Proceedings of ISAP'04, Sendai, JAPAN

Study of Wideband Mechanism of Inverted-F Antenna with LC Series Resonance Circuit

Masaki NISHIO, Takayoshi ITOH, Shuichi SEKINE, and Hiroki SHOKI
Corporate Research & Development Center, Toshiba Corp.
1, Komukai Toshiba-cho, Saiwai-ku, Kawasaki-shi, Kanagawa 212-8582, Japan
masaki.nishio@toshiba.co.jp

1. Introduction

An inverted-F antenna with a horizontal element added to a vertical element [1] provides wider bandwidth than a conventional inverted-F antenna, but the function of the additional element has not been clarified in [1]. This paper reports on an investigation of the function. In this paper, it is assumed that the additional horizontal element of the antenna operates as an LC series resonance circuit. Therefore, for the purpose of revealing the validity of this assumption, two antenna models are compared; one is an inverted-F antenna with an additional horizontal element and the other is an inverted-F antenna with an LC series resonance circuit. Also, the design method of the LC series circuit is reviewed.

2. Simulation model

Figure 1 shows the simulation models used in this work. Model A is the model proposed in [1] and Model B, Model C and Model D are applied to determine the wideband mechanism of Model A. Model A is the inverted-F antenna with an additional horizontal element and has the wideband and double resonance properties. Model B is the inverted-F antenna with the LC series resonance circuit instead of the horizontal element of Model A. Model C is a conventional inverted-F antenna that has neither a horizontal element nor an LC series resonance circuit. Model D is an LC series resonance circuit. The simulation tool is the NEC2 (Numerical Electromagnetic Code 2) based on the moment method. We simulated these models from 800MHz to 1GHz.

3. Simulation results

3.1 Resonance frequency of LC circuit

Firstly, for the purpose of deciding the resonant frequency of LC series circuit, we examined the characteristics of Model B using two LC resonant frequencies. One of the two resonant frequencies is slightly higher than that of Model C, and another is slightly lower. Model C resonates at the frequencies of 882MHz and 896MHz. We set the following two pairs of L and C as an LC series resonance circuit of Model B.

(1)L=0.157μH and C=0.1pF

(2)L=0.188μH and C=0.1pF

The case (1) is that Model D resonates at 945MHz, which is a slightly higher frequency than that of Model C, and the case (2) is that Model D resonates at 866MHz, which is a slightly lower frequency than that of Model C. We simulated the impedance and VSWR for each case.

Figures 2 and 3 show the impedance chart and VSWR of Model B and Model C for each case. In the case (1), Fig. 2 shows that Model B has the wideband property due to the addition of the LC series resonance circuit. In this case, parallel and series resonances caused by LC series resonance circuit occur at higher frequency than that of Model C, and it causes the impedance locus of Model B to make a loop. In the case (2), Fig. 3 shows that Model B does not have the wideband property although the impedance locus makes a loop. In this case, the real part of the impedance around 866MHz drops to a lower value because of the addition of the LC series resonance circuit. From these results, the resonance frequency of LC series resonance circuit has to be set slightly higher than that of Model C.

ISBN: 4-88552-207-2 C3055©IEICE

3.2 Impedance characteristic vs. variation of LC value

It is found that Model B has the wideband property if it satisfies the condition that the resonance frequency of the LC series resonance circuit is slightly higher than the Model C resonance frequency of 896MHz. In turn, we investigated the changes of the impedance and VSWR of Model B with the variation of the values of L and C, for the purpose of deciding the values of L and C. There are the following four pairs of L and C from (a) to (d). Using these values of four pairs, Model D is designed to resonate at 958MHz.

(a) C=1.0pF, L=0.017μH
(b) C=0.7pF, L=0.028μH
(c) C=0.3pF, L=0.07μH
(d) C=0.15pF, L=0.119μH

The impedance and VSWR of Model B is calculated by using these values of the four pairs. Figure 4 shows the impedance chart and VSWR for each case.

Figure 4 shows that the bandwidth (VSWR<2) is (a)15MHz, (b)25MHz, (c)45MHz, and (d)30MHz, respectively. In consequence, it is found from the results that Model B does not always have the wideband property even if the resonance frequency of the LC series resonance circuit is slightly higher than the Model C resonance frequency. It means that the values of L and C that make Model B wideband are decided uniquely.

