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Design and Development of Micro-Strip Quarter-Wave Resonator for WLAN

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Abstract: Design and development of micro-strip quarter-wave transmission line with one side open circuited and the other side short circuited (the quarter-wave type resonator) is investigated, and a generalized analysis is given for the resonance conditions. Small micro strip resonator with $0.2\lambda_g \times 0.9\lambda_g$ size have built by using standard synthesis method. Proposed resonator is measured to demonstrate higher frequency capabilities. This resonator is also used for Wireless Local Area Network (WLAN) applications which have the frequency range of 2.4GHz. IE3D software package is used for simulation of micro strip quarter-wave resonator. Measurement has done with vector network analyzer of Rohde & Schwarz (ZVH4).

Index Terms: *2.4 GHz resonator, Micro-strip quarter wave resonator and Resonator for WLAN.*

I. INTRODUCTION

Since the emergence of micro-strip technology as a dominant architecture, varying types of micro-strip resonators have been crucial to the development and design of microwave circuits. Micro strip ring resonators were initially used for micro strip line property characterization and measurement such as effective permittivity [1]. The moderate Q factor and low radiation, however, quickly made the ring a staple in circuit design. Some popular applications are narrow band, band pass dual-mode filters [2], active varactor-tunable band pass filters[3], and oscillators [4]. Recently, split-ring resonators have been used to demonstrate structures with negative permittivity and permeability in the area of metamaterials [5]. Bandpass filters are essential components in communication systems. The rapid growth of wireless and mobile communication has placed an increasing demand for new technologies to meet the challenge in meeting size, performance and cost requirements. For this purpose, there has recently been increasing interest in multilayer BPF.[6]-[8]. Generally, most of these filters are based on the resonators that are evolved from the classic quarter-wave and half-wave resonators. In [9], [10], and [11], filters with an ultra-small size are proposed based on quarter-wave resonators. These filters all achieve good performance. However, the structures of these filters are complicated, as a complicated folding topology and mass of shorted vias are required. In [12], well-performed band pass filters with a small size are proposed based on half-wave resonators. These filters do not require vias, but the sizes of them are slightly larger than the filters based on the quarter-wave resonators. In addition to the filter size reduction, much effort has also been made to introduce transmission zeros to improve the filter selectivity [13]–[16].The quarter-wave resonators are frequently used in inter digital filters [17].The quarter-wavelength inter digital-type filter is attractive because it is more compact than a conventional cross-coupled filter with half-wave resonators. The cross-coupled filter, using quarter-wavelength resonators, was first introduced in [18].The conventional micro-strip transmission line with one side short circuited and the other side open circuited [19] and the modified unit cell is shown in fig.(1)

II. DESIGN PROCEDURE

The quarter-wave resonator consists of one open-circuited end and one short-circuited end. The design values are given in (a) & (b),

B. Open-circuited λ/4 line:

A parallel type of resonance (anti-resonance) can be achieved using a open circuited transmission line of length λ/4.The input impedance of the open circuited line of length 'l' is

$$Z_{in} = Z_o \coth(\alpha + j\beta)l$$

Where the last result was obtained as

$$Z_{in} = Z_o[\alpha l + j\pi \square \omega / 2\omega_0] \quad (1)$$

This result is of the same form as the impedance of a Series RLC circuit

$$Z_{in} = 1/[(1/R) + 2j\Delta\omega C] \quad (2)$$

While comparing the equations (1) & (2), we can obtain Resistance of the equivalent circuit as

$$R = Z_0 \alpha l \quad (3)$$

Inductance of the equivalent circuit as

$$L = Z_0 \pi / 4\omega_0 \quad (4)$$

Capacitance of the equivalent circuit as

$$C = 1/\omega_0^2 L \quad (5)$$

B. Short circuited λ/4 line:

A parallel type of resonance (anti-resonance) can be achieved using short circuited transmission line of length λ/4.The input impedance of the shorted line of length 'l' is

