Analysis and Design of Small Size Short Circuited Microstrip T-Shaped Antenna

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Abstract
A small size short-circuited microstrip T-shaped antenna is presented. The antenna is analyzed by placing electric and magnetic walls at the plane of symmetry. Design equations and curves are introduced. The proposed approach has been validated through the design and implementation of an antenna at 850 MHz. Significant size reduction has been achieved. The IE3D soft ware is used to simulate the designed antenna. The experimental results agree well with the theoretical prediction.

I. Introduction

Recent progress in wireless communications requires small size and lightweight antennas. Generally speaking, microstrip antennas are well suited for such applications. Many different structures have been developed in response to this demand [1]. An important size reduction has been achieved through the proposed H-shaped antenna for single and multi-band operation [2,3]. Recently, the full wave analysis reported in [4] shows that introducing short circuit on the patch leads to significant size reduction, and the feeder should be located too close to the short circuit for good matching. The size reduction can also be achieved using short-circuited H-shaped structure [5]. Curves showing the resonance frequency of the antenna with its dimensions have been obtained from the different structures analyzed numerically using finite difference time domain FDTD technique.

In this paper we present a new small size short-circuited T-shaped antenna analyzed using the concept of electric and magnetic walls at the plane of symmetry. The advantages of this approach is the quick prediction of the resonance frequencies of a structure of any dimensions, the simplicity of finding the minimum size structure, and the flexibility of locating the two resonance frequencies in case of dual band operation. The antenna analysis is presented in section II. Design, simulation and experimental results of an antenna designed at 850 MHz are introduced in section III, followed by concluding remarks in section IV.

II. Radiation behavior and resonance frequencies

The physical structure of the T-shaped antenna is shown in Fig.1. Due to the symmetry of the structure about the X-axis, the electric and magnetic walls concept seems to be the most suitable and simple approach to determine the radiation behavior and resonance frequencies of the antenna [3]. Placing an electric or magnetic wall at the X-axis results in the following two modes:

(1) Mode with a magnetic wall at the X-axis

The current distribution of this mode is given in Fig. 2(a). The current flow is maximum at the center of the structure, so its radiation characteristics can be approximated by a horizontal dipole. The resonant frequency f_H, or wavelength of this mode, which is the lowest order mode, is governed by the condition that the mean current path length equals a quarter wavelength as:

$$L_2 + W_2/2 + W_1/4 + L_1 = \lambda_{gH}/4 \qquad (1)$$

This approximation is valid when $W_1/2$ close to W_2. However, for more compact circuit W_2 should be selected much greater than W_1. In this case eq. (1) will be inaccurate and better model is needed. Fig. 2(c) shows more accurate model suitable for analysis and design purpose.
It can be easily shown that the resonance condition is given by

$$K = \tan\theta_1 \tan\theta_2 \qquad (2)$$

Where $K = Z_2/Z_1$, and Z_1 and Z_2 are the characteristic impedances of a microstrip lines of widths $W_1/2$ and W_2, respectively. However θ_1 and θ_2 are the electrical lengths of microstrip lines shown in Fig. 2(c). These electrical lengths can be calculated from the physical lengths L_1, L_2, W_1, and W_2 where the influence of discontinuities should be taken into account. The resonator length, $\theta_T = \theta_1 + \theta_2$, can be plotted against θ_1 for different values of K as shown in Fig. 3. This shows that resonance occurs when the total electrical length is greater than 90^o for K >1 and less than 90^o for K<1. For the purpose of small size , K<1 is chosen.

