# A Chip Antenna for cdmaOne† Mobile Phones

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**ABSTRACT** Mobile phones, one of the representative mobile electronic equipment, are beginning to be installed with such functions as mailing and imaging as well as transmission and reception of moving pictures. Installation of such additional functions inevitably requires downsizing and weight reduction of constituting parts in order to maintain the weight and volume of existing equipment. With respect to the whip antenna that is extensively used conventionally, it has been pointed out that the antenna occupies much space in the casing thus placing design restrictions. To solve such a situation, Furukawa Electric has developed an ultra-compact, high-performance, built-in chip antenna for the 900 MHz band, which can be used as a main antenna for code division multiple access (cdmaOne) mobile phones. The antenna features the use of a high-performance resin material for its dielectric, and it has been confirmed that the antenna has superior mass productivity and long-term reliability.

## 1. INTRODUCTION

Whip antenna, a representative of external antennas, with a length corresponding to its resonant wavelengths is widely used in mobile phones. This type of antenna must have a storage space in the casing thus placing restrictions on the sizes of the battery and the circuitry substrate. In the current situation whereby function upgrading and design diversification are in progress with the exploding proliferation of mobile phones, it is obviously required that the main antenna, which is a major constituting part for mobile phones, should be small in size as well as low in cost.

In response to such a need for a compact, low-cost antenna for advanced mobile phones, we have succeeded in developing an ultra-compact chip antenna for CDMA mobile phones of global standard. The development has been realized based on the core technologies of a thermoplastic dielectric resin and a high-conductivity, high-strength copper material for leadframe, both technologies of which the company has long fostered.

In this report, the features of this ultra-compact chip antenna will be presented.

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† cdmaOne is a registered trademark of CDMA Development Group.

## 2. REQUIRED CHARACTERISTICS, TASKS AND SOLUTIONS

The major developmental tasks are described below.

### 2.1 Compact and Low-profile Antenna

Tasks of realizing antenna downsizing were constituted by development of a resin with the most suitable dielectric constant and by how to reduce the size of the radiating conductor while maintaining its desired resonant frequency.

We have investigated the optimum resin material for the working frequency of CDMA of 800 MHz to 900 MHz, and furthermore have succeeded in obtaining a compact antenna of desired frequency through such an approach, whereby a copper alloy material for leadframe is press worked to form a fine-pitched pattern, which is processed into a three-dimensional radiation circuit using the dielectric resin thus reducing the length of the antenna transmission line. The use of monopole-type antenna also helps achieve compactness and high-performance.

The antenna developed here has, as described above, a three-dimensional antenna configuration of copper conductor which is sandwiched using a thermoplastic resin, so that it has sufficient strength regardless of its small thickness. Accordingly, the antenna has satisfactory resistance against an accidental falling of the mobile phones.

### 2.2 Reduction of Resonant Frequency Changes Due to Ambient Conditions

It is essential for a mobile phone of folding-type to reduce the variation in frequency characteristics of the antenna as the equipment folds or unfolds. In particular, the monopole antenna tends to change in terms of resonant frequency and impedance due to such factors as the forms of metal casing and circuit substrate and the distance to the ground plane. Specifically, the resonant frequency in folded conditions is higher than that of unfolded conditions. Thus in designing the antenna, it is required to choose an antenna mounting place of less interference and to make it unsusceptible to environmental changes, i.e., to make it an antenna of high-isolation characteristics.

In order to meet these requirements, simulation techniques based on the moment method were extensively employed to study the designs. The moment method is one of the numerical analysis methods, whereby an integral equation is solved by discretization to obtain an accurate solution in a relatively short time. In the present analysis, a model for the metal conductors was discretized using a polygonal element of high degree of freedom, and current distribution over the model was calculated by solving Maxwell equations. From the current distribution obtained, antenna characteristics necessary for performance evaluation are calculated including the reflection versus frequency, the radiation pattern, etc.

Simulation are run for antenna characteristics, whereby the electromagnetic fields are analyzed using the moment method, significantly reducing the developmental time for new antennas. Modeling of not only the antenna itself but also the environmental effects enables quick response to customers' needs in the design step for the casing.

