A Half-loop Antenna with Dual Band-Notched Characteristics Using Three Parallel Line Elements

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1. Introduction

In recent years, we have been confronted with spectrum congestion problems for wireless communication systems. To solve this problem, many techniques have been examined to improve the spectrum efficiency. For instance, it is effective to reduce the adjacent channel interference for increasing the spectrum efficiency. Thus, designing antennas with narrow band or notched band to prevent the interference between a new system and the existing wireless communication systems has become a research topic. In particular, several band-notched antenna designs for ultrawideband (UWB) applications have been reported. Most of the previous works were focused on the single notched band design, while the minorities were concentrated on dual or multiple notched bands design in [1]-[4]. In these papers, the most popular approach is to embed slots in a radiation patch. By adjusting shape, length and position of the slots, the band-notched characteristics at rejected frequencies are generated. The optimization of these parameters is quite effective. However, these approaches are applied only to planar antennas, they therefore have not been examined to line antennas.

In this paper, we propose an antenna which consists of some line elements with the dual band-notched characteristics. The structure is based on a half-loop antenna placed over a ground plane. The proposed antenna is not complex in comparison with traditional line antennas, and makes the desired frequency response. Moreover, it can be manufactured easily and at low cost.

As an example, we design a vehicular antenna for a new ITS system in Japan, and describe the characteristics of it. In order to prevent interference problem due to existing nearby communication systems, a dual band-notched antenna is presented.

2. Antenna Structure

Figure 1 shows the structure of the proposed antenna. This is a half-loop antenna placed over a ground plane based on a one-wavelength square loop antenna. This antenna consists of three parallel lines. The ends of three lines are bundled at junctions A and B, respectively, where the height from the ground plane is H. These junctions A and B are connected by a line to the ground plane each other. One is a feed point, and the other is shorted to the ground plane. L1, L2 and L3 are the lengths of Element #1, #2 and #3. These values satisfy the relations formulated as follows;

$$(1/2)\lambda_{desired} = L2,\ (1/2)\lambda_{rejected\_lower} = (L1+L2)/2,\ (1/2)\lambda_{rejected\_upper} = (L2+L3)/2,\ L1>L2>L3,$$

where $\lambda_{desired}$ is the wavelength of the center-desired frequency, $\lambda_{rejected\_lower}$ and $\lambda_{rejected\_upper}$ are the wavelengths of the center-rejected frequencies lower and upper than the desired frequency, respectively. Consequently, the proposed antenna is implemented with dual-band notched characteristics.

The desired and rejected frequencies can be designed to be 760MHz(desired), 750MHz and 770MHz(rejected), considering the following specifications of the ITS system.

Frequency band: 755.5 – 764.5MHz, Guard band: 5MHz

The parameter H is tuned for the purpose of VSWR flatness over the desired band. From these conditions, the final parameters are L1=203mm, L2=198mm, L3=193mm, and H=8mm. Here, by changing the ratio of height to width of the antenna, it is possible to tune the input impedance. However, we use a fixed radio of height to width of 1:2 in this paper.

3. Antenna Characteristics

The simulated results were obtained by using FEKO based on the method of moments. FEKO can include the effect of an infinite ground plane. This setting provides for the inclusion of an infinite ground plane that coincides with the z = 0 plane. A perfect electric conductor is used as the ground medium.

Figure 2 shows the VSWR of the proposed antenna. This graph shows that the rejected bands at 750MHz and 770MHz have been achieved with VSWR > 2. At the desired band, 760MHz, the VSWR is lower than 2, which means the good radiation performance of the proposed antenna. At the other bands, at the frequencies lower than 740MHz and upper than 780MHz, the VSWR is low, but these bands can be suppressed by a band pass filter.

Figure 3 shows the frequency responses of the proposed antenna gain in the X-Y plane. The maximum gain is about 6dBi at the 760MHz. However, it can be observed that the significant gain reduction at the band notched frequencies, 750MHz and 770MHz, is clearly shown. As a result, we have a margin of 18-20dB in gain between the desired band and the rejected bands.