4. Comparison of additional element with LC series resonance circuit

Finally, the frequency characteristics of Model A and Model B for impedance and VSWR are compared for the purpose of revealing the validity of the first assumption. Figure 5 shows the impedance chart and VSWR of Model A, Model B and Model C. The arrows in Fig. 5 indicate the matching frequency of Model A, Model B and Model C, respectively. The LC series resonance circuit of Model B is set to L=0.07μH and C=0.3pF. Figure 5 shows that both Model A and Model B have the wideband property and similar frequency characteristics. It means that the additional horizontal element of Model A operates as an LC series resonance circuit.

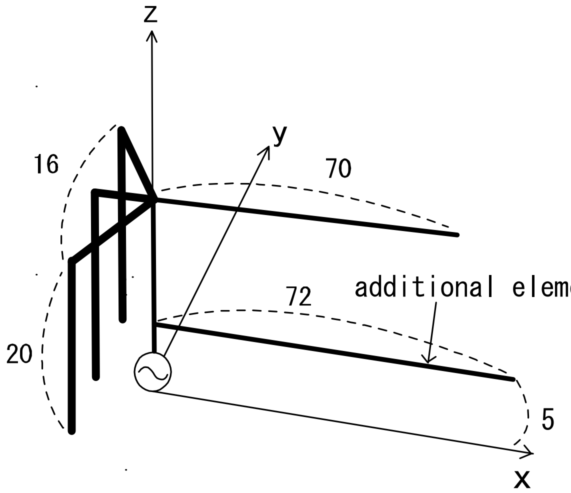
Although the impedance chart of Model A is similar to that of Model B, these loci do not agree with each other perfectly. It is because the additional horizontal element that is a distributed constant circuit is replaced with the LC series resonance circuit that is a lumped constant.

5. Conclusion

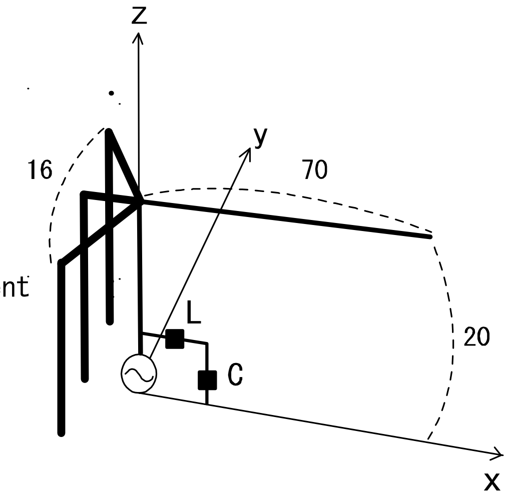
In this paper, we have shown the function of the additional element for wideband characteristic of inverted-F antenna by using the equivalent circuit of the additional element. We compared the inverted-F antenna with the additional horizontal element and the inverted-F antenna with an LC series resonance circuit, on the assumption that the additional horizontal element operates as an LC series resonance circuit. According to the results, these two models have similar frequency characteristics, indicating that the additional horizontal element of Model A operates as an LC series resonance circuit.

References

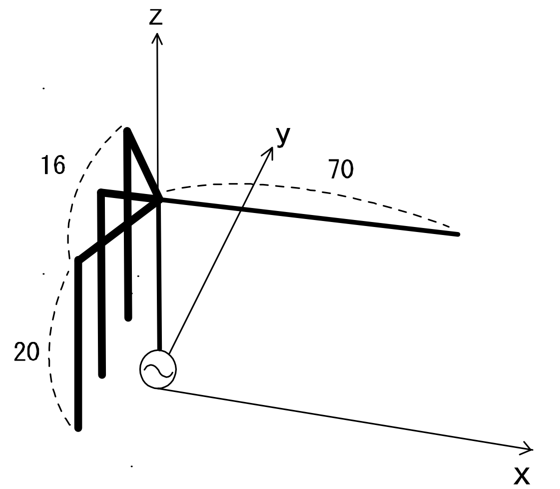
[1] T. Itoh, et al., “A inverted F-type antenna for double resonance,” 2001 IEICE Society Conference, B-1-76, Sep., 2001



