# MICROSTRIP RING RESONATOR USING SLOW WAVE STRUCTURE EXHIBITING HARMONIC SUPPRESSION

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**ABSTRACT**

This paper presents a microstrip ring resonator design which exhibits suppressed harmonic excitation and high quality factor. The resonator is constructed from four quarter-wave coupled-line couplers, connected in a square configuration. Of interest is the change in the frequency response of the ring when corrugated couplers are used in place of ordinary couplers. By direct comparison it is shown that the use of corrugated couplers in the construction of the ring results in an increase in quality factor from 34 to 47, and 30 dB rejection of the first harmonic, at the expense of a 1.5 dB increase in insertion loss and a reduction in harmonic frequency from 2.858 GHz to 2.701 GHz.

## INTRODUCTION

Ring resonators have found use in microstrip applications such as oscillators [1], filters [2], and characterization of microwave substrates [3]. The resonant frequencies of the ring are those frequencies for which the circumference of the ring represents an integral number of wavelengths. In some applications, resonance at the harmonics of the fundamental frequency is not acceptable. Recent work has investigated methods for suppressing the harmonic excitation in these rings [4] and in microstrip filters suffering from similar considerations [5].

This paper presents a modification to the symmetric square ring resonator described in [6]. The ring in [6] is composed of four quarter-wave couplers, one for each side of the ring. It exhibits resonance at the harmonic frequencies as described above. In this paper, the effect of replacing the ordinary couplers with corrugated couplers is investigated. The corrugated couplers have a pole in their frequency response at the first harmonic frequency. This is exploited to create a ring which suppresses the passband at this frequency. In addition, the increased isolation achievable with the corrugated coupler is exploited to construct a ring with increased quality factor.

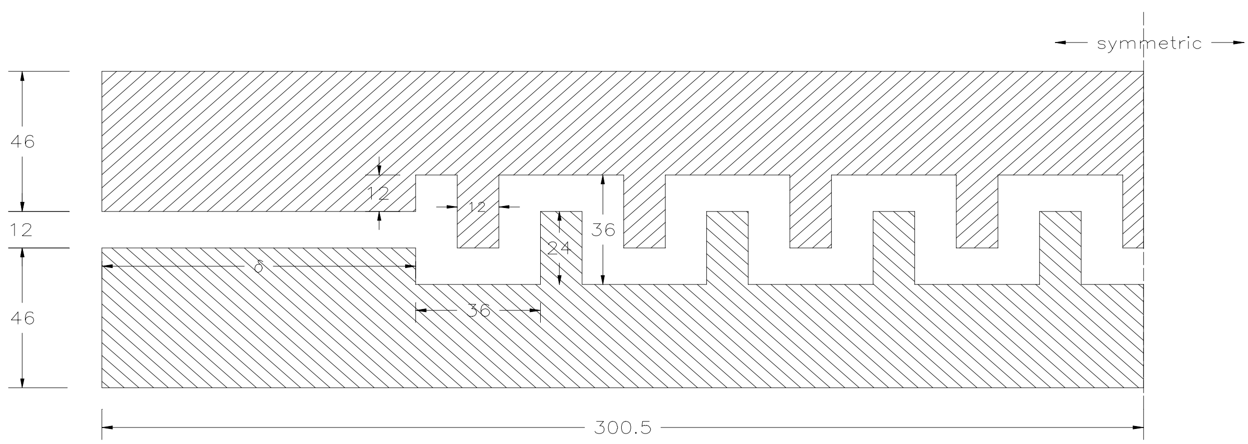


Fig. 1. Layout schematic of corrugated coupler showing dimensions (in mils) of corrugations. Note that only one half of the coupler is given; the opposite half is a mirror image which can be obtained by flipping the figure about its axis of symmetry as shown.

## DESIGN METHODOLOGY

The design process was broken into two major stages. First, a quarter-wave coupler was designed and optimized in terms of its isolation at a frequency of 3.0 GHz. Then, four of these couplers were connected to form a ring. Each of these steps is outlined in detail below. All circuits were designed for fabrication on a Rogers 4003 substrate, with a relative dielectric constant of 3.4 and a thickness of 20 mils.

### *A. Corrugated Coupler Design and Optimization*

The overall coupler dimensions are equal to those of a traditionally-designed quarter-wave coupler [7]. The length of the lines is $\lambda/4$ at a frequency of 3.0 GHz, or 601 mils. The width of each line is 46 mils, yielding a $50\Omega$ line impedance for the chosen substrate. The separation between the lines is 12 mils.

The coupler is corrugated along its coupled edges using an alternating square pattern, as shown in Fig. 1. The corrugations are periodic and symmetric about the midpoint of the lines. The separation distance of 12 mils between coupled edges is maintained at all times along the corrugation.

