# Frequency Tunable Antenna by Non-resonant Parasitic Element

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## 1. Introduction

Recently, trimming technique has become one of the most useful technologies with tunable antennas. Tunable antenna can change the resonant bandwidth of the antenna by the varicap diode and switch [1]-[2]. A problem of tuning is the change of antenna pattern by adjustment devices.

This paper proposes a new trimming method for frequency tunable antennas without changing the antenna pattern. The input characteristic of the antenna varies by arranging a non-resonant electric obstacle in its neighborhood, which does not cause the change in radiation pattern [3]. First, we analyze several kinds of antenna with parasitic elements to investigate the control of input characteristics. We optimize the geometry of adjacent parasitic elements to control the antenna input characteristics and demonstrate its effect by experiments. In addition, we consider the trimming method in order to achieve on/off switching; to obtain a new tunable antenna.

## 2. Antenna impedance variation by electrical obstacle

Trimming method proposed in this paper is provided by the parasitic element as shown in Fig. 1, where the non-resonant length element of the stick or loop is arranged near C and H-shaped antennas. As the position, length, and the shape of a parasitic element are changed, the variation of antenna input impedance is defined by the following equation.

$$\delta = \frac{|Z_i - Z_{if}|}{Z_{if}} \tag{1}$$

where $Z_{if}$ is input impedance in free space and $Z_i$ is input impedance with parasitic element. $\delta$ is the impedance variation at the series resonant frequency. The impedance change of C-shaped antenna is shown in Fig. 2, and H-shaped one in Fig. 3. The impedance variation $\delta$ is proportional to length L of the parasitic element, and $\delta$ of C-shaped antenna is larger than that of H-shaped one. The parameter $L=0.1\lambda$ can control the input impedance by 6～7% in C-shaped antenna. As the geometry of a parasitic element, the impedance change by loop element is larger than that of stick element. The reason is that the current distributions of two stub elements are almost the same. The maximum difference in radiation pattern for the two cases of w/ or w/o parasitic elements is less than 0.3dB, where the pattern is examined in the horizontal plane (xy plane in Fig. 1). The change in pattern is very small in any length of non-resonant parasitic element.

## 3. Measurement of impedance variation

This section presents input characteristic in measurement. In calculation, the characteristics of parasitic elements in the vicinity of the antenna are not correctly evaluated by numerical problems. This region is very important for the impedance control, then we confirm the change in input impedance by the closely placed parasitic elements. Measured antenna on finite sized ground model is shown in Fig. 4, where a parasitic element connects with the ground for inverted F and $\pi$-shaped antennas. The influence to input characteristic becomes large as arranging the loop element near C and H-shaped antennas as discussed in the previous section, then we use inverted U-shaped parasitic element. By the image method, loop element is equivalent to be inverted U-shaped one, then inverted F-shaped antenna is C-shaped one, and π-shaped antenna is H-shaped one.

The input characteristics of π-shaped antenna are shown in Fig. 5. In analysis, the antenna input characteristics are not evaluated for the case of $d<0.04\lambda$ in this prototype model. To confirm that the change in input characteristic causes for $d<0.04\lambda$, we measure input impedance variation of π-shaped antenna for $d>0.01\lambda$. The parameter L=14.0mm can control the input impedance by about 20%, but the difference between calculation and experiment is assumed to be caused for $d<0.08\lambda$ case by numerical problems due to very close spacing between observation and source positions.

## 4. Tunable antenna by parasitic element

This paper presents tunable antenna by proposed parasitic element. We measure $S_{11}$ as an antenna input characteristic, and check the pattern change by this method. In order to show the advantage of this method with the parasitic element, we compare this method with the stub tuning methods [4]. The method with the stub element is shown in Fig. 6, where $d_2$ is the distance between two stub elements. The first stub element is fixed in the position of 3mm from the feed element, and the second is arranged in the position of $d_2$ from the feed element. Trimming method is how the second element is moved along the x axis.

$S_{11}$ characteristics with the parasitic element are shown in Fig. 7, and the parasitic element changes the resonant frequency from 1.95GHz to 2.03GHz. The $S_{11}$ of the second stub element are shown in Fig. 9 and its advantage is wide frequency tuning range.

Radiation patterns by both tuning methods are shown in Figs. 8 and 10. It should be noted that the radiation pattern change of stub tuning is larger than that of proposed one for the same frequency shift. The proposed tuning method is effective to change the resonant frequency without radiation pattern distortions.

