systems.

4. CONCLUSION

A compact antenna most suitable for mobile phone handsets has been developed. The antenna developed here has been confirmed to have superior characteristics such as broad bandwidth, complete built-in mountability, multiband operation and environmental isolation. The features of the antenna structure include the radiation conductor pattern proprietarily developed and the use of a resin of high dielectric constant. The antenna has the triple bandwidth to be compatible with the GSM/DCS/PCS systems, achieving the antenna performance comparable to that of conventional PIFAs while occupying only one tenth the volume.

It is anticipated that bandwidth multiplexing is promoted using band combinations other than the GSM/DCS/PCS systems. Based on the technology cultivated in this development, Furukawa Electric intends to offer quick and flexible antenna solutions for various systems and also to strengthen our product lineup.

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