Proceedings of ISAP'04, Sendai, JAPAN

Study of Modified H Shaped Antenna for Digital Terrestrial Reception System

Hideo Iizuka, Toshiaki Watanabe, Kazuo Sato and Kunitoshi Nishikawa
TOYOTA Central Research & Development Labs., Inc.
Nagakute-cho, Aichi-gun, Aichi, 480 1192, Japan
Phone: +81 561 63 4213, Fax: +81 561 63 5426
Email:hiizuka@mosk.tytlabs.co.jp

1. INTRODUCTION

Digital television terrestrial broadcasting services have been available in Japan since December 2003. Frequency bandwidth is assigned from 470 MHz to 710 MHz and horizontal polarization is utilized. Installation positions of on-glass antennas for a car are specified in the point of view for safety, appearance of a car, antenna performance and so on. Antennas installed to the rear window have been developed for analog television and AM/FM radio [1]. TOYOTA CRDL, Inc. has set the goal of developing automotive digital terrestrial reception system to enable the enjoyment of high definition television in a car, adopting adaptive array using four antenna elements [2]. Thus the installation positions may be not only the rear window but also the front window to reach the goal. There would be a problem that the received signal level is unacceptably weak to the sides of the car in the horizontal plane when conventional loop antennas or dipole antennas are installed, because those antennas mainly have gain to the front and rear directions. A modified H shaped antenna and its arrangement are proposed to cover 360 degrees in the horizontal plane even when there is the mentioned installation limitation. Radiation characteristics of the proposed antenna element are focused and described in this paper. Since the proposed antenna belongs to a balanced antenna, a wideband balun is also presented.

2. CONFIGURATION OF MODIFIED H SHAPED ANTENNA

Configuration of the proposed modified H shaped antenna element is shown in Figure 1. Two wires *a-b-c-d-e* and *f-g-h-i-j* are symmetrically placed for the center *k* of the antenna. The parts *a-b-c* and *f-g-h* of the two wires are longer than the parts *c-d-e* and *h-i-j* so that the currents on wires *b-c-d* and *i-h-g* may flow in phase at parallel resonance. The antenna has the feature of inclined figure-8 radiation pattern from the *y* axis across the Digital Television (DTV) band. The feature is obtained using three resonant modes, which are the 1st series, the parallel and the 2nd series resonant modes, respectively. Each resonant mode is excited when a part of the antenna has the length of a half resonant wavelength. Figure 2 shows symmetrical arrangement of the four antenna elements having the feature. The symmetrical arrangement would avoid unacceptably weak signal level in the xy plane although the installation positions of antennas are limited like a car.

Figure 3 shows wideband LC balun circuit. The balun consists of High Pass Filter (HPF) and Low Pass Filter (LPF). Both are 5th order Butter-worth filters. 3 dB cutoff frequency is set at a lower frequency for the HPF and a higher frequency for the LPF than the DTV band so that both filters may give flat amplitude and out of phase at the balanced port F_b across the DTV band.

ISBN: 4-88552-207-2 C3055©IEICE

3. RADIATION CHARACTERISTICS

Figure 4 (a) shows calculated input impedance at the balanced port F_b for presenting original characteristic. The characteristic was calculated using the TLM method. Figure 4 (b) shows measured input impedance of a prototype antenna including a balun at the unbalance port F_u. The dimensions $H \times W$ were 6 cm×23 cm for calculation model and 6 cm×23.4 cm for the prototype antenna. The parallel resonance is occurred at 560 MHz in both figures. Two wires *a-b-c-d-e* and *f-g-h-i-j* are resonated at the parallel resonance. The 1st series resonance is seen at lower frequency than the parallel resonance in both figures. The wire *a-b-c-k-h-g-f* is resonated at the 1st series resonance. Whilst the 2nd series resonance is also seen at higher frequency than the parallel resonance in which the wire *e-d-c-k-h-i-j* is resonated. Figure 5 (a) and (b) show calculated and measured VSWR. Calculated VSWR was normalized to Z_0 = 110 Ω at the balanced port F_b. The value of 110 Ω was chosen to obtain the widest bandwidth. Calculated VSWR was less than 2.9 in the DTV band. The balun works as not only a balance-unbalance transformer but also an impedance transformer from 110 Ω to 50 Ω. Measured VSWR was less than 3 in the DTV band.