Tunable antenna proposed in this paper is provided by the parasitic element arrangement as shown in Fig. 11, where the Inverted U-shaped element is arranged near π-shaped antenna. The state ‘on’ defines, both edges of inverted U-shaped parasitic element are connected to the ground, and the state ‘off’, one of edges is connected and other is open. Fig. 12 shows that the frequency tuning is given by the combination of “on/off” sate.

## 5. Conclusion

We investigated the input impedance variation of the antenna with parasitic elements and showed that the non-resonant parasitic element provides the frequency control for the antenna input characteristic. In π-shaped antenna, we verified that the parasitic elemenent method could shift the antenna resonant frequency without changing the radiation pattern. In addition, we presented the control method for input characteristic by on/off switching of a parasitic element, as a new tunable antenna.

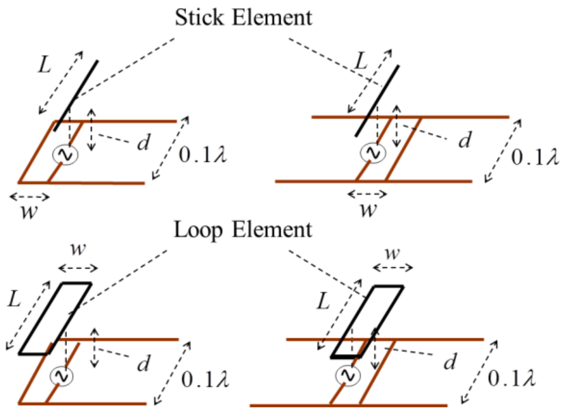
## References


[1] Nisio, et. al, “A study of handy terminal antenna with resonant frequency variability for Digital Terrestrial Broadcasting,” AP2005-170, pp. 67-70, Feb. 2006.

[2] Nisimoto,et. al, “Sleeve antenna with variable capacitors,” AP2004-196, pp1-6, Jan. 2005.

[3] H. Arai, “The Relation between Antenna Input Characteristics and Near Field Distributions,” AP2007-38, pp. 41-46, Jun. 2007.

[4] S.Muramatsu, “A study of tunable method of planar inverted F-shaped antenna,” Graduation thesis, cf.3, Yokohoma National University, Mar. 2000.




C-shaped Antenna H-shaped Antenna

Fig.1 Antenna geometry, w=0.027λ, L=0.1λ, 0.08λ, 0.04λ, unit is mm.

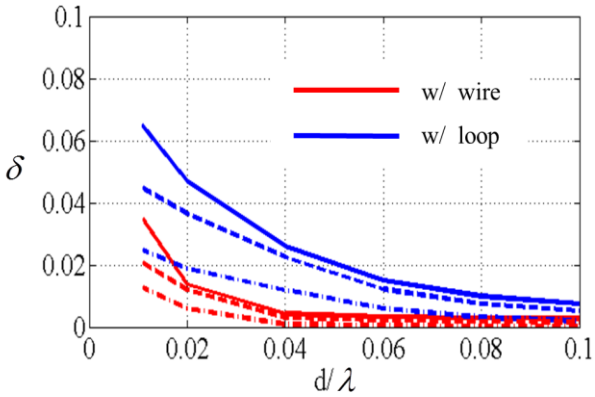



Fig. 2 Impedance variation of C-shaped antenna solid line is L=0.1λ, dashed line is L=0.08λ, dot and dashed line is L=0.04λ.

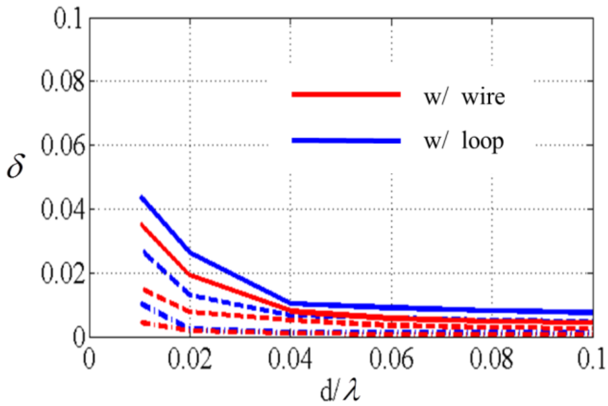



Fig. 3 Impedance variation of H-shaped antenna solid line is L=0.1λ, dashed line is L=0.08λ, dot and dashed line is L=0.04λ.

