Triple-Band Polarization Diversity Antenna with Loop Element

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Antennas for mobile communication base stations need to support a wide range of frequency bands, including 800 MHz, 1.5 GHz and 2.0 GHz, while also responding the demand for polarization diversity and size reduction for easier installation. We have developed a triple-band polarization diversity antenna using loop elements, which successfully reduces the antenna size by about 60% compared with the conventional dipole antenna.

Keywords: loop antenna, polarization diversity antenna, multiband

1. Introduction

In recent years, a wide range of frequency bands, including 800 MHz, 1.5 GHz and 2.0 GHz, are used for mobile communication. Antennas for mobile communication base stations need to support multi-band transmission and reception, as well as to respond to polarization diversity. They are also required to be reduced in size so that the installation work is simplified, load to antenna towers is reduced, and the scenery is not spoiled. Thus far, multi-band antennas[(1)-(3)] and dual polarized multiband antennas[(4)-(10)] have been reported. This report proposes a newly developed small-sized triple-band dual polarized antenna composed of loop elements and bent dipole elements.

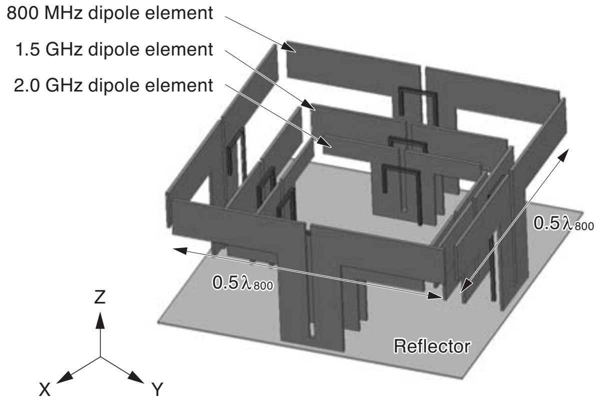

Fig. 1. Conventional antenna structure (Dipole, individual power feed)

2. Antenna Element

The target frequency bands of the developed antenna are 800 MHz, 1.5 GHz and 2.0 GHz.

Figures 1 and 2 show conventional triple-band dual polarized antenna structures. **Figure 1** shows a triple-band dual polarized antenna composed of conventional dipole elements. Each dipole element resonates at each frequency and has each power feed line. The antenna size is $0.5\lambda_{800} \times 0.5\lambda_{800}$ (λ_{800}: wavelength of the center frequency of the 800 MHz band), which is determined by the 800 MHz dipole element size.

Figure 2 shows a triple-band dual polarized antenna composed of dipole elements. Each dipole element resonates at each frequency and has a common power feed line. The antenna size is also $0.5\lambda_{800} \times 0.5\lambda_{800}$, which is determined by the 800 MHz dipole element as the antenna shown in **Fig. 1**.

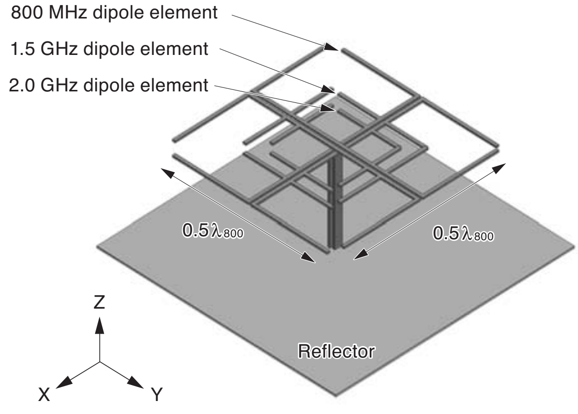

Fig. 2. Conventional antenna structure (Dipole, common power feed)

For downsizing, we built the triple-band antenna with loop elements and bent dipole elements. **Figure 3** shows the newly developed vertical polarized triple-band antenna structure. This antenna is composed by 800 MHz dipole elements, 1.5 GHz dipole elements, and 2.0 GHz loop elements. These dipole elements are bent in to reduce the size. A part of the 2.0 GHz loop element is used for the balanced line of the 800 MHz and 1.5 GHz bent dipole elements to simplify the triple-band antenna structure. To improve the return loss characteristics of the 1.5 GHz and 2.0 GHz bands, a parasitic element is placed above the vertically polarized antenna, and the gap between the balanced