$$Z_{in} = Z_o \tanh(\alpha + j\beta)l$$

Where the last result obtained is

$$Z_{in} = Z_o / [\alpha l + j\pi\Delta\omega / 2\omega_0] \quad (6)$$

This result is of the same form as the impedance of a Parallel RLC circuit

$$Z_{in} = 1/[(1/R) + 2j\Delta\omega C] \quad (7)$$

While comparing the equations (3) & (4), we can obtain Resistance for the equivalent circuit as

$$R = Z_0 \alpha l \quad (8)$$

Inductance for the equivalent circuit as

$$L = \omega^2{}_0 C \quad (9)$$

Capacitance for the equivalent circuit as

$$C = \frac{\pi}{4\omega_0 z_0} \quad (10)$$

I. UNIT CELL

In figure 1 one end is open circuited and the other end is short circuited because it acts as a quarter-wave resonator. Open circuited end acts as capacitive reactance and the short circuited end acts as inductive reactance.

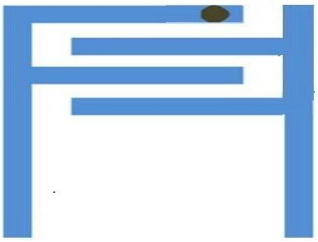
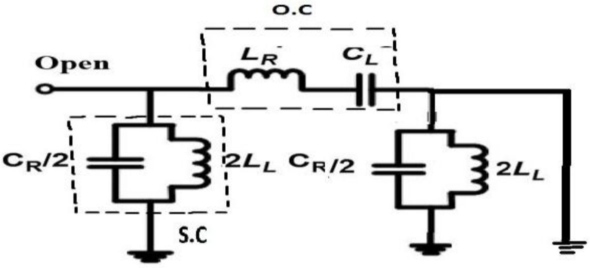


Fig. 1. Unit cell of the proposed quarter wave resonator

III. EQUIVALENT CIRCUIT AND DISPERSION DIAGRAM



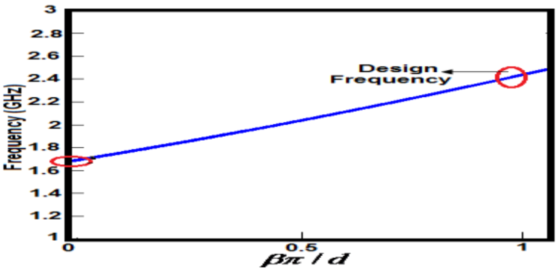


Fig. 2. Equivalent circuit of the proposed design. theproposed

Fig. 3. Dispersion diagram of unit cell of quarter wave resonator

In figure 2 inductance (L) and capacitance(C) are connected in series for open circuited end and they are connected in parallel for short circuited end. The parallel L and C values are calculated by using the equations (4) & (5) L= 4.2nH and C=1.042pF. The Series L and C values are calculated by using the equations (9) & (10) L=2.6nH and C=1.7 pF.

Table II. Inductance And Capacitance Calculated Value For Short And Open Circuit.

L_R	C_L	C_R	L_L
4.2nH	**1.042pF**	**C=1.7 pF**	**L=2.6nH**

To determine the resonating frequencies for the quarter wave resonator structure, the following expression for the phase constant must be utilized:

$$\beta(f) = \frac{-\phi(f)}{Nd} \tag{11}$$

Where N is the number of unit cells and d is the length of the unit cell. For each of the modes there are N+1 possible points of resonance. $\phi(f)$ can be represent as,

$$\varphi = -2\pi f \frac{\sqrt{\varepsilon_{eff}}}{c} Nd + \frac{N}{2\pi f \sqrt{L_L C_L}} \tag{12}$$

This phase relation can easily be converted to the dispersion relation using eq. (11).

$$\beta = 2\pi f \frac{\sqrt{\varepsilon_{eff}}}{c} - \frac{1}{2\pi f \sqrt{L_L C_L}\, d} \tag{13}$$

