วิธีอย่างง่ายและถูกต้องเพื่อคำนวณหาความถี่เรโซแนนซ์ของสายอากาศแผ่นแบบไมโครสตริปรูปสี่เหลี่ยมผืนผ้าซึ่งมีสลักจูนลัดวงจร

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บทคัดย่อ

วิธีอย่างง่ายและถูกต้องเพื่อคำนวณหาความถี่เรโซแนนซ์ของสายอากาศแผ่นแบบไมโครสตริปรูปสี่เหลี่ยมผืนผ้าซึ่งมีสลักจูนลัดวงจรได้นำเสนอไว้ในบทความนี้โดยทั้งนี้แผ่นสายอากาศจะถูกป้อนสัญญาณด้วยสายส่งแกนร่วม และขณะเดียวกันก็จะถูกลัดวงจรด้วยสลักจูนลัดวงจร ทั้งนี้เพื่อให้สามารถทำการปรับความถี่เรโซแนนซ์ของสายอากาศได้ สูตรที่ได้นำเสนอเป็นสูตรโดยประมาณอย่างง่ายและมีความถูกต้อง ซึ่งเป็นฟังก์ชันของตำแหน่งของสลักจูนและพารามิเตอร์อื่นของสาย ผลการคำนวณหาความถี่เรโซแนนซ์จากสูตรที่ได้นำเสนอมีความใกล้เคียงกับผลการทดลองมาก

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Simple and Accurate Method for Calculating the Resonant Frequency of a Rectangular Microstrip Patch Antenna with a Single Shorting Post

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Abstract

A simple and accurate method for calculating the resonant frequency of a rectangular microstrip patch antenna with a single shorting post is presented. The coaxial probe-fed rectangular patch incorporates a shorting post which significantly tunes the operating frequency of a rectangular microstrip patch antenna. A simple and accurate approximate formula for the resonant frequency as a function of the post location, and of the other characteristic parameter of the antenna is given. It is found that the experimental and theoretical results are in very good agreement.

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I. Introduction

Many methods have been proposed for tuning the resonant frequency of rectangular microstrip path antenna [1]-[5], however in these methods, the resonant frequency can be tuned by using magnetic substrate. A simple method to tune the resonant frequency of a rectangular microstrip patch antenna is to terminate the radiating patch with a short circuit [6]-[9]. The short circuit can be obtained by using a metal clam or a series of shorting posts (e.g., switching diodes). Recently, it was shown that by changing the number of shorting posts and their relative position, the resonant frequency of the short circuited microstrip patch can be tuned [6]. In fact, by changing the number and the locations of shorting posts, the resonant frequency of the rectangular patch can be tuned. Thus, for a set of the resonance frequency, a significantly tuning can be achieved by using this method and compared to the one obtained by the conventional microstrip sized patches

In this paper, a method for calculating the resonant frequency of a rectangular microstrip probe-fed patch antenna with a single shorting post is presented. Herein a shorting post is incorporated in the design, and the resulting resonant frequency of the rectangular microstrip patch antenna is found to be significantly tuned over a f_r - to - f_r + 138 MHz range. Comparisons among the previous theoretical resonant frequency and experimental results are given.

II. Calculations

The geometrical configuration of a rectangular microstrip patch antenna with a shorting post is shown in Fig. 1. A perfectly conducting rectangular patch is placed on the top of a dielectric substrate backed by a perfectly conducting ground plane. The rectangular patch has a physical dimension $w \times l$ cm. The dielectric substrate has a relative permittivity of ε_r and thickness h.

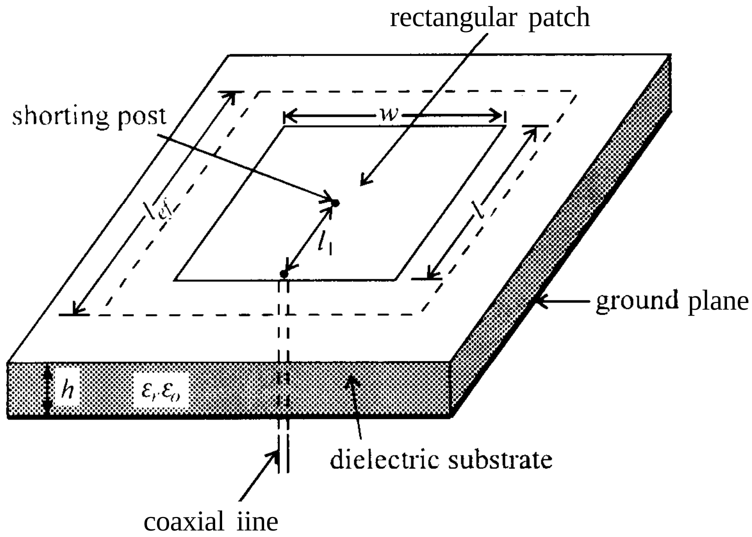

Fig. 1. Geometrical configuration of a rectangular microstrip patch with a shorting post.