Figure 4 shows the current distributions on the three line elements between the junction A and B at each frequency. The upper graph shows the magnitude of the current on the elements, and the lower shows phase of those. From Fig.4, we found that at the notched bands, 750MHz and 770MHz, the magnitude on Element#2 and #1 (or #3) are strong. Moreover, the each phase on the two elements is opposite. For that reason, the radiation is suppressed effectively. On the contrary, at the desired band, 760MHz, only the current on Element#2 is dominant. Consequently, it is good efficiency to radiate power from the Element#2.

Figure 5 shows the 3D radiation patterns at each frequency. From this figure, we can easily find out that the radiation is suppressed in all directions at the 750MHz and 770MHz, band-notched frequencies. At 760MHz, the desired frequency, the good radiation performance is observed.

4. Conclusion

In this paper, we have proposed the dual band-notched antenna which consists of three line elements to reduce the adjacent channel interference. We have designed the half-loop antenna placed over the ground plane for 760MHz ITS system, and described the characteristics. The proposed antenna has a good radiation performance at the desired frequency, 760MHz. Furthermore, we have confirmed that the significant gain reduction is observed at the band-notched frequencies, 750MHz and 770MHz.

References

[1] Yan Zhang, Wei Hong, Chen Yu, Zhen-Qi Kuai, Yu-Dan Don, Jian-Yi Zhou, “Planar Ultrawideband Antennas With Multiple Notched Bands Based on Etched Slots on the Patch and/or Split Ring Resonators on the Feed Line”, *IEEE Trans. Antennas Propag.*, vol.56, no.9, pp.3063-3068, 2008

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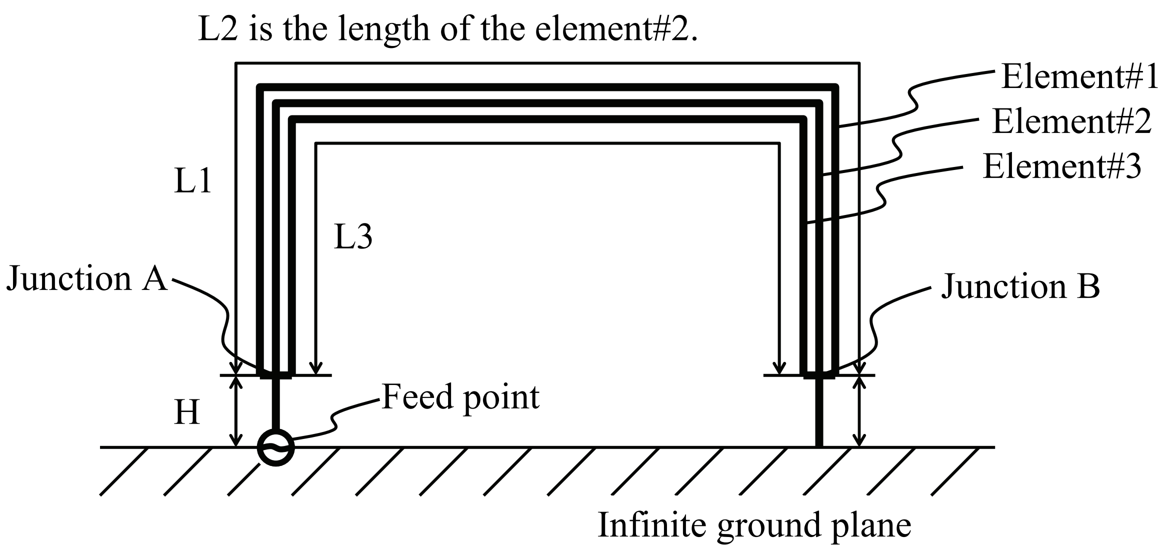