(2) Mode with an electric wall at the X-axis
As shown in Fig. 4(a), the net current flow in the horizontal arm is almost zero because of the presence of the electric wall on X-axis; hence the radiation behavior can be considered as that of radiation from a vertical dipole. Therefore the horizontal arm has little effect on the antenna properties. One can estimate the resonant frequency of this mode (f_E) by asuming that the L_2 line is terminated by the parallel combination of two short circuited lines as suggested by Fig.4(b). The parallel combination of the two short circuited lines has the effect of another short circuited line of width W_2 and effective length, L_{SCeff}. In this case, resonance occur when

$$4(L_2 + L_{SCeff}) = \lambda_{gE} \qquad (3)$$

where L_{sceff} is given by $L_{sceff} = \dfrac{W_1/2}{1 + Z_2 W_1/Z_1(W_2 + L_1)}$

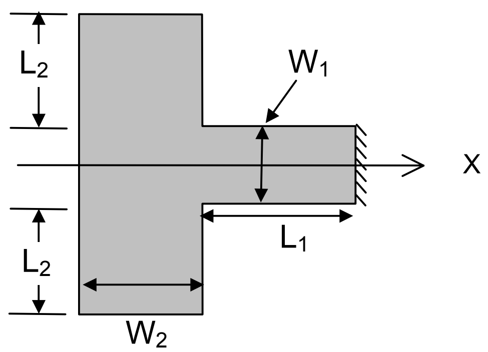

Fig. 1 T-shaped antenna structure

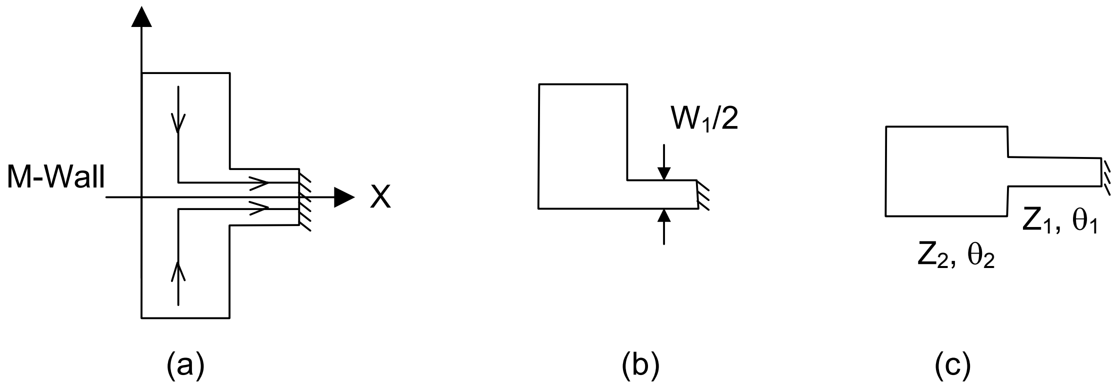

Fig. 2 T-shaped antenna mode due to magnetic wall at the X- axis and its circuits equivalent

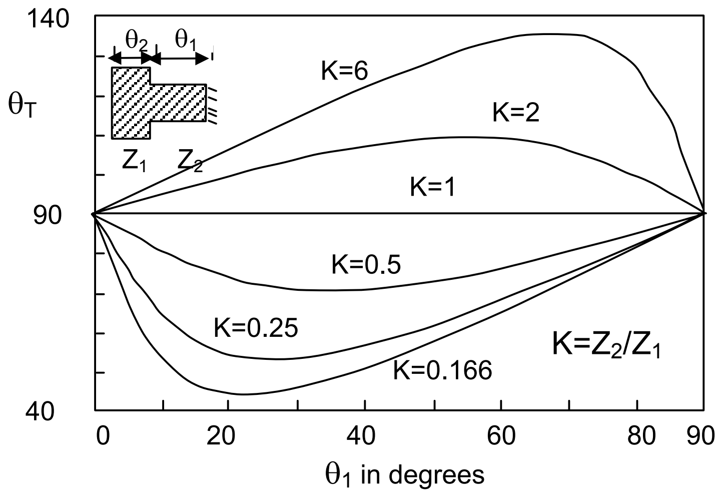

Fig. 3 Total electrical length θ_T against θ_1 for different values of $K=Z_2/Z_1$.