Calculated and measured radiation patterns are shown in Figure 6 (a) and (b). Figure-8 radiation pattern is rotated clockwise with increasing frequency, which corresponds to the current distributions of the three resonant modes. Received signal level to the x direction increased in the DTV band. Since the shape of radiation pattern is varied across the DTV band, the gain behavior is discussed by not peak gain but the following averaged gain G_{ave} calculated from the xy polar plot.

$$G_{ave} = \frac{1}{2\pi}\int_0^{2\pi} |D(\phi)|^2 d\phi \qquad (1)$$

Where $D(\phi)$ is directional pattern in the xy plane. Figure 7 shows measured averaged gain G_{ave} of the prototype antenna. The averaged gain G_{ave} gave a relatively flat characteristic from –4 dBi to –2.3 dBi in the DTV band. Since ideal standard dipole has an averaged gain of –1.36 dBi, the loss of the prototype antenna is mainly caused by loss of reflection and balun. Measured transmission coefficient of the fabricated balun had also a flat characteristic shown in Figure 8. Loss of the fabricated balun was 0.3 dB in the DTV band.

4. CONCLUSION

A modified H shaped antenna and its arrangement have been proposed. The prototype antenna had inclined figure-8 radiation pattern and a relatively flat gain characteristic in the DTV band. The symmetrically arranged antennas could be applied for automotive digital terrestrial reception system.

ACKNOWLEDGEMENT

This work was supported in part by Telecommunications Advancement Organization of Japan.

REFERENCES

[1] H. K. Lindenmeier, et al, "Antenna and diversity techniques for broadcast reception in vehicles", IEEE Int. Antennas Propagat. Symp. Dig., pp.1097-1100, Chicago, Illinois, USA, Jul. 1992.

[2] J. Imai, et al, "Experimental results of diversity reception for terrestrial digital broadcasting", IEICE Trans. Commun., vol.E85-B, No.11, pp.2527-2530, Nov. 2002.

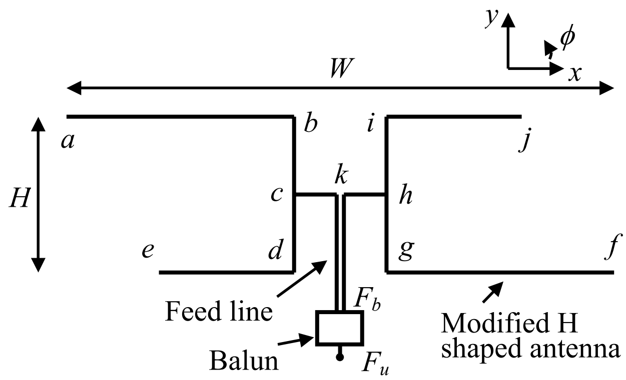


Fig.1 Configuration of the modified H shaped antenna.

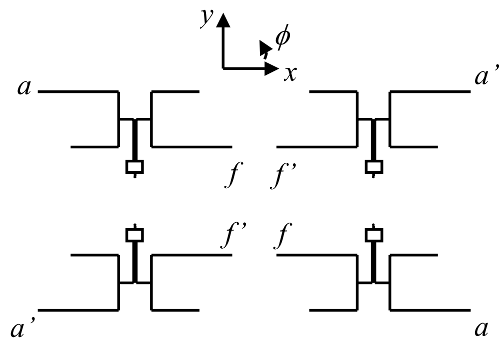


Fig.2 Symmetrical arrangement of four antenna elements.

