

Wide Bandwidth Filtering Antenna with an L -Shaped Resonator

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Abstract— This study presents a filtering antenna that operates at 3.5 GHz. The design utilizes a rectangular radiator and a single L -shaped resonator. A feedline extension is inserted between the L resonator and the rectangular radiator with a coupled connection. The S_{11} parameter demonstrates three minimal responses with a bandwidth of 7.45%, centered at a frequency of 3.52 GHz. The selectivity is evidenced by the gain response, which remains flat over the range of 3.42-3.62 GHz and drops sharply outside this range, indicating good performance. The design is fabricated and the S_{11} measurement result shows an agreement with the simulation.

Keywords—filtering antenna, 5G, a quarter wavelength resonator, via through hole.

I. INTRODUCTION

In modern communication systems, the demand for compact, efficient, and multifunctional components is ever-increasing. One such innovative component that has gained significant attention is the filtering antenna. A filtering antenna, integrates the functions of a filter and an antenna into a single device. This integration leads to several advantages, including reduced size, lower insertion loss, and improved overall system performance. A filtering antenna combines the radiation properties of an antenna with the frequency-selective characteristics of a filter. Traditionally, these two functions are performed by separate components: an antenna for transmitting or receiving electromagnetic waves and a filter for selecting or rejecting specific frequency bands. By merging these functionalities, a filtering antenna can provide both radiation and filtering in a single structure, simplifying the design and potentially reducing the cost of the system.

Various method have been studied to add the antenna with selectivity feature. One widely-used approach is to add a resonator to the radiator to design a filtering antenna. Some resonator such as hairpin [1], cavity resonator [2], interdigital [3], [4], [5], dielectric resonator [6], and E-shape slot [7], [8]. The primary technique to integrate an antenna and filter involves adding a resonator to the antenna feedline, which generates two transmission zeros. Many half-wavelength resonators are used to creates a filtering antenna, such as

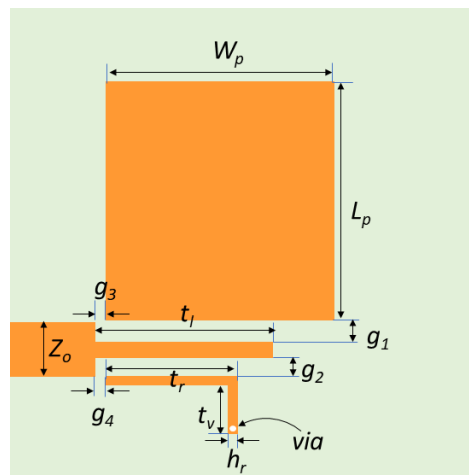


Fig. 1 Configuration of the filtering antenna where $Z_0 = 4.8$, $g_1 = 0.9$, $g_2 = 1.2$, $g_3 = 1.1$, $g_4 = 1.05$, $t_l = 18$, $t_r = 12.4$, $t_v = 4.5$, $h_r = 1$, $L_p = 26.9$, and $W_p = 26$ (all unit dimensions in mm)

hairpin, interdigital, and E resonator. Some design using a quarter wave-length resonator as in, [3], [9], [10] to design a filtering antenna. A quarter wave-length resonator is created by adding a via (vertical interconnect access) through hole at the ending arm of resonator. This method will change the capacity and inductivity of the resonator thus change the resonance frequency of the resonator to the lower frequency. In this study a filtering antenna using L -shape resonator is designed and fabricated. A via through hole is added to the one of the resonators arm for miniaturized a lower frequency operation resonator. The design based on second order band pass filter. The novelty of the design lies in the placement of the transmission line, which is coupled and inserted between the resonator and the radiator. This feeding method is intended to achieve an orthogonal vector relationship between the radiator and the feedline source. Additionally, the introduction of a gap induces a delay between the two vectors, resulting in circular polarization. However, in this study, the discussion is focused solely on the antenna's selectivity feature. The

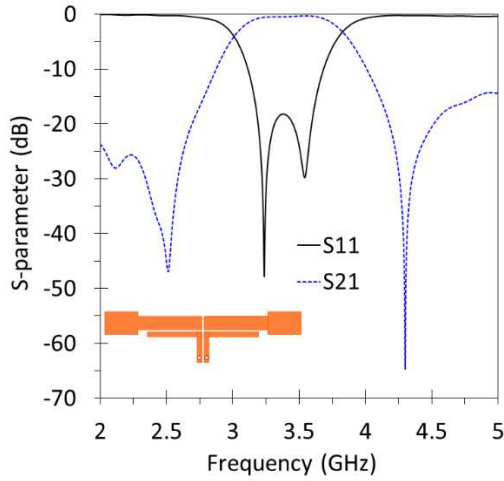


Fig. 2. Second order bandpass filter using L-shaped resonators with via through hole

proposed design is fabricated and measured, and the S_{11} measurement is presented to validate the design.