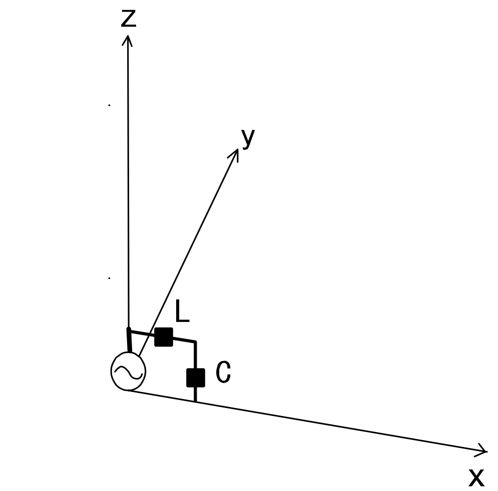
(a) Model A



(b) Model B

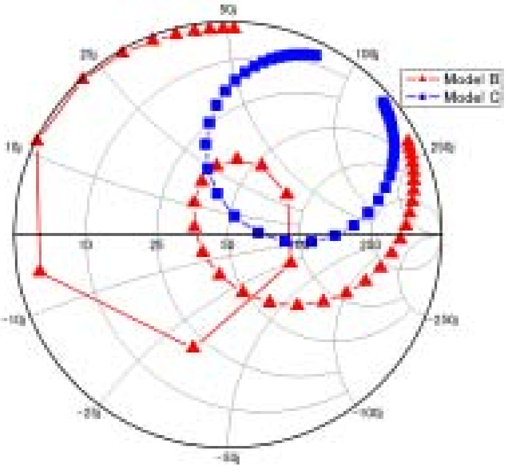


(c) Model C

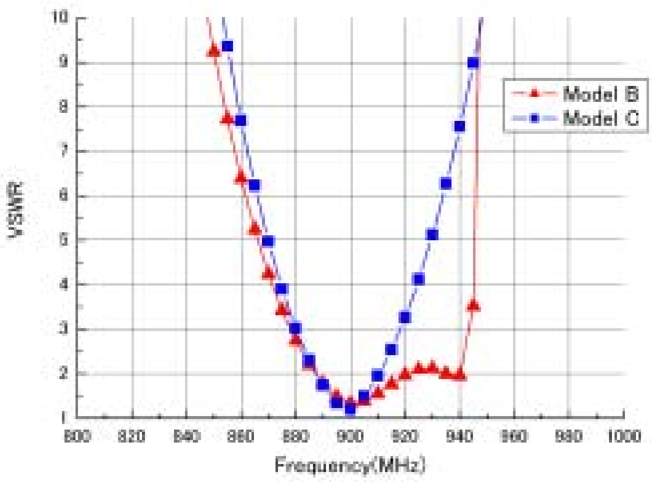


(d) Model D

Figure 1 Simulation models

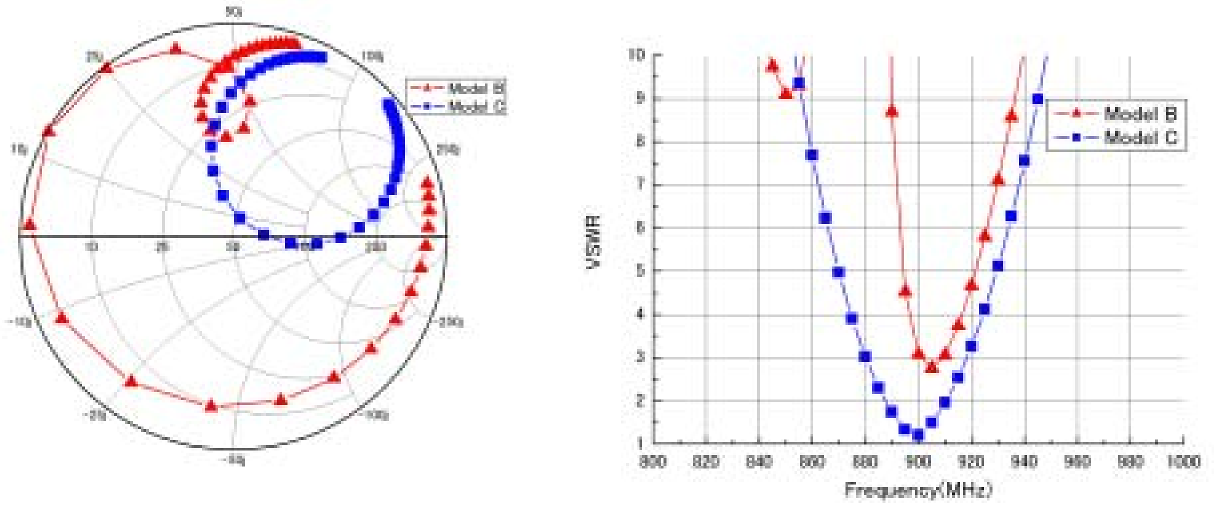


(a) Impedance Chart



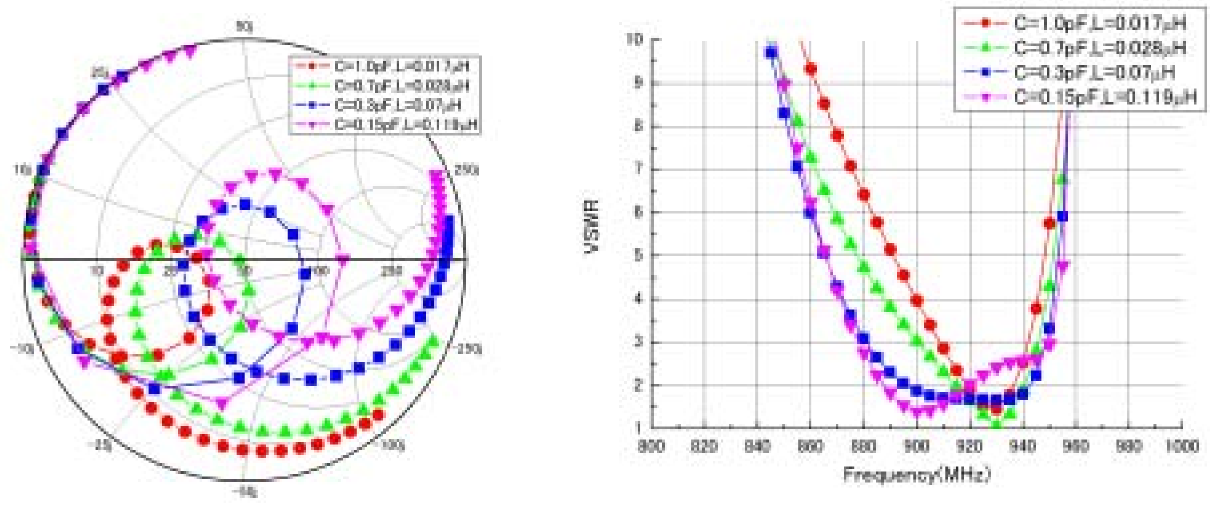
(b) VSWR

Figure 2 Frequency characteristics of case (1)



