Three-band Modified Transmission Line Antennas for Mobile Communication

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Abstract—In order to respond to recent increases in the number of mobile telephone users, three frequency bands are currently used for mobile telephone systems. We herein propose a three-frequency-band antenna that is useful for mobile telephone base stations. We first developed a two-band antenna called the Double Modified Transmission Line Antenna (DMTLA) that consists of two simplified MTLA of different lengths. By attaching a parasitic element to the DMTLA based on the multi-band technique using parallel transmission line loading, we realize the three-band Double Modified Transmission Line Antenna (3-B DMTLA) for the base station antenna of a mobile telephone system.

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1. INTRODUCTION

We previously developed the Modified Transmission Line Antenna (MTLA) and have reported several applications of the MTLA to the mobile telephone antenna [1]. The MTLA provides a low-profile antenna with good impedance characteristics that is suitable for mobile communication.

The present approach is to design a simplified MTLA, as indicated in Figure 1, where the total element length of this antenna \( L + 2(H + W) \) is designated as a half wavelength of the resonant frequency. This simplified MTLA can reduce antenna space without losing the characteristics of the originally developed MTLA. Using two simplified MTLAs of different lengths, we developed the Double Modified Transmission Line Antenna (DMTLA) for two-frequency-band operation.

We also developed the multi-band monopole antenna for the portable telephone using the transmission-line loading technique and reported the double-folded monopole antenna in previous studies [2, 3].

A parasitic element parallel to the main antenna element works as a loading impedance for the main antenna. The position of the impedance element is located at the open-end position of the main element. When the length of the parasitic element is a quarter wavelength of higher frequency than the resonant frequency of the main antenna, the impedance of the parallel transmission line becomes infinity. This antenna can be then separated at the loading point of the parasitic element and can resonate at two frequencies: the frequency of the main antenna and the frequency of the parasite [4].

By utilizing this parallel line loading technique to the DMTLA, we can realize the multi-band antenna for a base station of a mobile telephone system.

![Figure 1: Simplified MTLA.](image1)

![Figure 2: Double MTLA.](image2)
2. DOUBLE MTLA

Figure 2 shows the fundamental structure of the DMTLA for two frequency bands of $f_1 = 900$ MHz and $f_2 = 1.5$ GHz. The simplified MTLA drawn by the broad line in the figure, with a total length of $L_1 + 2(H + W_1)$, is the MTLA designed for $f_1$. Whereas the other simplified MTLA drawn by the thin line, with a total length of $L_2 + 2(H + W_2)$, is the simplified MTLA for $f_2$.

Figure 3 shows the return loss characteristics of the DMTLA for a characteristic impedance of $Z_0 = 50$ Ω. The parameters of the DMTLA are $H = 2.0$ cm, $L_1 = 6.0$ cm, $W_1 = 4.0$ cm, $L_2 = 2.0$ cm, and $W_2 = 2.5$ cm, and the wire radius is $a = 0.5$ mm.

This DMTLA can clearly operate on two frequency bands of 900 MHz and 1.5 GHz. This result was obtained using the Method of Moment computer program. Initially, the total length of $L_1 + 2(H + W_1)$ was adjusted until the antenna resonated at 900 MHz. Then, $L_2 + 2(H + W_2)$ was adjusted to meet the 1.5 GHz resonance.

This DMTLA radiates mainly a vertically polarized electric field around the driving element, and its radiation pattern is omni-directional.

3. THREE-BAND DMTLA

In this section, we explain how to add a new frequency band to the DMTLA using the parallel line loading technique introduced in Section 1. Figure 4 shows the parallel-line-loaded three-band DMTLA, in which a parasitic element of length $H + W_3$ is attached along with the element of the DMTLA for parallel line loading. Note that the parasitic element must be constructed such that the distance $d$ between the parasitic element and the element of the DMTLA remains constant. Since, along with a part of the element of the DMTLA, this parasitic element constitutes the parallel transmission line, it is considered that equivalent lumped impedance is loaded at the open end point of DMTLA. When the length of the parasitic element is equal to a quarter wavelength of frequency $f_3$, the impedance of the transmission line with a short-circuited end becomes infinity at $f_3$. This parasitic element then electrically cuts off the element of DMTLA at point $W_3$ from a
corner, and this antenna resonates at a new frequency of $f_3$.

Figure 5 shows the rerun loss characteristics of the three-band DMTLA, where the length of the attached parasitic element is $W_3 = 1.6$ cm and the distance is $d = 0.5$ cm. It is clear from the figure that this three-band DMTLA has three resonant frequencies. $f_1 = 900$ MHz and $f_2 = 1.5$ GHz are the resonant frequencies of the original DMTLA without parasitic elements, and $f_3 = 2.0$ GHz is the resonant frequency due to the parasitic elements.

![Graph showing return loss characteristics](image)

Figure 5: Return loss of the 3-B DMTLA.

In the figure, the dots indicate the measured results, and the calculated results are confirmed experimentally.

4. CONCLUSIONS

We proposed the DMTLA using two simplified MTLAs to reduce the space of the two-band antenna for a mobile telephone system. We first realized a two-band antenna with 900 MHz and 1.5 GHz. For these frequencies, the bandwidth of the return loss of less than $-10$ dB are 5.6% and 6.3%, respectively.

Our approach was to use the parallel transmission line for the loading element of the DMTLA in order to add an additional frequency band to the DMTLA. We completed the three-band DMTLA by attaching a simple parasitic element with an inverted-L shape.

Without affecting a significant change in the return loss of the original two-band DMTLA, we obtained a bandwidth of 4.7% for the new frequency.

We realized a three-band antenna for a mobile telephone system with a relatively simple structure. It is expected that this three-band antenna will be applied as a base station antenna of a mobile telephone system.

REFERENCES