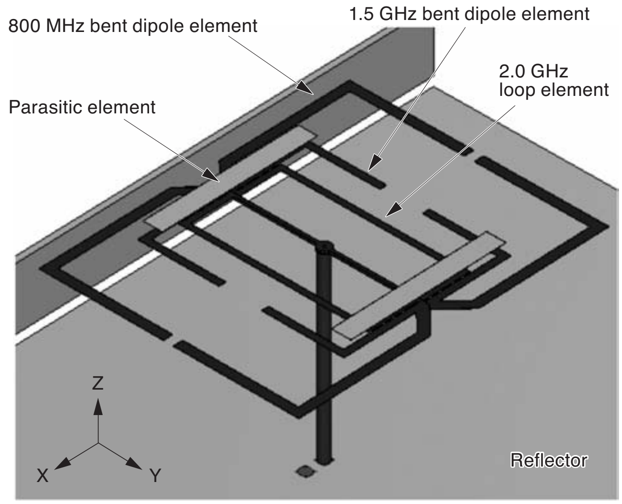

Fig. 3. Vertical polarized antenna

lines is widened from the feeding point of the 1.5 GHz dipole element to that of the 2.0 GHz dipole element.

The developed dual polarized antenna is composed of a vertical polarized antenna and a horizontal polarized antenna. The structure of the horizontal polarized antenna is similar to that of the vertical polarized antenna rotated 90 degrees around the Z-axis. The horizontal polarized antenna is placed above the vertical polarized antenna. A sub refractor is placed between the main refletor and the horizontal polarized antenna to improve the vertical polarized antenna radiation pattern. The dimension of each antenna element is shown in **Table 1**.

Table 1. Dimensions of antenna elements

	H-pol.	V-pol.
800MHz element	approx. $0.35\lambda_{800}$	approx. $0.25\lambda_{800}$
1.5GHz element	approx. $0.3\lambda_{1.5}$	approx. $0.3\lambda_{1.5}$
2.0GHz element	approx. $0.35\lambda_{2.0} \times 0.2\lambda_{2.0}$	approx. $0.4\lambda_{2.0} \times 0.15\lambda_{2.0}$
Prasitic element	approx. $0.25\lambda_{1.5}$	approx. $0.25\lambda_{1.5}$
Sub Reflector	approx. $0.5\lambda_{1.5}$	–
Distane from Reflector	approx. $0.25\lambda_{800}$	approx. $0.18\lambda_{800}$

(λ_{800}: wavelength of 800 MHz band, $\lambda_{1.5}$: wavelength of 1.5 GHz band, $\lambda_{2.0}$: wavelength of 2.0 GHz band)

Figure 4 shows a prototype model of the vertical polarized antenna and the dual polarized antenna. **Figure 5** shows the measured return loss characteristics of a prototype dual polarized antenna. In this figure, the solid line shows the return loss of the vertical polarizazion antenna and the dotted line shows that of the horizontal polarized antenna. The return loss is less than -10 dB at the 800 MHz, 1.5 GHz and 2.0 GHz bands. **Figure 6** shows the measured isolation characteristics of the prototype model. In this figure, isolation is less than -25 dB at each frequency band.

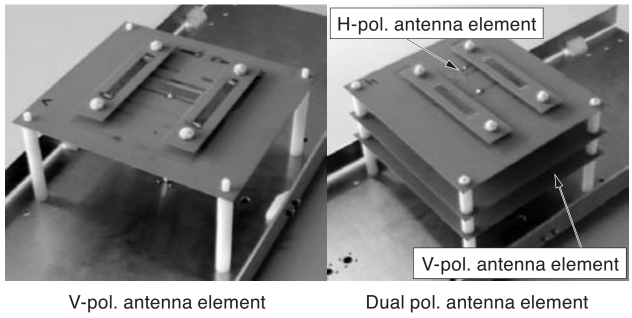

Fig. 4. Perspective picture of prototype model

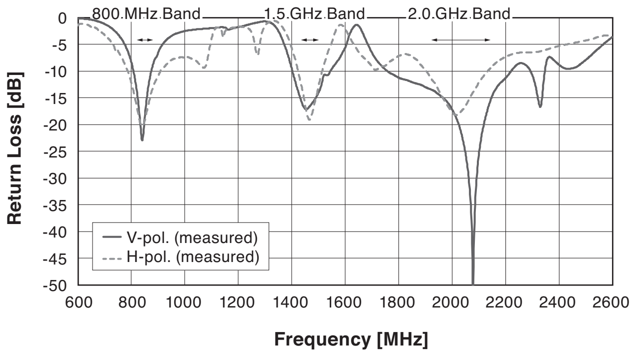

Fig. 5. Return loss (antenna element)

