**Co2Z hexaferrite T-DMB antenna for mobile phone applications**

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Co$_2$Z hexaferrite T-DMB antenna for mobile phone applications

Seok Bae$^1$, Yang-Ki Hong$^{1,*}$, Jae-Jin Lee$^1$, Jeewan Jalli$^1$, Gavin S. Abo$^1$, Won-Mo Sung$^2$, Gi-Ho Kim$^2$, Sang-Hoon Park$^2$, Jun-Sig Kum$^2$, and Hyuck M. Kwon$^3$

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We fabricated 0.029 $\lambda$ miniaturized Co$_2$Z hexaferrite T-DMB antenna. T-DMB antenna was fabricated by winding 12 turn Cu tape around the Co$_2$Z rectangular block. Antenna was mounted on the ground substrate with connection of coaxial feeding line. Fabricated Co$_2$Z antenna showed 196.2 MHz of center frequency, -6.55 dB of 3 dimensional average gain and 22.13 % of radiation efficiency at 195 MHz. Average gain of Co$_2$Z antenna is found to be greater than -17.4 dB in the range of 174 ~ 216 MHz.

Index Terms—T-DMB, Co$_2$Z, hexaferrite, antenna

I. INTRODUCTION

The frequency of digital mobile TV service, such as T-DMB (Terrestrial Digital Multimedia Broadcasting), is assigned in the range of 174 MHz to 216 MHz [1]. Currently, commercial T-DMB antennae are still based on a monopole rod antenna design. Since the length of a monopole antenna is proportional to $\lambda/4$ (= 38.5 cm at 195 MHz), the miniaturization of the T-DMB antenna is an issue to address. A dielectric chip T-DMB antenna was previously demonstrated as a potential replacement for the conventional T-DMB rod antenna [2]. However, volume of the dielectric chip T-DMB antenna is still larger than 2 cm$^3$ because 1.4 cm$^3$ is desired for T-DMB internal antenna. The ferrite possesses permeability ($\mu$) and permittivity ($\varepsilon$), and $\mu$ and $\varepsilon$ are effective in changing of electro-magnetic (EM) wave velocity $v$ and wavelength $\lambda$ ($v = c/\sqrt{\varepsilon\mu}$, $\lambda = \lambda_0/\sqrt{\varepsilon\mu}$). Therefore, ferrite was proposed to miniaturize the VHF antenna [3-7], but the performance of electrically small magneto-dielectric antenna is not satisfied due to large magnetic loss in the range of 100 ~ 300 MHz.

In order to further miniaturize T-DMB antenna and to achieve higher antenna gain, we developed low loss Co$_2$Z hexaferrite particles in the T-DMB frequency range [8, 9]. In this paper, we report performance of Co$_2$Z hexaferrite T-DMB antenna.

II. EXPERIMENT

A. Design

We used an inverted L antenna (ILA), which is one type of electrical small antenna. Figure 1 (a) shows a helical 12 turn ILA which was fabricated by winding the Co$_2$Z block with a 1.5 mm wide Cu tape with 2 mm wide interval. The ground of ILA was 48 x 80 x 0.6 mm in size, is approximated motherboard size of mobile phone, and of double side CCL (Cu Clad Laminate) FR4 substrate. The fabricated antenna is shown in the Fig. 2. An additional matching device or circuit is not used for tuning of frequency and impedance.

B. Measurement

Anechoic chamber system (volume: 10 x 7 x 7 m$^3$; shielding: - 105 dB; ripple < ± 1 dB in 0.17 ~ 3 GHz) as shown in the Fig. 1 (b) and network analyzer (Agilent ENA 5070B) were used to evaluate antenna performance.

III. RESULTS AND DISCUSSION

The synthesis of Z-type hexaferrite has been reported by the authors [8, 9]. We used the Z-type hexaferrite block for our antenna fabrication. The magnetic properties and frequency dependence of permeability and loss tan $\delta$ of the Co$_2$Z are shown in Fig. 3 and 4.

The real part of permeability and loss tan $\delta$ of Co$_2$Z are 8.4 and 7.4 % at 195 MHz, respectively, as shown in Fig. 4. We used the design in which Cu radiator is wound on the surface of ferrite block.

