Radiation Characteristics of a Multi-band Antenna Using a Coupling Phenomenon

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Abstract

We have proposed a multi-band antenna which is composed of plural conductive wires with a coupling effect. In this paper, we present the measured radiation characteristics of the antenna. It is confirmed that the measured patterns almost agree with the analytical patterns. The radiation pattern can be controlled by adjusting the current distribution of internal resonances.

Keywords : Multi-band antenna Coupling phenomenon Radiation characteristics

1. Introduction

In recent years, a multi-band antenna is needed to integrate various kinds of wireless services [1]. We have proposed a multi-band antenna using plural conductive wires with an internal coupling phenomenon [2]. The configuration of this antenna is simple. Using a coupling phenomenon between wires [3], the currents of particular modes are excited on the wires to give the multi-band characteristics.

We have measured the radiation characteristics of the antenna. By devising the feeding structure, the measurement was carried out accurately. This paper first explains the measured radiation patterns. Next the design principle of the radiation pattern is presented in order to improve its symmetry as for radiation angles.

2. Structure of the Proposed Antenna and Trial Manufacturing

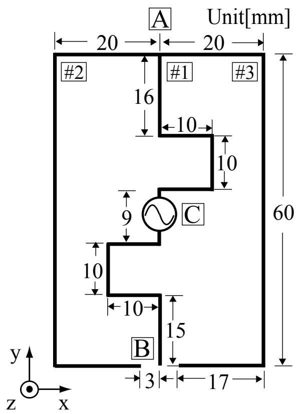


Figure 1: Configuration of Proposed Antenna

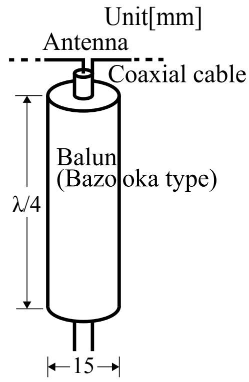
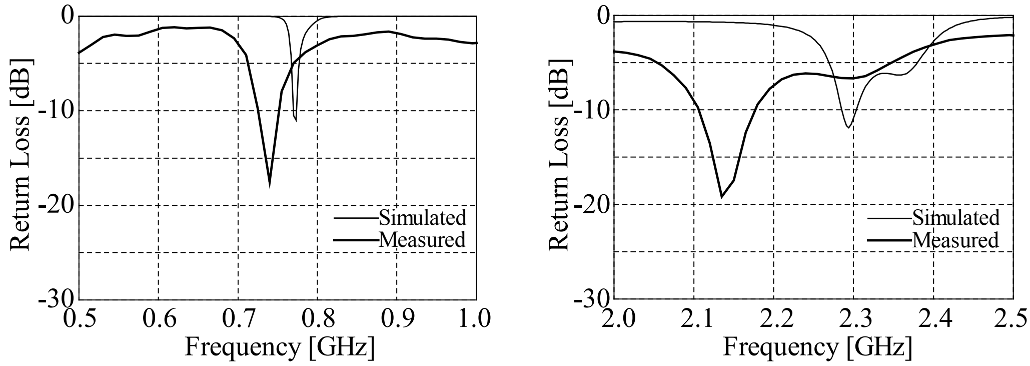


Figure 2: Balun at Feeding Point

Fig.1 shows the structure of a proposed antenna which has three wires each measuring approximately 100mm. The three wires are connected with each other at point A, but are opened at point B. The antenna is fed at the centre point C of #1 wire. The #1 wire has two cranks. The #1 wire is close to #2 wire at the lower crank than the feed point, and close to #3 wire at the higher crank than the feed point. It is expected that the coupling phenomenon occurs in each portion. The antenna was analyzed using the moment method. It was confirmed that the antenna has two resonant frequencies of 0.77GHz and 2.3GHz [2].

We have manufactured the antenna according to the simulation result with wires of 1mm diameter. It is fed with a semi-rigid coaxial cable. In the analysis, it is necessary to model the feed structure exactly. However the semi-rigid cable was not taken into account in the analytical model. When we measured the radiation characteristics of the antenna, we noticed that the leak current on the semi-rigid cable affected the radiation patterns significantly. In order to suppress the leak current, a bazooka type balun was introduced at the feeding point as shown in Fig.2. The balun is parallel to the z axis. It is made of brass cylinder with a diameter of 15mm and a thickness of 1mm. The length is a quarter wavelength, 97mm at 0.77GHz and 32mm at 2.3GHz.