II. FILTERING ANTENNA DESIGN

The configuration of the proposed filtering antenna is shown at Fig. 1. A rectangular patch radiator is coupled to the L-shaped resonators and a 1.3 mm feed is inserted between the two circuit. The L-shaped resonator, with a thickness of 1 mm, has a via through hole at the end of the arm, making it a $\lambda/4$ resonator [3]. Using the same length resonator will result in a lower resonance frequency if we add a via through hole at the end of the resonator's arm; in other words, the via hole also miniaturizes the resonator. For example, in [11], a filter with an L-shaped resonators operating at 3.45 GHz has a longer dimension than the filter with an L-shaped resonators with a via through hole shown in Fig. 2, despite having the same operating frequency. The filter and antenna are printed on 45 mm \times 50 mm Roger Duroid 5880 substrate, with a permittivity 2.2, and thickness of 1.575 mm.

A. Filter Design

The design of the filter with an L-shaped resonator employs a second-order bandpass filter (BPF) configuration. The resonator features a via through hole at the end of the arm with a diameter of 0.8 mm. The L-shaped resonators are positioned in an opposing arrangement and are coupled to transmission lines that are also mutually coupled. The filter achieves a 500 MHz bandwidth with an impedance of -10 dB and an insertion loss of 0.5 dB at an operating frequency of 3.5 GHz. Fabricated on a 41.5 mm \times 14 mm substrate, the proposed filter not only exhibits a wider bandwidth but also demonstrates a size reduction compared to the L-shaped resonator filter described in [11] which dimension is 60.5 mm \times 20 mm. The incorporation of a via through hole in our proposed design results in a 73% miniaturization factor.

B. Integration Antenna-Filter

A second-order BPF is used to design a filtering antenna utilizing the same resonator. To integrate the filter and antenna, we must design the radiator to resonate at 3.5 GHz. The next step involves coupling the rectangular radiator to the transmission line, which is then coupled to the resonator, positioning the transmission line between the radiator and the resonator. The optimization of the antenna depends on four

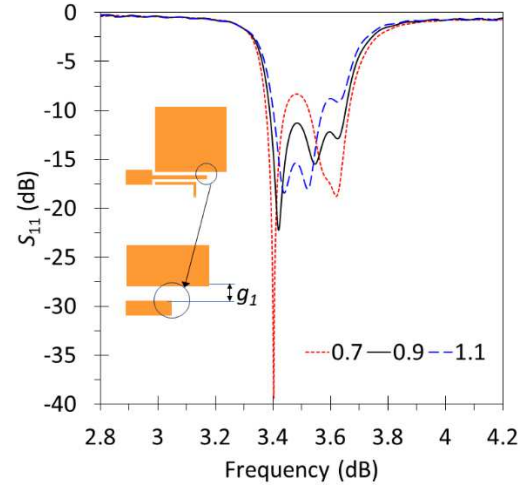


Fig. 3 S_{11} response with various g_1 (all unit dimensions in mm)

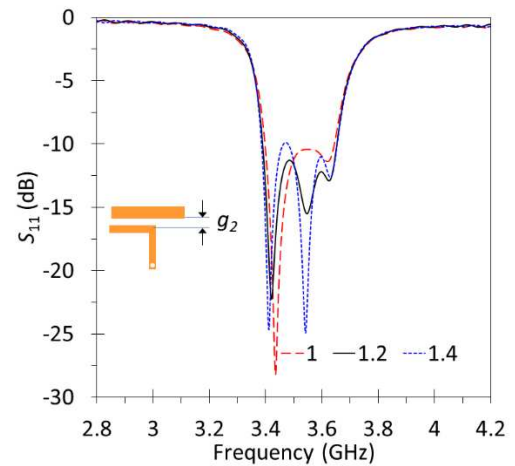


Fig. 4 S_{11} response variation with g_2 (all unit dimensions in mm)

parameters: the length, width of the radiator, the gap between the transmission lines and resonator (g_1) and the gap between transmission line and resonator (g_2). Figure 3 shows the S_{11} of the filtering antenna with various g_1 values. Increasing or decreasing g_1 from 0.9 mm degrades the S_{11} response. Fig. 4 shows the impact of g_2 to S_{11} response. Adjusting g_2 from 1.2 mm, either by increasing or decreasing it, results in an increase in the S_{11} value. Both g_1 and g_2 affect the S_{11} response at the middle bandwidth, they have only a slight effect on the lower side or upper side S_{11} .