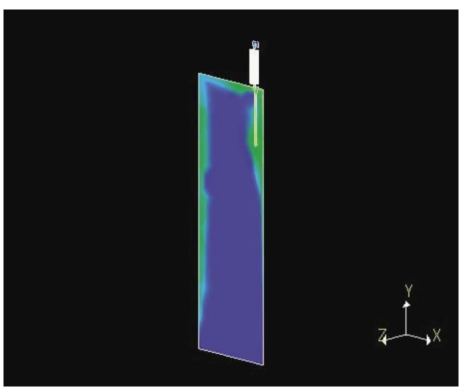


**Figure 1 Simulated current distribution on an antenna mounting model.**

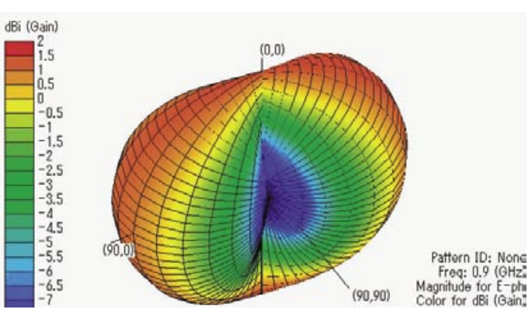


**Figure 2 Simulated antenna directivity.**

Thus the simulation technology has become a must in developing high-value added products such as multi-band antennas, ultra-wide band antennas and directivity controlled antennas, for which demands are increasing in recent years.

Figures 1 through 3 show some results of simulations, and Figures 4 and 5 show the results of improvement in resonant frequency changes in the folded and unfolded conditions of folding-type mobile phones, before and after improvement, respectively. It can be seen that the improvement of the resonant frequency changes due to environmental conditions has been achieved using simulations.

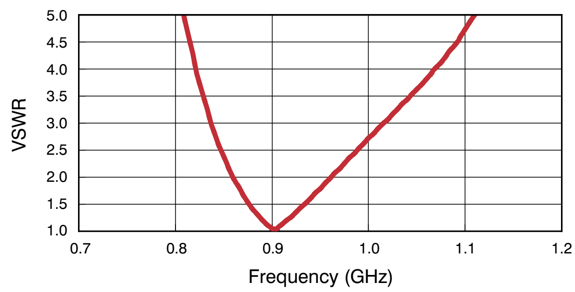


**Figure 3 Simulated VSWR vs. frequency characteristics.**

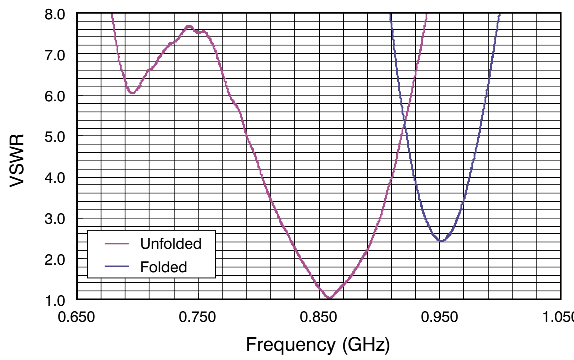


**Figure 4 Simulated changes in VSWR characteristics in folded and unfolded conditions (before improvement of antenna mounting).**

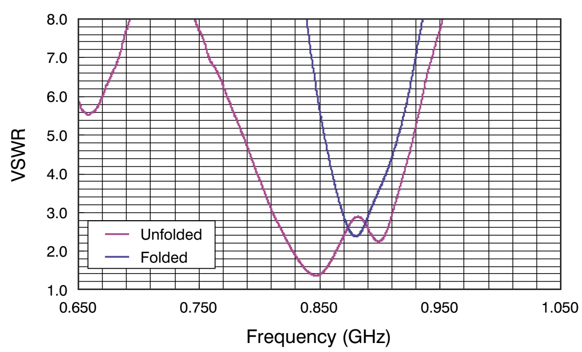


**Figure 5 Simulated changes in VSWR characteristics in folded and unfolded conditions (after improvement of antenna mounting).**

# 3. FEATURES

The features of the antenna developed here will be described in detail below.

## 3.1 Antenna Structure

Figures 6 and 7 show the appearance and dimensions of the antenna, respectively. It is generally said that an antenna requires one-quarter wavelength in size, but the size of the antenna developed here is only one-twentieth the wavelength, with a volume of 4.8 mm×16.4 mm×1.5 mm.

