A Small Quadrifilar Helical Antenna with Parallel Resonance Circuit for Dual-Band Application

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Abstract **–Methods such as branching of the antenna element and meandering into a spiral are typically proposed for achieving dual-band quadrifilar helical antennas (QHAs). However, these methods suffer from drawbacks such as radiation pattern degradation of the antennas and a large number of design parameters. This paper proposes a dual-band QHA whose simple structure is realized by applying a parallel resonance circuit to the QHA. This antenna achieves dual-band resonance and is smaller than its conventional counterpart.**

Index Terms **— Helical Antenna, Dual band, Parallel resonance circuit, Miniaturization**

1. Introduction

In recent years, satellite telephone services and global positioning system (GPS) satellites have been widely used. In the case of a portable terminal, the direction of the antenna changes with human motion. Circular polarization antennas are therefore well-suited for communication with satellites.

Spiral antennas [1] and patch antennas [2] exhibit excellent circular-polarized characteristics. However, equipping an antenna with a terminal leads to a significant increase in the size of the terminal. On the other hand, a quadrifilar helical antenna (QHA), which has a good axial ratio in the case of a small ground, can be readily used with a terminal. Portable-terminal miniaturization has become increasingly important in recent years and hence, antenna miniaturization is also necessary. Furthermore, each antenna consists of multiple systems and multiple bands are required for multi-functionality; multi-band antennas are therefore required.

Methods, such as branching an antenna element, meandering the antenna element into a spiral shape [3], and using various pitch angles on the wires [4], have been proposed for realizing multi-band miniaturized QHAs. The method described in [3] results in miniaturization, but a large number of design parameters is required. Moreover, the simple method described in [4] yields large antennas.

As such, this paper proposes a simple structure and dual-band miniaturized QHA consisting of a parallel resonance circuit. Using the proposed method, an antenna with excellent circular polarization is realized, and fewer design parameters are required than in the case of conventional antennas. In addition, design frequencies of $0.85f_0$ and $1.15f_0$ are achieved.

2. Dual Band Using Parallel Resonance Circuit

The proposed antenna structure is shown in Fig. 1. This antenna is composed of four parallel arms printed on a thin dielectric substrate wrapped around a polycarbonate, which acts as a support material. A feeding circuit is formed by the microstrip line in front of the ground plate. The arms of the helical antenna are fed in phase quadrature, and an SMA connector is connected behind the ground plate. The diameter of the ground plate, thickness of the substrate, and line width of the pattern are Φ_{gro}=0.228λ_0, t=0.005λ_0, and 0.01λ_0, respectively (λ_0 is the free-space wavelength of the center frequency).

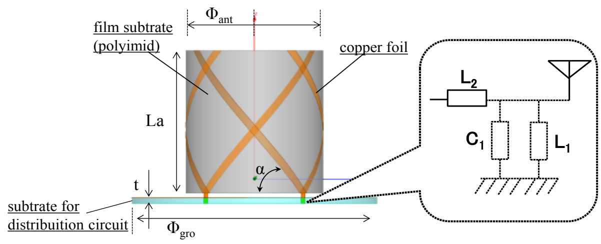
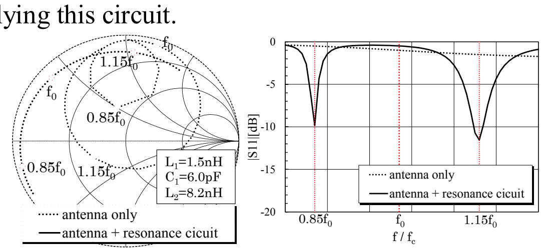
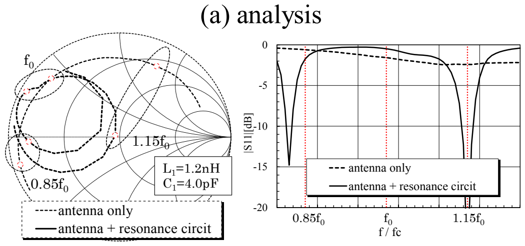


Fig. 1. Proposed antenna structure

Based on the results of a parameter study, we used respective values of 0.137λ_0, 0.128λ_0, and 50° for the helical height (La), diameter (Φ_{ant}), and pitch angle (α) (Fig. 1) of the structure. Figure 2 shows the analytically determined and measured impedance obtained from applying a parallel resonance circuit to the antenna (Fig. 1). A characteristic impedance of 100 Ω is used for impedance matching; we determined the dual-band resonance by applying this circuit.



(a) analysis



(b) measurement

Fig. 2. Impedance of the antenna

As Fig. 2 shows, excellent impedance matching, on the desired dual band, is obtained by adding a parallel resonance circuit. Errors in the resonance frequency of the measured data may arise from the slight change in size.

