Design of Compact-size and High-Q Resonator with Composite of Folded Meander-line and Spiral

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Abstract

In this paper, a new compact and high loaded quality factor (QL) resonator with composite of folded meander-line and spiral structure on low dielectric substrate is designed and simulated. The proposed resonator is connected directly to feeding line in order to get high QL and frequency responses. The resonator is designed to operate at 5.5 GHz and the simulation result shows the QL value of 170. The entire size of resonator is 2.60 x 1.61 mm².

Keywords: compact size; high loaded quality factor; folded meander-line; spiral; resonator.

1. Introduction

Recently, the mobile communication has rapidly grown with the extension of the wireless local area network (LAN) and intelligent transport system (ITS) service. There have been increasing researches on high loaded quality factor (QL) with sharp-skip, high selectivity characteristics, and small size for the resonator as an ITS mobile communication system.

Also, a high-QL resonator is essential for position detection in vehicle mobile communication. Thus, the QL is the most important parameter in a position detector because it determines the overall performance of the detector device. The cavity and dielectric resonator (3D) are promising elements because of its high-QL characteristic. It is, however, due to its three-dimensional (3D) structure, only limited to the system on chip (SoC) and integrated circuit (IC) realization but also is not adequate for mass production [1].

In order to reduce the size of resonator, high dielectric (εr) substrate can be used, but the cost is high [2]. In this paper, the compact-size and high-QL resonator with composite of folded meander-line and spiral structure is presented.

2. Analysis of the Compact size Resonator

The A hair-pin resonator consists of λg/2 open-circuited line with folded structure and 50 Ω coupled feeding line as shown in Fig. 1 [3].

This type of U-shaped resonator is the called hair-pin resonator. The conventional hair-pin resonator [3] consists of electrical lengths as shown in Table I. As depicted in the Table, Zs is the characteristic impedance of the single line, Zpe and Zpo are the even-and odd-mode impedances of the capacitance-load parallel coupled lines and θs is the electrical length of microstrip-line, θpe and θpo are the even-and odd-mode electrical lengths of parallel coupled line [4].

The resonance conditions of hair-pin resonators can be obtained by the ABCD matrix, which expresses a transmission line and a capacitor [4]. Table II shows the
experimental results for the QL and size.

![Figure 1. Schematic of the hair-pin resonator.](image)

**Table II.** Dimensions of the hair-pin resonator.

<table>
<thead>
<tr>
<th>Parameter value [mm]</th>
<th>Parameter value [mm]</th>
<th>Parameter value [mm]</th>
<th>Parameter value [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric constant</td>
<td>Frequency [GHz]</td>
<td>Dielectric constant</td>
<td>Frequency [GHz]</td>
</tr>
<tr>
<td>a 4.10</td>
<td>2.52</td>
<td>b 3.45</td>
<td>10.0</td>
</tr>
</tbody>
</table>

**Table II.** Experimental results of the loaded quality factor.

<table>
<thead>
<tr>
<th>Ref [#]</th>
<th>QL</th>
<th>Parameter</th>
<th>Frequency [GHz]</th>
<th>Size [mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[3]</td>
<td>82</td>
<td>2.52</td>
<td>10.0</td>
<td>1.35X1.96</td>
</tr>
</tbody>
</table>

In the table, the exhibition of resonators has low QL and the size is larger than proposed resonator at 10 GHz.

### 3. Proposed Resonators

The proposed resonator is composed of outer folded meander line and inner spiral structure as shown in Fig. 2. From the Figure, the Z1 is characteristic impedance of resonator and the Z0 is characteristic impedance of feeding line.

![Figure 2. Structure of the proposed resonator.](image)
The Z₀ is 50 Ω and the Z₁ is 120 Ω. Also, the w and s are the width of microstrip line in the resonator and a gap between microstrip lines respectively. In the same way, l₁ and l₂ are lengths of the resonator. Then, the wavelength of a resonator is λg/2. In this characteristic, the proposed resonator is coupled to directly connection with feeding line. In this way, the spiral meander line is built by folding to make the size small. Figure 3 shows the equivalent circuit of the proposed resonator.

![Figure 3. Equivalent circuit of the proposed resonator.](image)

From the Figure, the L is inductance corresponding to the length of the resonator and the C is capacitance corresponding to the gap size in resonator. R is conductance in microstrip line. Also, the Vs and Rs are voltage source and source resistance in feeding line and the RL is the load resistance. In the equivalent circuit, the circuit is like a spiral resonator circuit.

4. Experimental Results

The simulation has been carried out by EM simulator tool, IE3D and the simulation result for QL of the proposed resonator is 170 at the resonant frequency of 5.5 GHz as shown in Fig. 4. Since the QL is higher, we can have a good input reflection coefficient characteristics.

The loaded quality factor can be calculated from the equivalent circuit shown in Fig. 2 using the equation (1) as follows [6]:

![Figure 4. Simulation result of the proposed resonator.](image)
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\[ Q_L = \frac{\omega_o}{R + 2Z_o} \frac{R \cdot 2Z_o}{C} \]  

(1)

It can also be computed from the measured reflection coefficient, S11 as depicted in Fig. 5. (2).

\[ \Delta \omega = \frac{\omega_o}{Q_L} \]

(2)

Figure 5. Definition of the loaded quality factor measurement.

where \( \phi \) is the phase, \( \beta \), the phase constant, and \( l \), the equivalent electrical length of the spurline.

\[ Q_L = \frac{\omega_o}{\Delta \omega} \]  

(2)

The entire size of the proposed resonator is 2.60 Χ 1.61 mm2.

5. Conclusion

In this paper, a new reduced size with high-QL resonator and with composite folded meander-line and spiral structure. In this case, the proposed resonator is connected directly to couple the feeding line. The proposed resonator has used a low dielectric substrate and the size is decreased due to folded structure. The resonator is designed to operate at 5.5 GHz and the simulation result shows the QL value of 170. The total size of the resonator is 2.6 X 1.61 mm2. The resonator can be possible to fabricate with integrated passive device (IPD) in semiconductor technique due to its entirely planar structure. Also, it can be applied to wireless local area network (LAN) system and intelligent transport system (ITS).

References