Structural members adopted are as follows.

In order to raise the antenna efficiency, it is necessary to increase the electrical conductivity of the antenna radiation circuit. To this end, a high-conductivity copper material for leadframe is used as the antenna conductor, and its structure is such that the finely patterned radiation conductor is covered with a dielectric resin to improve the durability of the antenna. Lead terminals of J-Lead are used to meet the requirement for surface mounting with higher density.

Moreover, considering that the environmental issues that are causing global concerns recently should also be taken into account in the field of electronic parts industry, we introduced Pb-free plating for the lead terminals thus responding to such environmental requirements.

## 3.2 Manufacturing Process

The manufacturing process for the antenna developed here will be presented below.

This is a continuous, reel-to-reel, product-on-the-hoop process covering all the press working of radiation conductor, insertion molding into resin, and final product. The details are as follows.

With regard to the manufacture of the radiation conductor, a high-conductivity, high-strength copper alloy based on Furukawa Electric's proprietary technology is press worked into a fine-pitched radiation conductor. The stamping accuracy at press working is sufficiently high to achieve a stable form as well as mass productivity.

The radiation conductor thus manufactured is continuously inserted into a forming die to be injection molded with a dielectric thermoplastic resin. The resin has a small contraction coefficient so that, helped by the dimensional stability of injection molding, contributes a great deal to achieving a very high degree of dimensional stability of the final product.

## 3.3 Radiation Characteristics

The radiation characteristics of the antenna will be presented below.

Figure 8 shows the reference board, matching circuit, and antenna configuration for characteristics measurement, and Figure 9 the results of VSWR measurement using this reference board. It can be seen