Figure 1: Antenna structure

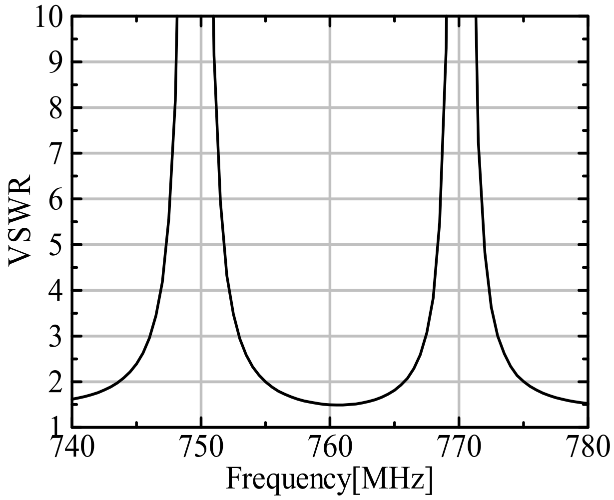


Figure 2: VSWR

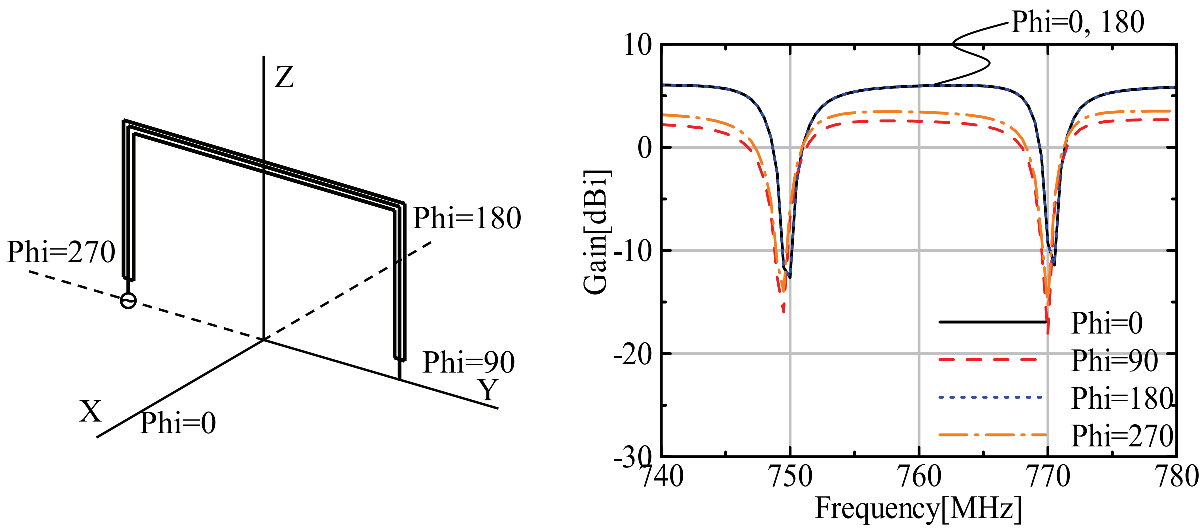
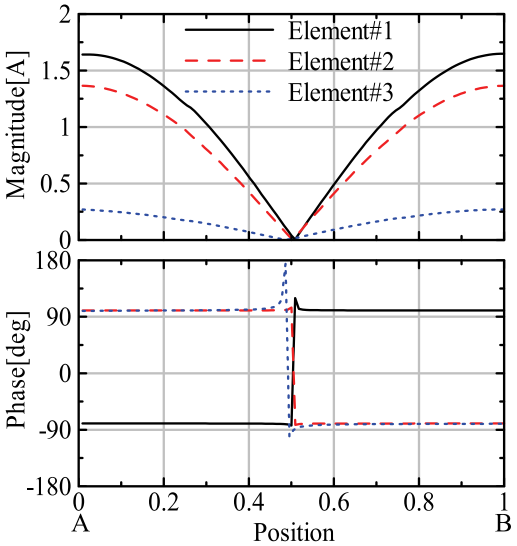
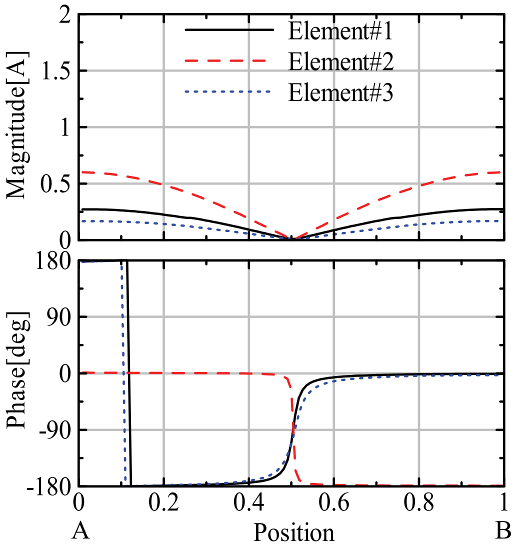