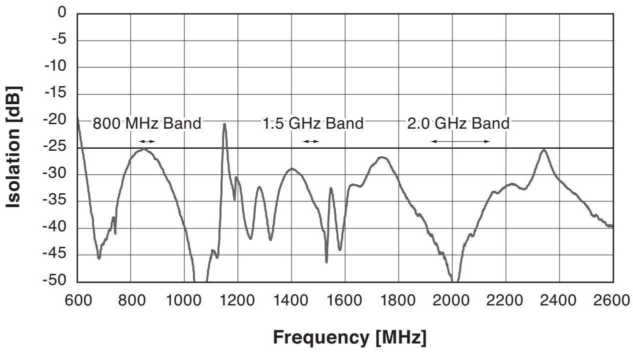

Fig. 6. Isolation (antenna element)

Figures 7 and 8 show the measured radiation pattern in the horizontal plane of the vertical polarized antenna and that of the horizontal polarized antenna, respectively. In **Fig. 7**, the 3 dB beam width is about 60-90 degrees and the gain of the antenna is over 7 dBi at each frequency band. In **Fig. 8**, the 3 dB beam width is about 60-80 degrees and the gain of the antenna is over 7 dBi at each frequency band. **Table 2** shows the characteristics of the prototype model.

The newly developed antenna element is $0.35\lambda_{800} \times 0.25\lambda_{800}$ (Y-axis size × X-axis size), which is about 60% smaller than the conventional dipole antenna shown in **Figs. 1 and 2**.

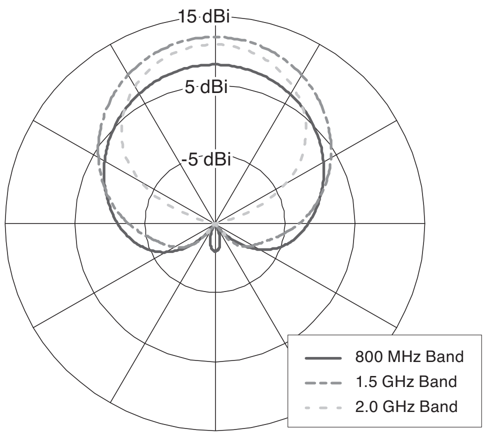

Fig. 7. Radiation pattern of antenna element (V-pol., Horizontal plane)

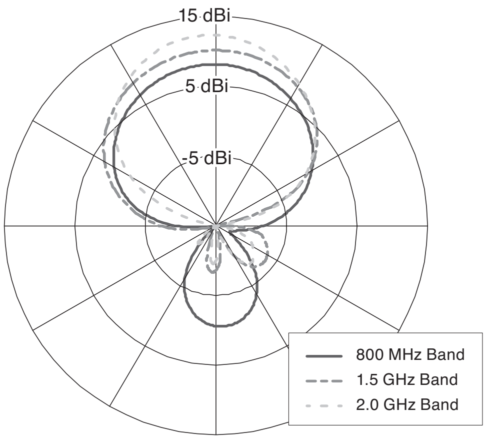

Fig. 8. Radiation pattern of antenna element (H-pol., Horizontal plane)

Table 2. Prototype model characteristics (Antenna element)

	Measured Data
Frequency	800 MHz, 1.5 GHz, 2.0 GHz
Gain	V-Pol. : > 7 dBi H-Pol. : > 7 dBi
Return Loss	< -10 dB
Beam width (Horizontal plane)	V-Pol. : 60-90 deg. H-Pol. : 60-80 deg.
Isolation	< -25 dB
Element size	$0.35\lambda_{800} \times 0.25\lambda_{800}$

3. Array Antenna

The size of the conventional dipole antenna element is $0.5\lambda_{800} \times 0.5\lambda_{800}$. Therefore, the spacing between the adjacent array elements (array pitch) is longer than $0.5\lambda_{800}$. It means that the array pitch is longer than 1.2λ at the center frequency of the 2.0 GHz band, which causes grating lobes and thus the gain of the antenna is decreased.

The size of our new antenna element is $0.35\lambda_{800} \times 0.25\lambda_{800}$ (Y-axis size × X-axis size). Therefore, the array pitch can be reduced to $0.4\lambda_{800}$. In this case, the array pitch is about 0.95λ at the center frequency of the 2.0 GHz band, and grating lobes can be eliminated.

The performance of the prototype model of the three-element array antenna was measured in an anechoic chamber. **Table 3** shows the characteristics of the prototype model. **Figure 9** shows the measured radiation pattern in the vertical plane of the vertical polarized antenna, and **Fig. 10** shows that of the horizontal polarized antenna. The solid line, the dashed line and the dotted line show the radiation patterns of the 800 MHz, 1.5 GHz and 2.0 GHz bands, respectively. Grating lobes are eliminated at the 2.0 GHz band.