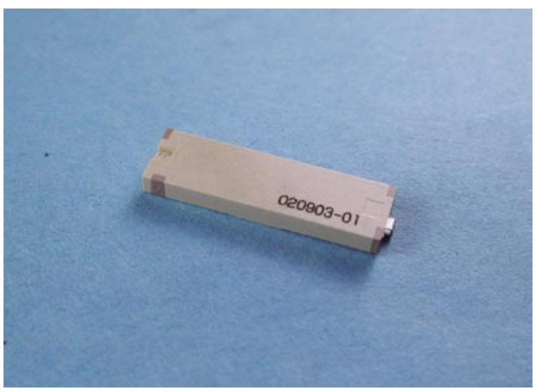


**Figure 6 Appearance of antenna.**

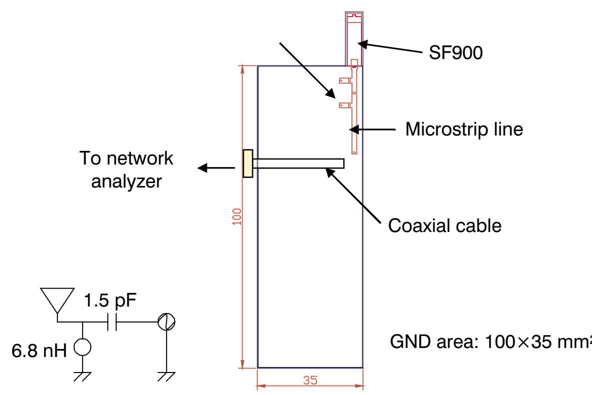


**Figure 8 Reference board and antenna configuration for measurement.**

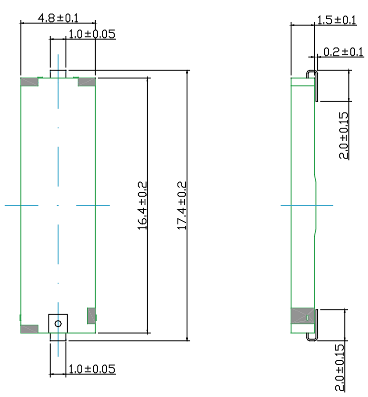


**Figure 7 Dimensions of antenna.**

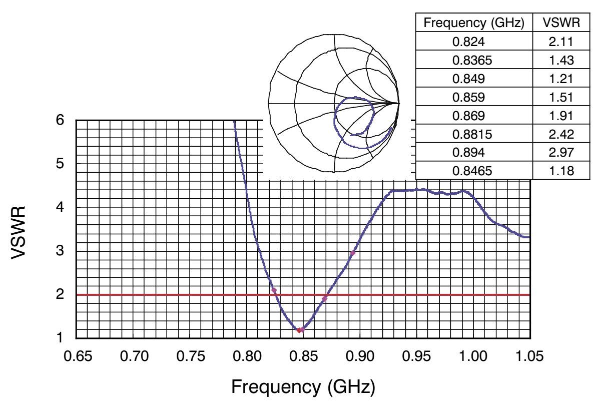


**Figure 9 Relationship between VSWR and frequency.**

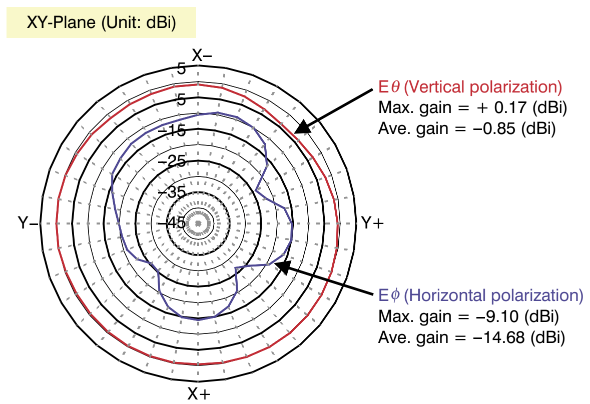


**Figure 10 Results of radiation pattern and gain measurements.**

**Table 1 Reliability test items and conditions.**

| No. | Test item | Conditions | Time |
|---|---|---|---|
| 1 | Low-temperature storage | −40° C | 1000 hr |
| 2 | High-temperature storage | +80° C | 1000 hr |
| 3 | High-temperature and high-humidity storage | 85° C · 85 % RH | 1000 hr |
| 4 | Heat shock | −40° C↔+85° C, 30 min each | 1000 cycle |
| 5 | Salt spray | 35° C, 5% salt concentration | 96 hr |

**Table 2 Results of reliability test.**

| No. | Test item | Change after test | |
|---|---|---|---|
| | | Resonant frequency | Bandwidth (VSWR=2) |
| 1 | Low-temperature storage | ±1 % or less | 5 % decrease or less |
| 2 | High-temperature storage | ±1 % or less | 5 % decrease or less |
| 3 | High-temperature and high-humidity storage | ±1 % or less | 5 % decrease or less |
| 4 | Heat shock | ±1 % or less | 5 % decrease or less |
| 5 | Salt spray | ±1 % or less | 5 % decrease or less |

that the bandwidth for VSWR of not greater than 2.0 is 50 MHz --no doubt a wide bandwidth when its extremely small size is considered.

Figure 10 shows the results of gain and directivity measurements. It can be confirmed that the average gain is high and the directivity is omnidirectional, satisfactorily meeting application requirements.

## 4. RELIABILITY EVALUATION

The results of reliability evaluation of the antenna will be presented below.

Table 1 shows the items and conditions of evaluation. The evaluation included five items of low-temperature storage, high-temperature storage, high-temperature and high-humidity storage, heat shock, and salt spray test. Each test was preceded by a series of pre-processing comprising a humidity-absorbing process of 85°C/RH85 %×168 hr and three repetitions of a reflow process for solder melting of 30~40 sec duration at 230°C or higher with 250°C peaks. Subsequently, the electrical characteristics were measured using our proprietary instruments including a shielding room.

Table 2 shows the results of the evaluation. As shown in the table, the initial characteristics scarcely changed by the tests, thus confirming that sufficient reliability has been achieved. Incidentally, initial characteristics before the tests were as follows.

Averaged resonant frequency: 903 MHz
Averaged bandwidth (VSWR=2): 100 MHz or more

## 5. CONCLUSION

A chip antenna for cdmaOne mobile phones has been developed. The development was carried out placing much emphasis on making the antenna mounting space saving, highly flexible in casing design, and capable of built-in configurations. An extremely small size has been realized helped by the investigations of molding resin materials together with the adoption of a three-dimensional radiating circuit, and the antenna has been confirmed to have good long-term reliability.

Hereafter, we plan to develop multi-band antennas of dual- and triple-band type using the same manufacturing technologies, thus promoting expansion of the product lineup.