3. Feeding circuit

The feeding circuit is shown in Fig. 3. This circuit is four distribution and 90 degree phase difference circuit. This circuit is composed of three Wilkinson couplers and a ±90° phase shifter that imparts the phase difference to each port. Furthermore, this circuit is formed on the ground plate and hence, must be small to order to facilitate antenna miniaturization. Therefore, each component in the circuit uses lumped elements. We added an impedance transformer, for impedance matching, since the characteristic impedance of the helical antenna is 100 Ω.

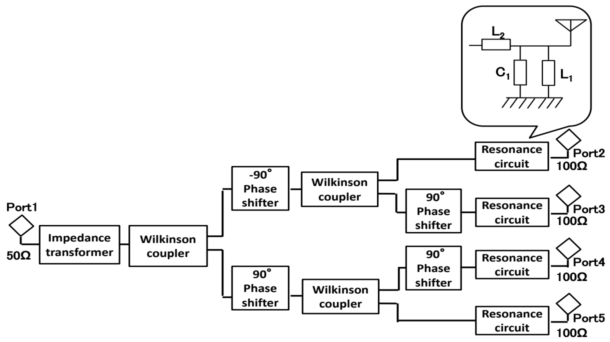
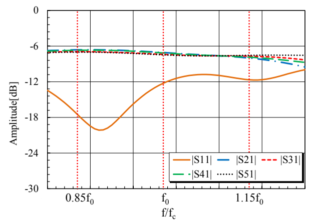
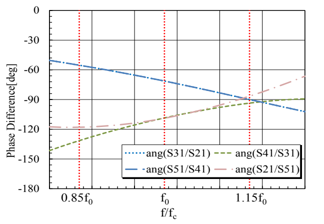


Fig. 3. Components of the feeding circuit

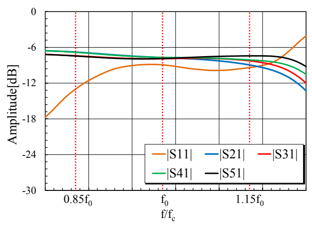
Figure 4 shows the distributed amplitude and excited phase that are fed to the proposed antenna by the circuit. A comparison of Fig. 4(a) and Fig. 4(c), reveals that the variation in the measured amplitude is greater, by ~1 dB, than that of the amplitude obtained via the analysis. Fig. 4(b) and Fig. 4(d) show the phase difference between the ports; a difference of approximately -90° is indicative of a small error. In addition, a comparison of Fig. 4(b) and Fig. 4(d) reveals that the error associated with low frequency is larger than that associated with high frequency.



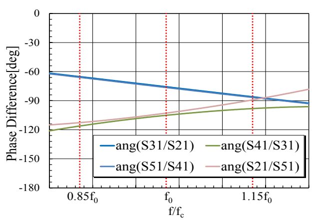
(a) amplitude (analy)



(b) phase difference (analy)



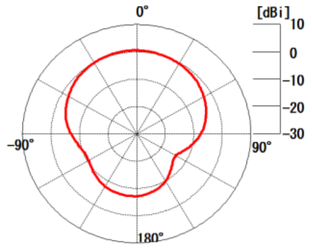
(c) amplitude (meas)



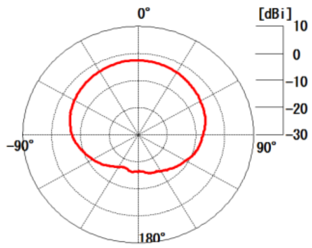
(d) phase difference (meas)

Fig. 4. Characteristics of the feeding circuit

The feeding circuit (Fig. 3) was combined with the proposed QHA (Fig. 1). The measured radiation pattern, corresponding to this combination, is shown in Fig. 5. Fig. 5(a) shows the backward radiation of the proposed antenna; this radiation results from the phase error associated with low frequency. However, this antenna exhibits circular polarization characteristics in the desired dual band. Radiation efficiencies of -3.1 dB and -6.9 dB, and peak gains of 0.6 dBi and -2.5 dBi are achieved at frequencies of $0.85f_0$ and $1.15f_0$ (Fig. 5), respectively.



(a) $0.85f_0$



(b) $1.15f_0$

Fig. 5. Radiation pattern (measurement)

More importantly, TABLE I reveals that the height and diameter of the proposed antenna are both lower than those of the conventional antenna.

TABLE I
Size Ratio

	Conventional antenna	Proposed antenna	Size ratio
Diameter	$0.164\lambda_0$	$0.128\lambda_0$	0.78
Height	$0.329\lambda_0$	$0.137\lambda_0$	0.42

4. Conclusion

We proposed a dual-band miniaturized quadrifilar helical antenna consisting of a parallel resonance circuit. This antenna is smaller than its conventional counterpart and operates on a dual band.

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