There are essentially two design parameters, either L_L or C_L or and Nd that can be used to create the desired dispersion relation and the Q factor. Structure will resonate when the phase ∅=0, ±2π, ±4π…. and, using (11), this resonating phase condition can be converted to the normalized phase constant that is found in the dispersion diagram shown in Figure 3. The dispersion relation will be used to analyze the properties of the quarter wave resonator and provides information on both the phase constant (relating to the phase response), as well as the pass band and stop band regions. Note that the number of resonances that occur within the pass band for a given structure depends on the number of unit cells N. dispersion diagram shows it have two resonating frequency at $\beta = 0$ and 1, and at $\beta = 1$ designed frequency of resonator occur.

IV. STRUCTURE OF QUARTER-WAVE RESONATOR

The proposed structure is numerically tested using IE3D and calculated by the very fundamental equations. During the simulation we must set the unit in mm and set the meshing frequency (it should be the maximum frequency) with the appropriate grid size. The capacitive and inductive length can obtain by given equation.

For Capacitive Length:

$$C = \frac{1}{\lambda_g f Z_0} \tag{14}$$

Where C is the capacitive length, λ_g is wavelength f is resonant frequency and Z_0 is the impedance.

For Inductive Length:

$$L = \frac{Z_0}{\lambda_g f} \tag{15}$$

Where L is the inductive length, λ_g is wavelength f is resonant frequency and Z_0 is the impedance.

For Width:

$$\frac{w}{d} = \frac{8e^{A}}{e^{2A} - 2} \tag{16}$$

Where,

$$A = \frac{Z}{\frac{60(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{(\varepsilon_r + 1)}\left[\frac{0.23 + 0.11}{\varepsilon_r}\right]}$$

ε_r = *dielectric constant*

Z = *characteristic impedance*

Table II. Dimensions Of The Micro Strip Quarter Wave Resonator

Parameters	**S.C**	**O.C**
Inductive length (mm)	**15**	**10**
Capacitive length (mm)	**10**	**15**
Width (mm)	**3**	**3**

In table. II. Dimension of micro strip quarter wave resonator has been shown. Inductive and capacitive length and width have calculated by the above discussed formulas. These parameters have been calculated for the both case short and open circuit transmission line.

Layout Of The Structure

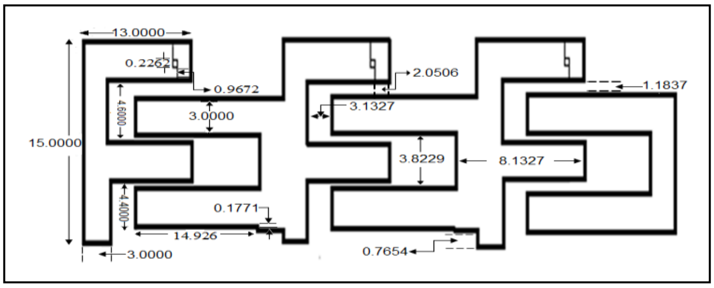


Fig. 4. Layout of the fabricated structure of quarter wave resonator, units are in (mm).

II. LAYOUT OF FABRICATED STRUCTURE

The proposed quater wave resonator is fabricated on FR 4 substrate with a dielectric material constant of 4.4 and a thickness of 1.6 mm, as shown in Figure 5. The shorting is conducted via silver, which is a material with good conductivity.