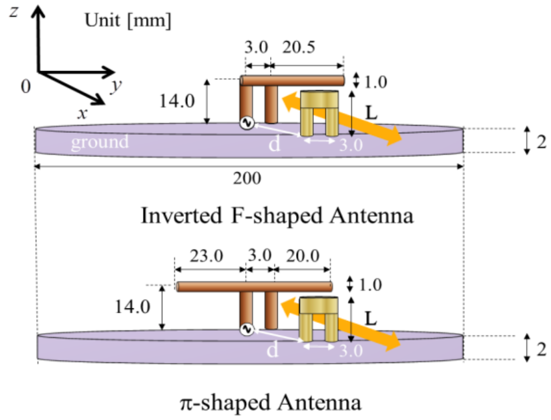



Fig. 4 Geometry of inverted F/π- shaped antenna for measurement.

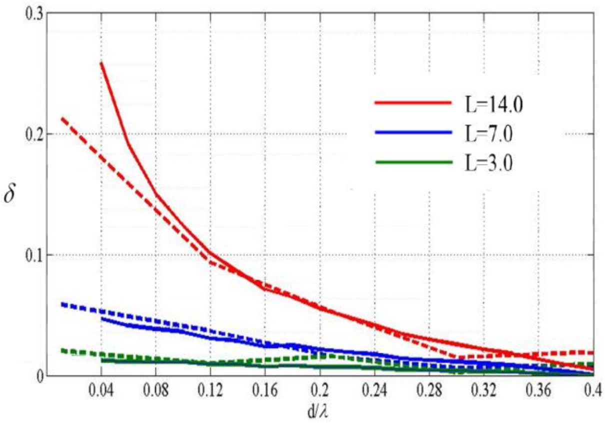



Fig. 5 Impedance variation solid line is cal., dotted line is exp.

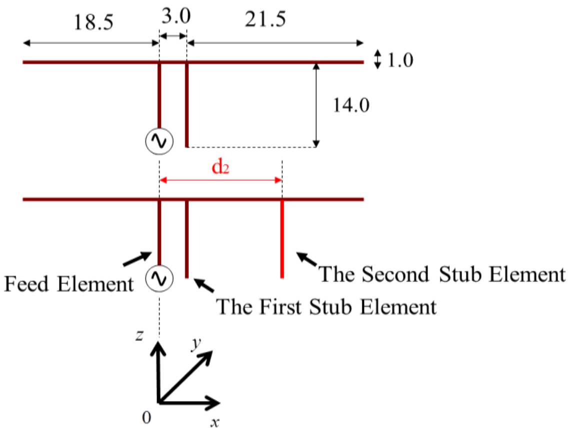



Fig. 6 Trimming method with a stub element $d_2$ is distance between two stub elements, unit is mm.

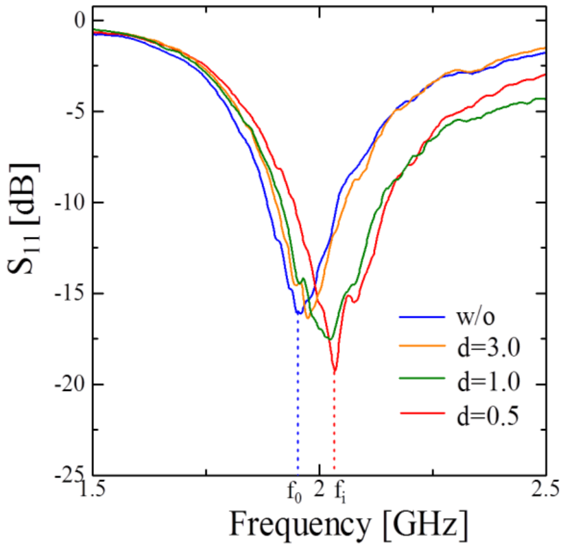



Fig. 7 $S_{11}$ characteristics with a parasitic element
$f_0$=1.95GHz, $f_i$=2.03GHz, unit is mm.