III. RESULT AND DISCUSSION

The optimized S_{11} and gain result of filtering antenna is shown in Fig. 3 and Fig. 4 with solid black line curve where it has -10 dB bandwidth impedance of 262 MHz or 7.45% in a range of 3.39–3.65 GHz and center frequency of 3.52 GHz. The S_{11} shows three minima values at 3.42 GHz, 3.55 GHz and 3.63 GHz. Although the design using single resonators as in the second-order filtering antenna, the S_{11} result have three minimal values. The proposed design has a maximum gain of 6.7 dBi at 3.54 GHz. Gain response is flat along the operational bandwidth and decreases to less than -15 dB at lower frequency and -14 dB at the upper frequency.

The design is fabricated as depicted in Fig. 5 and measured using Vector Network Analyzer Agilent N5230C. The S_{11}

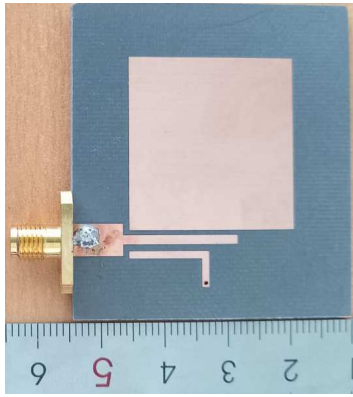


Fig. 5 Fabrication of filtering antenna

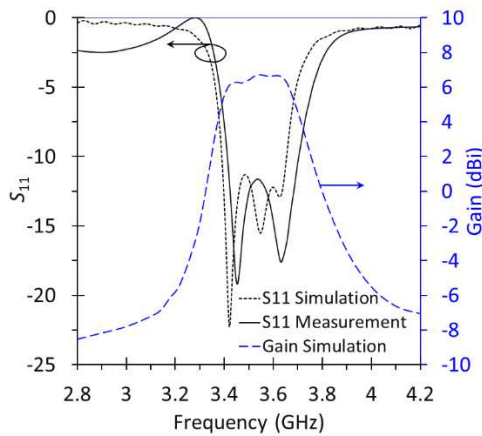


Fig. 6 Simulation and measurement results of filtering antenna

measurement result is shown in Fig. 6 where the -10 dB bandwidth impedance is laid between $3.41 - 3.7$ GHz (286 MHz) or 8.1%, which is 0.55% wider than the simulation results. The center frequency measurement is 3.56 GHz or shifted slightly to the higher frequency. The S_{11} measurement result show two minimal response at 3.45 GHz and 3.63 GHz similar as a second-order filtering antenna with value of -19.17 dB and -17.61 dB respectively. The discrepancy between the S_{11} simulation and measurement result is due to fabrication accuracy because the difference of 0.1 mm dimension of patch or gap determines the oscillation occurred. The normalized radiation pattern simulation at 3.6 GHz is shown in Fig. 7, where there is more than 20 dB cross polarization discriminant at $\phi = 0^\circ$ and $\phi = 90^\circ$. The radiation pattern shows a unidirectional in a broadside direction for both planes.

IV. CONCLUSION

A filtering antenna with a quarter wavelength L - resonator has been design and measured. The inserted coupled transmission line between the resonator and radiator affected the S_{11} oscillation. Using one resonator the antenna performed three minimal S_{11} as in the third order filtering antenna. The gaps between the transmission line and radiator, as well as between the resonator and radiator, play a crucial role in determining the S_{11} and the selectivity of filtering antenna.

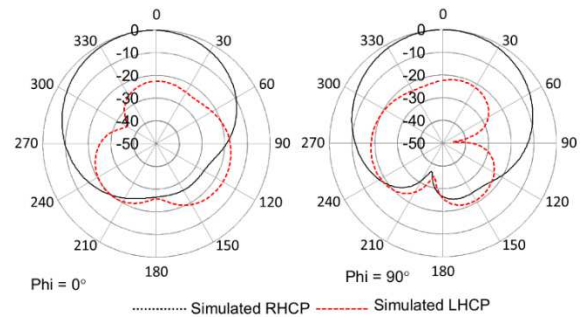


Fig. 7 Normalized radiation pattern of the proposed design

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