Table 3. Prototype model characteristics (Three-element array)

	Measured Data
Frequency	800MHz, 1.5GHz, 2.0GHz
Gain	800MHz : > 8 dBi 1.5GHz : > 10 dBi 2.0GHz : > 10 dBi
Return Loss	< -10 dB
Beam width (Horizontal plane)	V-Pol. : 60-90 deg. H-Pol. : 60-80 deg.
Beam width (Vertical plane)	800MHz : 45 deg. 1.5GHz : 30 deg. 2.0GHz : 20 deg.
Isolation	< -25 dB
Dimensions	ø200 × 500 mm
Weight	4 kg
Input connector	N-J

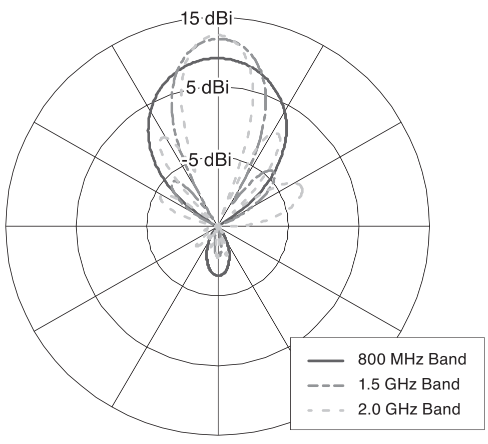

Fig. 9. Radiation pattern of three-element array (V-pol., Vertical plane)

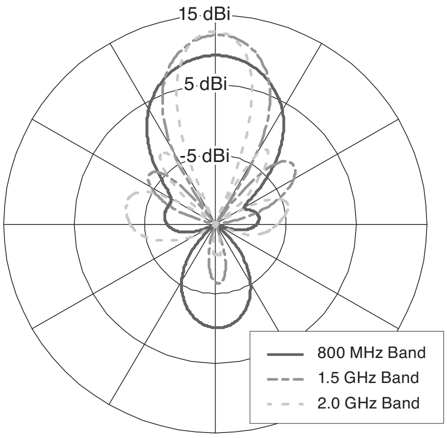

Fig. 10. Radiation pattern of three-element array (H-pol., Vertical plane)

4. Conclusion

This paper presented a new dual polarized triple-band (800 MHz, 1.5 GHz and 2.0 GHz) antenna composed of loop elements and bent dipole elements. The antenna size was reduced by about 60% compared with the conventional dipole antenna.

We will continue our efforts for the development of a four-band antenna that responds to the 700 MHz band, which has been newly assigned for mobile communication.

References

(1) Yoshio Ebine, “Design of base station antennas for next generation cellular mobile radios (IMT-2000),” IEICE Technical Report, AP2000-4, pp.23-30, 2000

(2) Yuki Sugimoto, Yoshio Ebine, “A Triple frequency Base Station Antenna with 60˚ and 120˚ beam-width in horizontal plane for Cellular Mobile Radios,” IEICE Technical Report, AP99-47, pp.35-42, 1999

(3) Yuki Sugimoto, Yoshio Ebine, “A Triple frequency Base Station Antenna for Cellular Mobile Radios,” IEICE General Conference, B-1-64, 2000

(4) Hironori Kakefuda, Masahiro Karikomi, Yoshio Ebine, “A 0.8/1.5/2.0 GHz base station antenna having dual 60degrees beams for 2GHz band,” IEICE General Conference, B-1-65, 2000

(5) Norihiko Shimada, Koichi Mori, Yoshiaki Tsuchisawa, “A Dual Polarization Antenna with 60-Degree Beamwidth,” IEICE General Conference, B-1-69, 2000

(6) Norihiko Shimada, Koichi Mori, Seiichi Hoshino, Hideaki Hayama, Yoshiaki Tsuchisawa, “A 0.8/2GHz Band Dual Polarization Antenna with 60-degree Beamwidth,” IEICE Society Conference, B-1-92, 2000

(7) Takashi Shimura, Masahiro Karikomi, Yoshio Ebine, “A 800/1500 MHz Dual Frequency Bands and Dual Polarization Antenna of 120 deg. Beamwidth for Mobile Base Station,” IEICE General Conference, B-1-136, 2001

(8) Toshiyuki Ando, Ryoji Matsubara, Motohiro Ito, Osamu Tasaki, “A 1.5GHz/2GHz Band Polarization Diversity Antenna,” IEICE General Conference, B-1-137, 2000

(9) Toyohisa Takano, Ichiro Kuwayama, Hidetoshi Kojiri, Shinji Nakaue, Masayuki Nakano, “Multiband Antenna with a loop element,” IEICE General Conference, B-1-90, 2011

(10) Toyohisa Takano, Suguru Yamagishi, Shinji Nakaue, Masayuki Nakano, Hiromi Matsuno, “3band Antenna with a loop element,” IEICE Society Conference, B-1-117, 2012

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