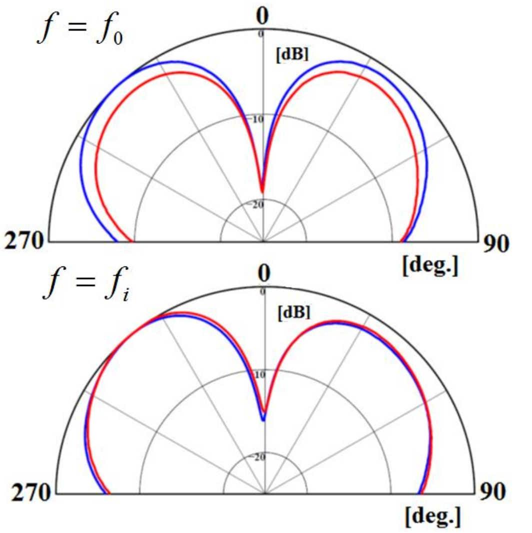



Fig. 8 Radiation pattern with a parasitic element
blue line is w/ o, red line is w/, d=0.5mm

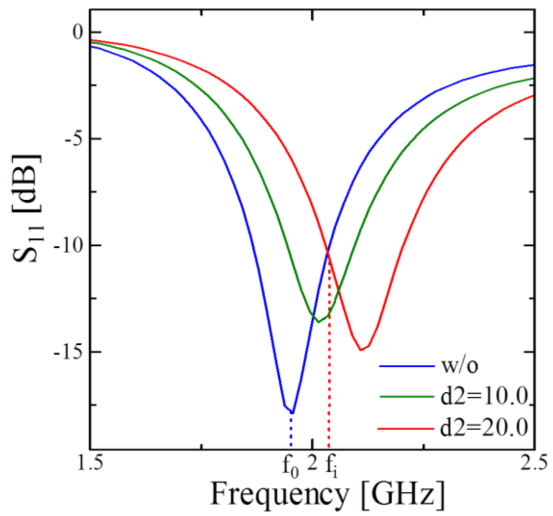



Fig. 9 $S_{11}$ characteristics with a stub element
$f_0$=1.95GHz, $f_i$=2.03GHz, unit is mm

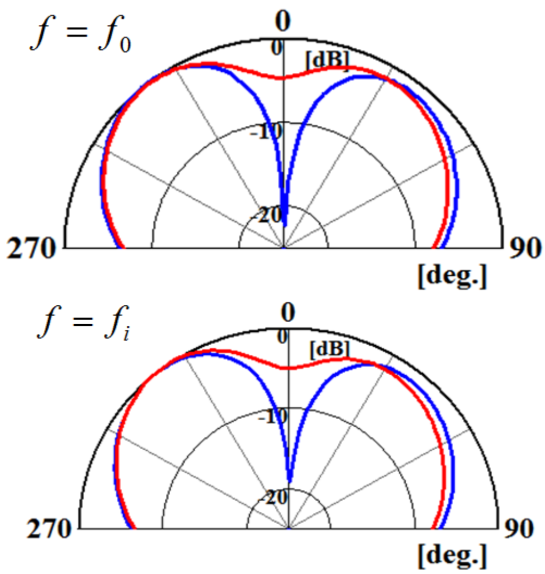



Fig. 10 Radiation pattern with a stub element
blue line is w/o, red line is w/, d=0.5mm

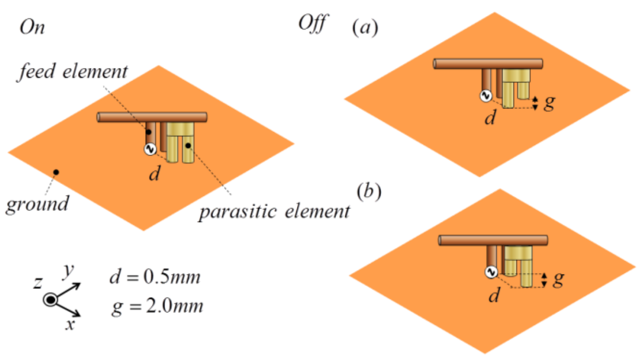



Fig. 11 Proposed tunable antenna

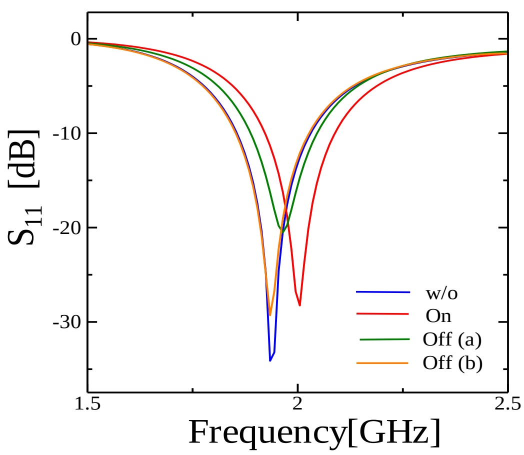



Fig.12 $S_{11}$ characteristics by tunable method