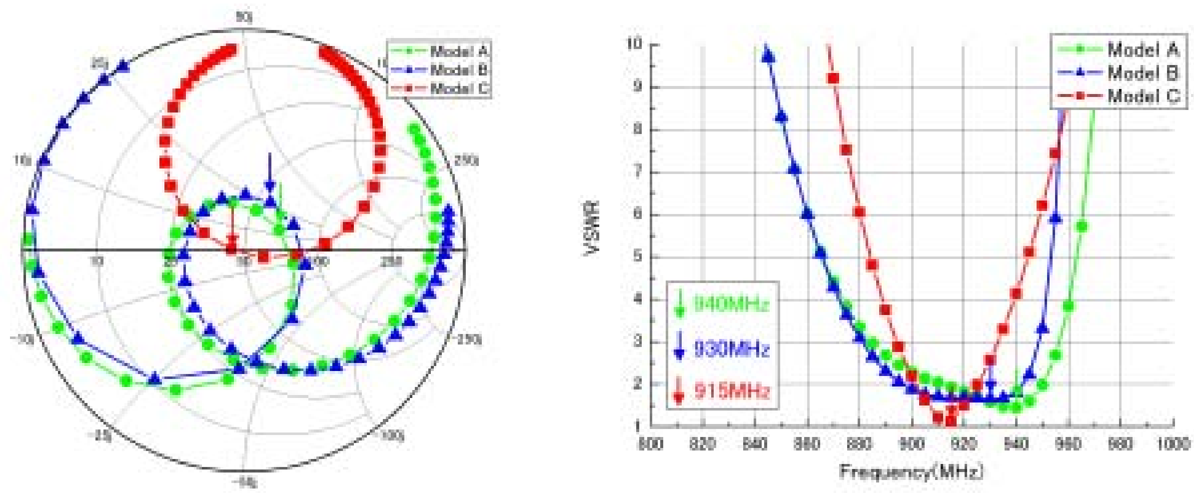
(a) Impedance Chart (b) VSWR

Figure 3 Frequency characteristics of case (2)



(a) Impedance Chart (b) VSWR

Figure 4 Frequency characteristics corresponding to values of L and C



(a) Impedance Chart (b) VSWR

Figure 5 Comparison of horizontal element with LC series resonance circuit