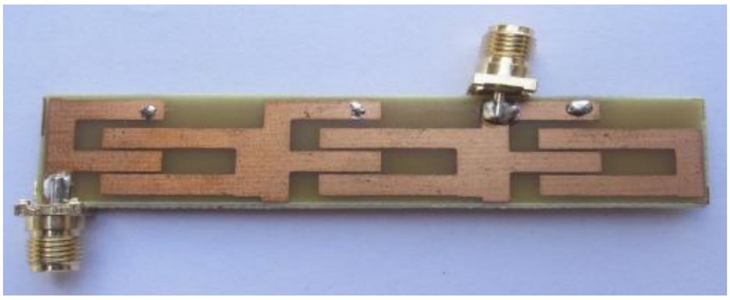
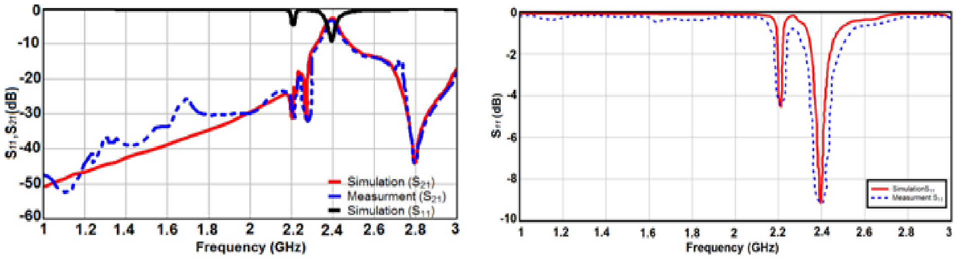


Fig. 5. Fabricated structure of quarter wave resonator

V. SIMULATION AND MESURMENT RESULT

In order to verify the response, and visualize the benefits, of the quarter-wave resonator of Fig. 5, its measurement results are in well match against its simulation results, shown in Fig. 6(a) and (b). The simulation response has been obtained using the IE3D simulation tool.The mesurment has been done by vector network analyzer of Rohde & Schwarz. Fig. 6. illustrates its simulated and measured responses of quarter wave resonator, return loss and insertion loss have been discussed. The minimum loss occur at desire resonance frequency 2.44 GHz. The measured passband insertion loss is approximately -3 dB, and the passband return loss is better than -10 dB. In fig. 6 (b). S_{11} have been calculated for mesurment and simulation, they are in well match for the desire frequency 2.44 GHz. And also the bandwidth of quarter wave resonator is approximately 40 MHz with 3.3 percentage of fractional band width as shown in the fig.6.(a) and fig 6(c) shows the quality factor Q of the proposed quarter wave resonator.



(a) **(b)**

Fig. 6(a). Simulated (solid red line) measured (blue dashed line) results (S_{11} and S_{21}) of quter wave resonator.

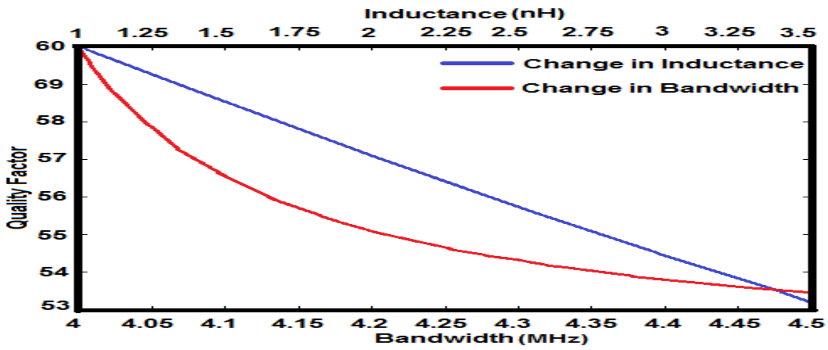


Fig. 7. Quality factor for quater wave resonator.

Quality factor is used to measure the efficiency of the resonator. For proposed quarter wave resonator the quality factor has been measured as 60. The bandwidth and inductive length of the proposed resonator circuit can be optimized by the relation of quality factor. Fig 7. shows that the maximum quality facor is achieved at the desired bandwidth and inductive length.

VI. CONCLUSION

The microstrip quarterwave resonator with one side open circuited and the other side short circuited has been designed in this paper. This resonator acts as a band pass filter ,which allows the frequency 2.4GHz. the electrical length of the quater wave resonator is found to be $0.2\lambda_g \times 0.9\lambda_g$ .The spurious pass band of the proposed basic-type filter can be controlled by simply adjusting the impedance and length ratios of the λ/4 resonators. This resonator is used for WLAN application.

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