With regard to antenna performance, we located the Co$_2$Z hexaferrite antenna in anechoic chamber which is connected to network analyzer. Figure 5 shows VSWR (voltage standing wave ratio) for the Co$_2$Z ferrite antenna. Bandwidth (BW) was estimated to be 14 MHz between 188 and 202 MHz at VSWR of 3. The VSWR at 174 and 216 MHz are 13.06 and 14.70, respectively. Even though these VSWR values are high, we obtained reasonable antenna gains of -16.02 and -17.4 dB at 174 and 216 MHz, respectively. The center frequency ($f_c$) was
196.2 MHz as marked by an open arrow 3 in Fig. 5. This frequency exactly meets the requirement of T-DMB application. This is attributed to the high inductance per volume of helical radiator with high permeability of Co$_2$Z hexaferrite.

Fig. 5 HERE

The average gains of antenna were measured in anechoic chamber system as shown in Fig. 1 (b). Four average gains for xy, yz, xz-planes and 3 dimension were estimated by S$_{ij}$ parameters in terms of frequency ranging from 174 to 216 MHz. The results are presented in Fig. 6. The average gains increase up to about 190 MHz and then followed by a gradual decrease.

We calculated radiation efficiency (RE) by the following relationship:

$$10 \log \text{RE} = 3\text{D average gain [dB]}$$

The 3D average gain and radiation efficiency (RE) are -6.55 dB and 22.13 % at 195 MHz, respectively. Maximum 3D average gain and RE are -5.41 dB and 28.8 % at 189 MHz. This small RE is attributed to the Chu's limit [10]. The lowest 3D average gain is – 17.4 dB at 216 MHz as shown in Fig. 6.

Figure 7 shows 2D average gain patterns at 192 MHz. Gain patterns of xy- and xz-planes are omni-directional. The insignificant gain for yz-plane at 270 degree is attributed to the position of measurement cable in the DUT (Device Under Test) system.

Fig. 6 HERE

Fig. 7 HERE

Summary of antenna dimension, material, and characteristics is given in table I. We used dielectric and conventional rod antennas [2] for comparison. The dielectric antenna is shown in Fig. 8, which consists of two spiral radiators to meet T-DMB frequency. The Co$_2$Z hexaferrite antenna shows superior performance to dielectric and conventional rod antennas. Furthermore, the Co$_2$Z antenna volume is 60 % smaller than the dielectric antenna and rod antenna is longer than the Co$_2$Z hexaferrite antenna. Electrical and physical antenna sizes of Co$_2$Z antenna are 0.23 $\lambda$ (Cu tape length/wavelength at 195 MHz) and 0.029 $\lambda$ (Antenna length/wavelength at 195 MHz), respectively.

Table I HERE

Fig. 8 HERE

IV. CONCLUSION

The miniaturized 1.32 cc Co$_2$Z hexaferrite T-DMB antenna was fabricated for mobile phone applications. The maximum 3D gain and radiation efficiency were found to be -5.41 dB and 28.8 %, respectively, at 189 MHz, while -6.55 dB and 22.13 % at 195 MHz. The Co$_2$Z hexaferrite antenna size is 60 % smaller than the dielectric antenna. It is noted that the Co$_2$Z hexaferrite is an excellent candidate material for 0.029 $\lambda$ miniaturized T-DMB antenna.

REFERENCES


Manuscript received March 6, 2009. Corresponding author: Yang-ki Hong (e-mail: ykhong@eng.ua.edu).
Fig. 1. (a) The designed Co$_2$Z hexaferrite antenna, and (b) anechoic chamber system for antenna gain pattern measurement.

Fig. 2. Fabricated Co$_2$Z hexaferrite antenna.

Fig. 3. Magnetizations of synthesized M, Y and Co$_2$Z powders by MCP.

Fig. 4. Frequency dependencies of permeability and tan $\delta$ of Co$_2$Z hexaferrite.
Table I. Comparison on size, material, and 3D gains for ferrite, dielectric, and conventional rod antenna.

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<td>Size</td>
<td>44×10×3 mm³</td>
<td>10×36×6 mm³</td>
<td>Length: 100 mm</td>
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<tr>
<td>Material</td>
<td>Co₂Z ferrite (µ = 8.4, ε = 9.0)</td>
<td>Dielectric composite (µ = 1, ε = 20)</td>
<td>Steel</td>
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<tr>
<td>Gain at 195 MHz</td>
<td>- 6.55 dB</td>
<td>- 21.40 dB</td>
<td>- 20.34 dB</td>
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<td>RE at 195 MHz</td>
<td>22.13 %</td>
<td>0.72 %</td>
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Fig. 5. Frequency dependencies of VSWR (Voltage Standing Wave Ratio).

Fig. 6. Frequency dependencies of average gain of ferrite antenna.

Fig. 7. Frequency dependencies of average gain patterns of ferrite antenna at 192 MHz.

Fig. 8. Structure of dielectric antenna for T-DMB application [2].