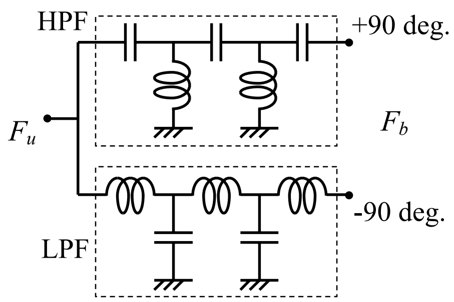
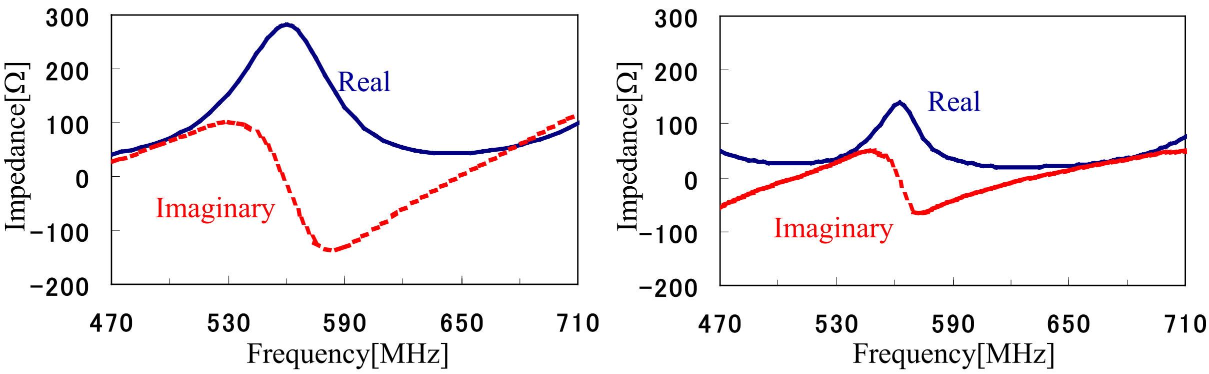