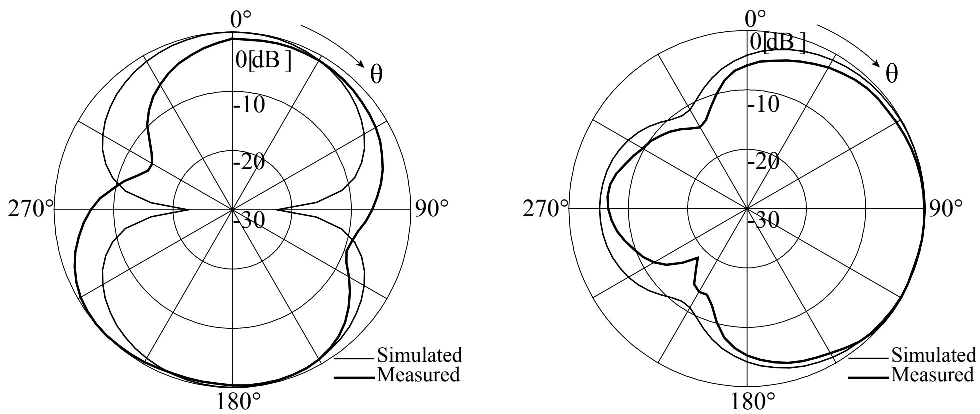


(a) balun of 97mm (b) balun of 32mm

Figure 3: Frequency Characteristics of Return Loss

The return loss characteristics of the antenna were measured with each balun. The experimental results are shown in Fig.3. The low resonant frequency is 0.735GHz and the high resonant frequency is 2.13GHz. The low and high measured resonant frequencies agree with the analytical low and high resonant frequencies with 4.6% and 7.4% difference. The measurement of radiation patterns were carried out at 0.735GHz and 2.13GHz, respectively.

3. Radiation Pattern Measurement



(a) E_θ at 0.735GHz (b) E_φ at 2.13GHz

Figure 4: Radiation Pattern in x-z Plane

The Eθ and Eφ patterns in the x-z and y-z planes were measured at 0.735GHz and 2.13GHz. In the measurement, the proposed antenna was set the transmitting antenna and a horn antenna was set the receiving antenna. The radiation patterns were measured by rotating the proposed antenna in the horizontal plane. Space of this paper is lacking for a full explanation concerning eight combinations of the electric component, measured plane and frequency. The Eθ pattern in the x-z plane at 0.735GHz and the Eφ pattern in the x-z plane at 2.13GHz are represented. The former is a typical pattern and the latter is a particular pattern.

The measured Eθ pattern in the x-z plane at 0.735GHz is shown in Fig.4(a). The pattern is normalized by its maximum value. The measured Eθ pattern shows a figure "8" pattern whose line of symmetry is not parallel to the z axis.

The analytical Eθ pattern is also shown in the same figure. The measured Eθ pattern shows almost the same characteristics as the analytical pattern. In principle, an Eθ pattern in the x-z plane is determined by the current distribution parallel to the x axis. In the measured case, it is thought that the residual leak current on the coaxial cable and the bazooka radiated the θ component of the electric field.

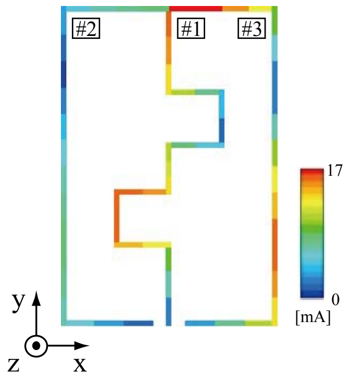


Figure 5: Current Distribution at 2.3GHz

The measured Eφ pattern in the x-z plane at 2.13GHz is shown in Fig.4(b). This radiation pattern has a single main beam at θ=90°.

Fig.5 shows the current distribution on the antenna at 2.3GHz, which is analyzed using the moment method. The current is distributed on the #1 and #3 wires, but hardly distributed on the #2 wire due to a coupling effect. The current distribution on the #1 and #3 wires looks sinusoidal with three half periods. In principle, an Eφ pattern in the x-z plane is determined by the current distribution parallel to the y axis. The current parallel to y axis is distributed on #1 and #3 wires. The unsymmetrical Eφ pattern is caused by phase discrepancy between these current distributions.

The analytical Eφ pattern is also shown in the same figure. The measured Eφ pattern agrees well with the analytical pattern.