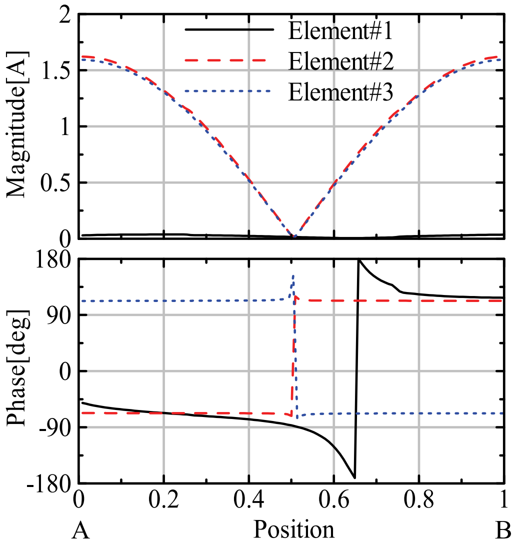
Figure 3: Frequency response of the antenna gain at X-Y plane



(a) 750MHz

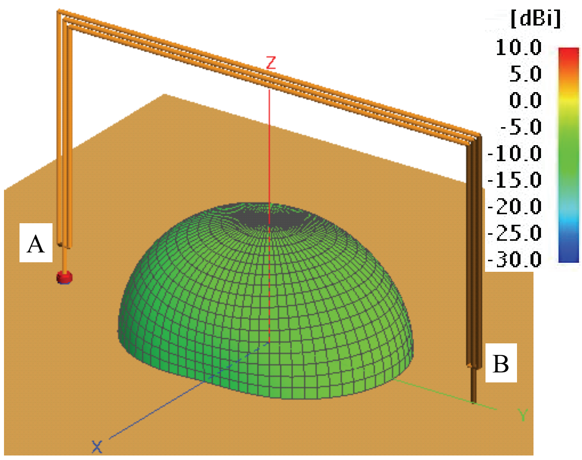


(b) 760MHz

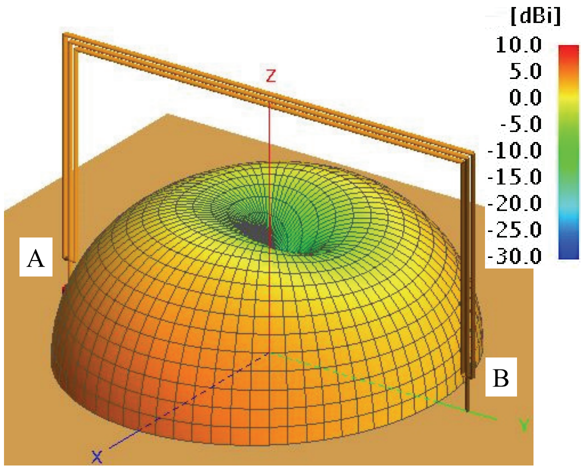


(c) 770MHz

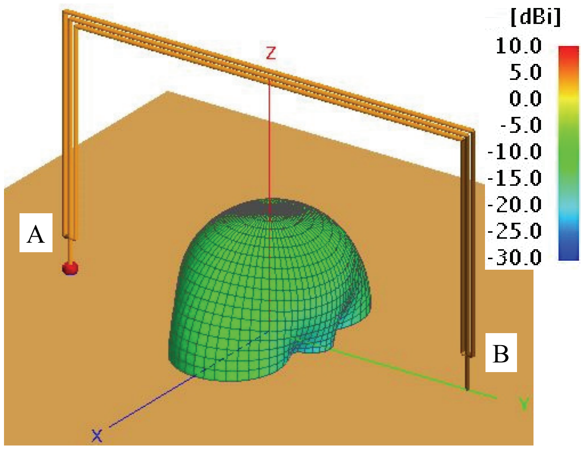
Figure 4: Current distributions on the elements between the junction A and B



(a) 750MHz



(b) 760MHz



(c) 770MHz

Figure 5: 3D radiation patterns