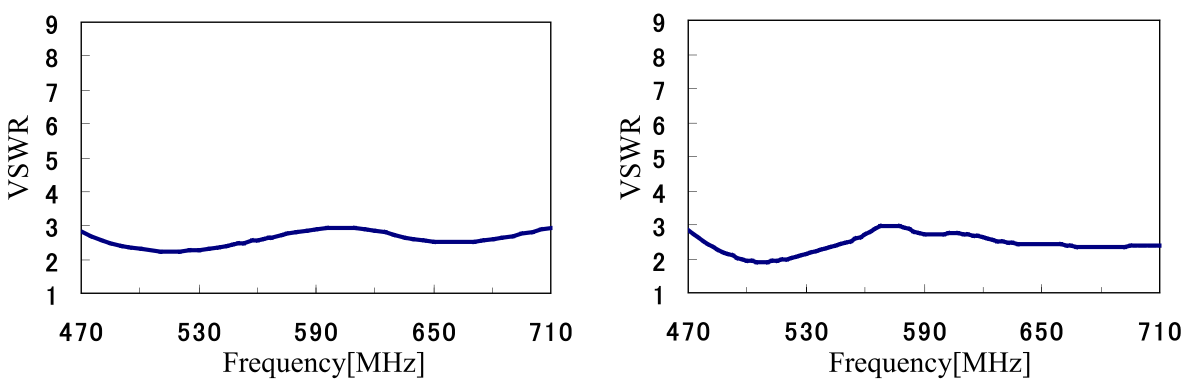
Fig.3 LC balun circuit



(a) Calculated input impedance at F_b

(b) Measured input impedance at F_u

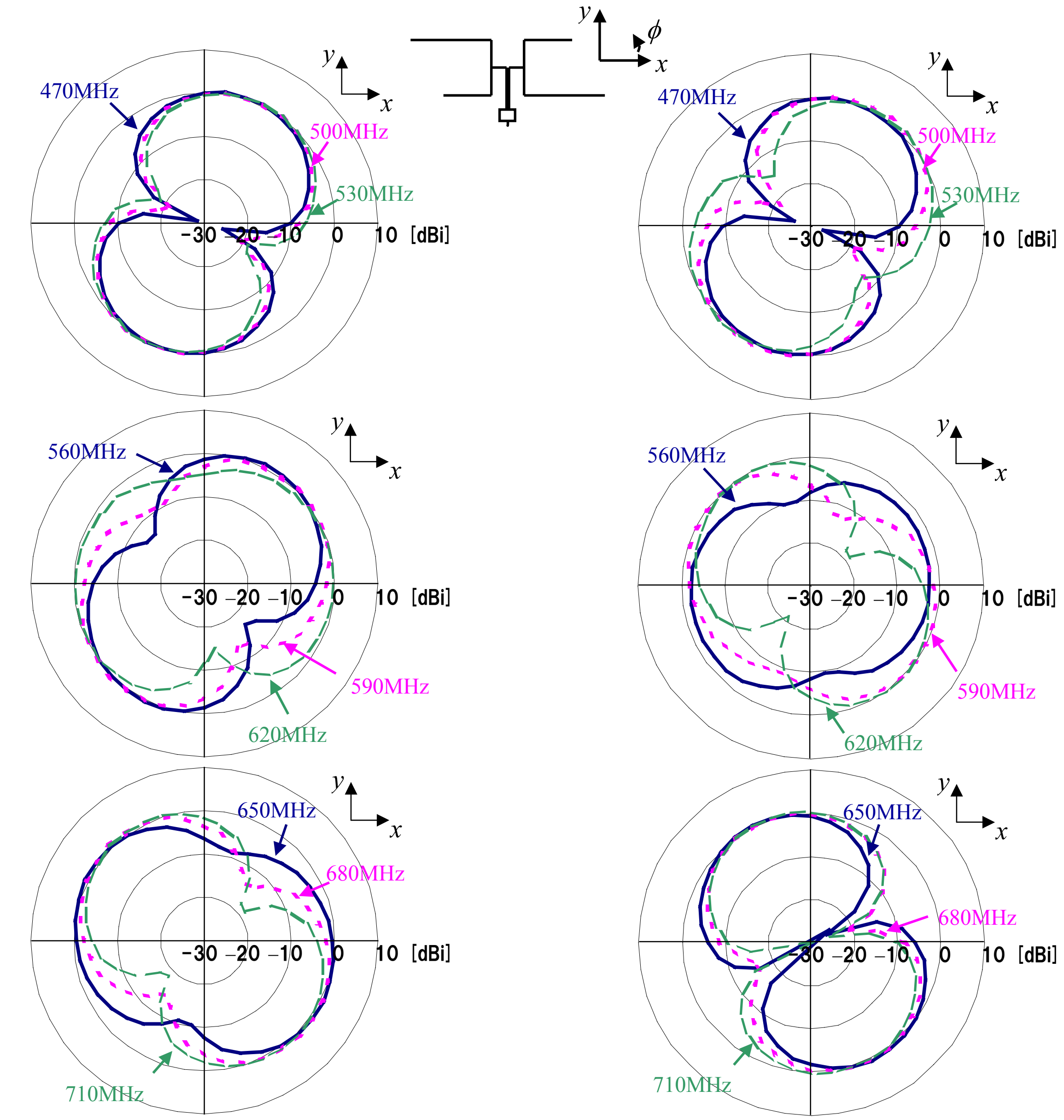
Fig.4 Input impedance of the modified H shaped antenna.



(c) Calculated VSWR at F_b (Z_0=110Ω)

(d) Measured VSWR at F_u (Z_0=50Ω)

Fig.5 VSWR of the modified H shaped antenna.



(a) Calculated radiation patterns (b) Measured radiation patterns

Fig.6 Radiation patterns of the modified H shaped antenna in the *xy* plane.

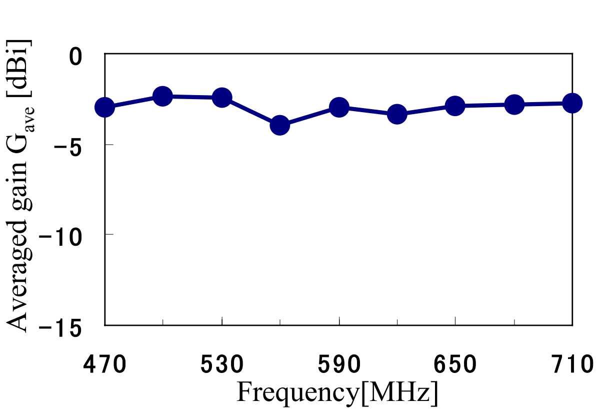


Fig.7 Measured averaged gain of the modified H shaped antenna.

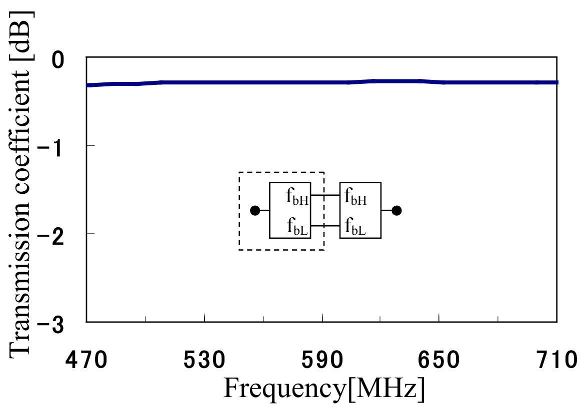


Fig.8 Measured transmission coefficient of a single balun.