The resonant frequency of a conventional rectangular microstrip patch antenna is given by [10]. For this paper, the lowest order resonant frequency in the simple formula from [10] is given as

$$f_r = \frac{15}{l(\varepsilon_r)^{1/2}} \tag{1}$$

where f_r is the resonant frequency in GHz and l is the physical length in cm. The calculated results of the resonant frequency f_r are higher than the measured results due to effective (electrical) length l_{ef} and the effective permittivity ε_{ef} taking into account the energy stored in the fringing fields at the edges of a rectangular patch. Thus, the resonant frequency can be corrected by replacing the physical length l with the effective length l_{ef} and the relative permittivity ε_r with the effective permittivity ε_{ef} in (1) as

$$f_r = \frac{15}{l_{ef.}(\varepsilon_{rf})^{1/2}} \tag{2}$$

For the rectangular microstrip patch which has the same geometrical configuration as the planar waveguide ([11],[12]), the effective length in (2) can be obtained as

$$l_{ef} = l + \frac{1}{2}\left(\frac{120\pi h}{Z_0\sqrt{\varepsilon_{ef}}} - w\right)\left(\frac{\varepsilon_{ef} + 0.300}{\varepsilon_{ef} - 0.258}\right) \tag{3}$$

where Z_0 is the characteristic impedance given in [13] and is written as

$$Z_0 = \frac{377}{\sqrt{\varepsilon_{ef}}}\left[\frac{w}{h} + 1.393 + 0.667 \times \ln\left(\frac{w}{h} + 1.444\right)\right]^{-1} \tag{4}$$

where ε_{ef} is the effective permittivity :

$$\varepsilon_{ef} = \frac{1}{2}\left[(\varepsilon_r + 1) + (\varepsilon_r - 1)\left(1 + \frac{10h}{w}\right)^{-1/2}\right] \tag{5}$$

To determine formula of the resonant frequency of the rectangular microstrip patch antenna with a shorting post, the measured data from [14] is used and compared to the conventionally sized patches (patches without a single shorting post), which can be obtained as

$$f_{r_s} = \frac{15}{l_{ef}\left(\varepsilon_{ef}\right)^{1/2}}\left[1 + \cos^2\left(\pi l_1 / l\right)\right] \tag{6}$$

where f_{r_s} is the resonant frequency of a rectangular patch with a shorting post in GHz, and l, l_1 and l_{ef} are in cm.

III. Results and Comparisons

In Table I, the theoretical resonant frequencies of a shorting post of a rectangular microstrip patch antenna, which have been obtained by using (3)-(5), and (6) are given and compared with those obtained from the previous study [8] and the measured data [14]. In order to gain more confident, self measurements have been made on typical RT/Duroid 5880 sample (0.1524 cm thick substrate, ε_r = 2.20). The measurements have been carried out using an Automatic Network Analyzer : Advantest R3762A. Numerical results of the measured and calculated frequencies are given in Table II and are found to be in very good agreement. Therefore, it can be concluded that this method has advantages over the others in its simple calculation and accurate results.

Table I.

Comparisons of Measured and Calculated Resonant Frequencies of a Rectangular Microstrip Patch Antenna with a Shorting Post

l_1/l	Resonant Frequencies (GHz)			
	Measured [14]	Present method	Analytical method [8]	Numerical method [8]
0.0	1.588	1.576	1.656	1.645
0.1	1.594	1.563	1.640	1.640
0.2	1.573	1.529	1.597	1.600
0.3	1.533	1.486	1.544	1.545
0.4	1.485	1.452	1.501	1.501
0.5	1.466	1.438	1.485	1.485
0.6	1.480	1.452	1.501	1.501
0.7	1.525	1.486	1.544	1.545
0.8	1.562	1.529	1.597	1.600
0.9	1.590	1.563	1.640	1.640
1.0	1.580	1.576	1.656	1.645

l = 6.2 cm., w = 9.0 cm., ε_r = 2.5.5 cm., h = 0.16 cm.

Table II.

Comparisons of Measured and Calculated Resonant Frequencies of a Rectangular Microstrip Patch Antenna with a Shorting Post

l_1/l	Resonant Frequencies (GHz)	
	Measured [14]	Present method
0.0	3.188	3.175
0.1	3.122	3.116
0.2	2.991	2.962
0.3	2.788	2.771
0.4	2.664	2.617
0.5	2.591	2.558
0.6	2.668	2.617
0.7	2.812	2.771
0.8	2.901	2.962
0.9	3.130	3.116
1.0	3.180	3.175

1= 3.75 cm., w = 7.424 cm., ε_r = 2.20 cm., h = 0.1524 cm.

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