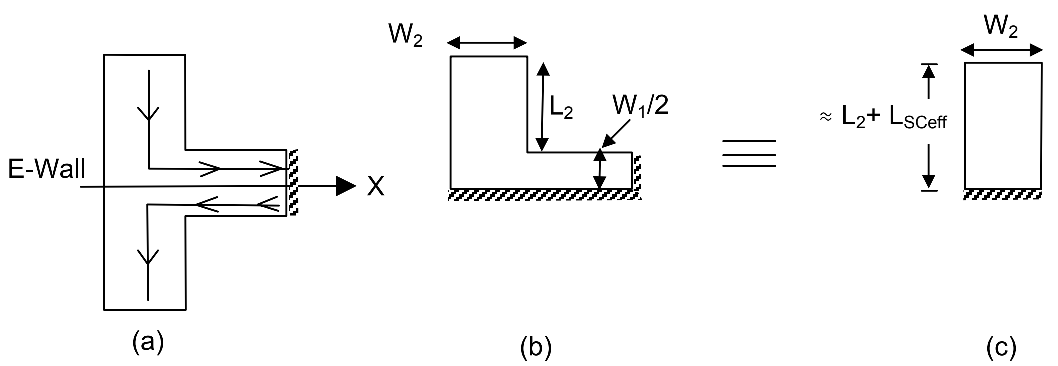

Fig. 4 T-shaped antenna mode due to electric wall at the X- axis and its circuits equivalent

III. Design Case

We introduce now a T-shaped antenna designed for single band operation at 0.85 GHz. Duroid substrate RT/5880 with ε_r=2.2 and h=1.57 mm is used. For small size antenna the K factor should be less than 1 (Fig. 3). For K equal to 0.25, the minimum antenna electrical length will be about 54^o. The total length can be achived for different varieties of θ_1, since the curve is almost flat from θ_1= 20^o to 30^o. The following dimensions have been chosen: W_1= 2 mm (Z_1 = 115 Ω, for microstrip line of 1mm width), W_2 =11 mm (Z_2 = 28 Ω for microstrip line of 11mm width), L_1= 12 mm and L_2=11 mm. A coaxial feed located 0.5 mm far from a single post at the center edge of the narrow line is used. Such type of feed [3,4] enable only the mode having a magnitic wall at the X-axis. The simulation and experimental results are shown in Fig. 5. The simulation results have been performed using IE3D software. The 10 dB return loss measured bandwidth is 0.41% centered at 0.845 GHz. Frequency shift of 50 MHz has been observed between simulation and measurements. This may be due to the feeding and mounting inaccuricy using the available tools. The resonance frequency has been decreased, for a short circuit quarter wave antenna has the same total length (23 mm) and width equal to 30 mm, from 2.25 to 0.845 GHz. No harmonics have been appeared in the measured band up to 5 GHz. This can be predicted from the resonance condition of the resonator shown in Fig. 2 (c).This property is needed in many applications in order to improve the power amplifier efficiency [6] and reduce the electromagnetic interference. Further study for dual band operation is underway.

IV. Conclusion

A new small size T-shaped microstrip antenna has been proposed. The analysis has been carried out based on the electric and magnetic walls concept. Single band antenna operated at 0.845 GHz has been designed and measured. The antenna bandwidth is 0.41 %. This antenna finds application in many wireless communications systems where the bandwidth is not a constraint.

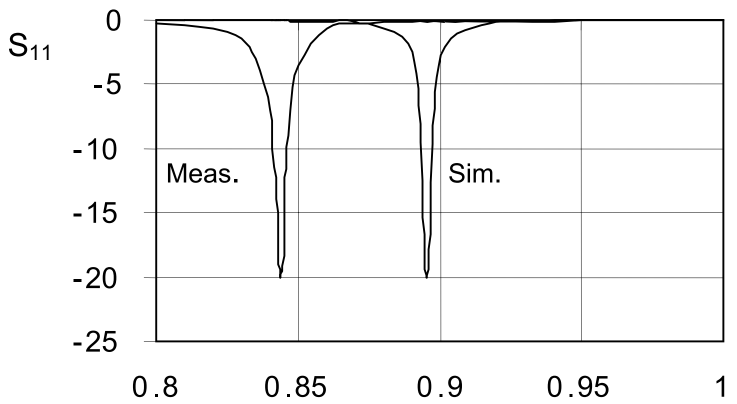

Fig. 5 Simulated and measured input reflection coefficients of stepped antenna with W1=2 mm, L1=12 mm, W2=11 mm and L2 = 11 mm

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