4. Design Method to Adjust Radiation Patterns

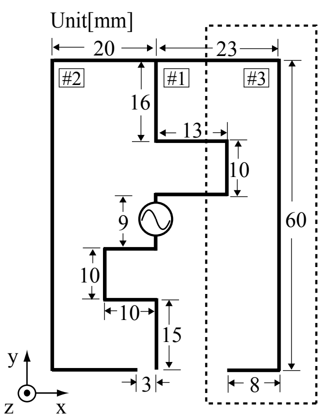


Figure 6: Adjusting the Configuration

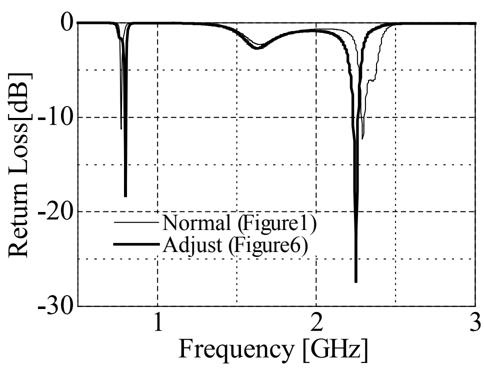


Figure 7: Frequency Characteristics of Return Loss

If the proposed antenna is applied to a wireless mobile communication, the radiation pattern should have an omni-directional characteristic. The E_φ pattern in the x-z plane at 2.13GHz is not symmetrical with respect to the right and left sides of the line 0° to 180° as shown in Fig.4(b). Here, as an example, we will improve the symmetry of this E_φ pattern.

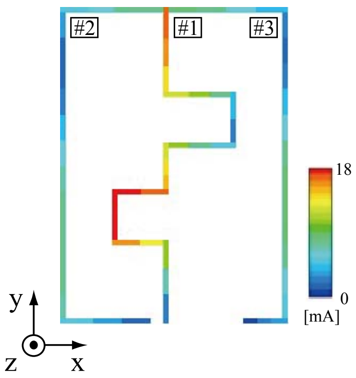


Figure 8: Current Distribution at 2.3GHz

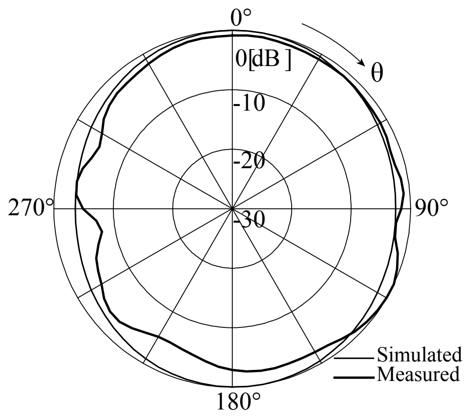


Figure 9: E_φ Pattern in x-z Plane at 2.13GHz

Adjusting the current distribution, the E_φ pattern can be controlled. In Fig.6, keeping the total wire lengths inside the square frame of a dotted line, the frame is pulled to the right side by 3mm. Thus the position of the current distribution is changed while the coupling effect between #1 and #3 wires is not changed. The total length of #1 and #3 wires increases by 9mm. The high resonant frequency is determined by the total length of #1 and #3 wires. In order to keep the high resonant frequency, the length of #3 wires decreases by 9mm as shown in Fig.6. Fig.7 shows the return loss characteristic of this antenna, which was analyzed using the moment method. The analytical return loss characteristic of the previous antenna (Fig.1) is shown also. From these results, it is confirmed that the return loss characteristics show almost no change.

Fig.8 shows the current distribution on the antenna. Although the amplitude of the current distribution on #3 wire becomes lower, the position of the current distribution can be changed.

We manufactured the antenna as shown in Fig.6. Fig.9 shows the measured radiation pattern. It is noted the measured pattern has a symmetry with respect to the right and left sides of the line 0° to 180°. The analytical patterns are shown in this figure. The measured pattern agrees well with the analytical pattern. Thus the radiation pattern can be controlled by adjusting the current distribution.

5. Conclusion

The bazooka type balun was introduced at the feeding point in order to suppress the leak current on the coaxial cable. Thus the measured patterns of eight combinations of the electric component, measured plane and frequency, almost agreed with the analytical patterns. Next the experimental results showed that the radiation pattern can be controlled by the design method without changing the resonant frequencies. Through the design method, the E_φ pattern in the x-z plane at 2.13GHz had a symmetry with respect to the right and left sides of the line 0° to 180°.

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