The distance $\delta$ was determined empirically through simulation, using the Agilent Momentum circuit simulator. Couplers with various lengths of $\delta$ and hence varying numbers of corrugations were simulated and compared in terms of their isolation at 3.0 GHz. According to this criteria and symmetry considerations the optimum value for $\delta$ was found to be 90.5 mils, which gives a total of 17 corrugations along the length of the coupler.

### *B. Ring Resonator Design*

A square ring resonator constructed from four corrugated quarter-wave couplers is shown in Fig. 2. Two of the couplers are used to couple energy into and out of the ring. The remaining two couplers maintain the symmetry of the device and eliminate the split-resonant behaviour of the ring [6]. The inner circumference of the ring is 4 x 601 mils = 2.404 in, corresponding to a resonant frequency of 3.0 GHz for the chosen substrate. The mitered bends used to connect the couplers together act to increase the circumference of the ring and reduce the resonant frequency.

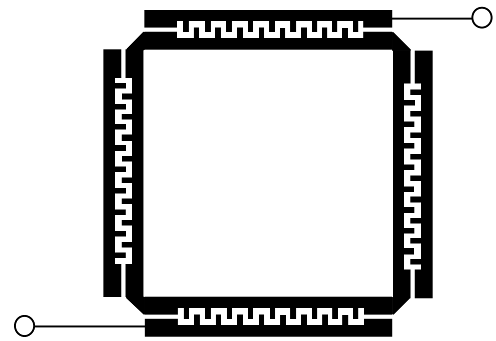

Fig. 2. Schematic of ring resonator constructed from corrugated quarter-wave couplers.

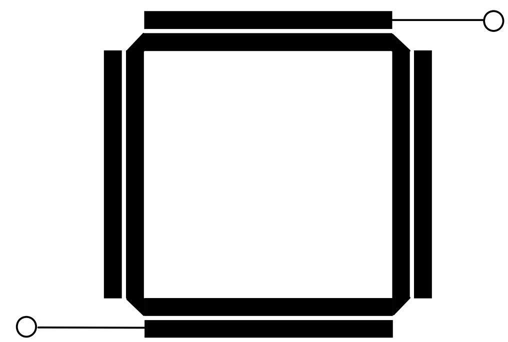

Fig. 3. Schematic of square ring resonator constructed from ordinary quarter-wave couplers.

## MEASUREMENTS

A square ring resonator constructed from ordinary quarter-wave couplers is shown in Fig. 3. Other than the absence of corrugations it is identical to the coupler described in Fig. 2. Each of the couplers comprising the ring has length 601 mils, separation 12 mils, and line width 46 mils. The inner circumference of the ring is 2.404 inches, corresponding to a fundamental resonant frequency of 3.0 GHz for the chosen substrate neglecting the effect of the mitered bends.

This ring was used as a reference for comparison with the ring implemented with corrugated couplers. The frequency response of this circuit is given by Fig. 4. An Agilent 8510C network analyzer with TRL calibration was used to realize all measurements.

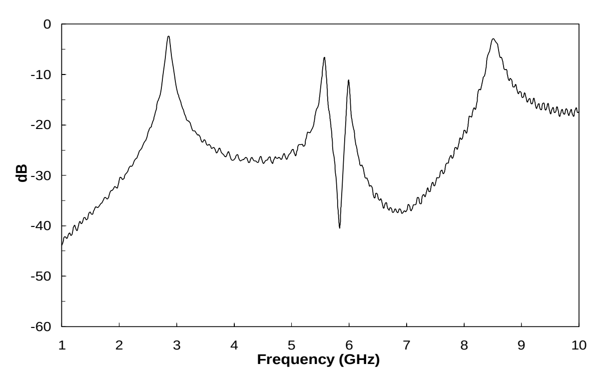


Fig. 4. Frequency response of square ring resonator constructed from ordinary couplers.

The fundamental resonant frequency of the device is 2.858 GHz, with an insertion loss of 2.24 dB (Fig. 4.). As expected, the resonant frequency has been shifted down from 3.0 GHz due to the effect of the mitered bends. The 3 dB bandwidth at this frequency is 83 MHz, which yields a Q-factor of 34.4, using the following expression for Q:

$$Q = \frac{f_0}{\Delta f} \quad (1)$$

where $f_0$ is the fundamental frequency and $\Delta f$ is the 3dB bandwidth. The plot also displays a significant response centered at 5.7 GHz, the first harmonic frequency. This response reaches a maximum of -4 dB with respect to the fundamental peak.

The frequency response of the ring resonator implemented with corrugated couplers is given in Fig. 5. The fundamental resonant frequency of this circuit is 2.701 GHz, with an insertion loss of 3.72 dB. The 3 dB bandwidth is 58 MHz, which yields a Q-factor of 46.6 via (1). Thus, an increase in Q of 12.2 is realized when the corrugated couplers are employed in the construction of the ring, most likely as a result of the increased isolation exhibited by those devices.

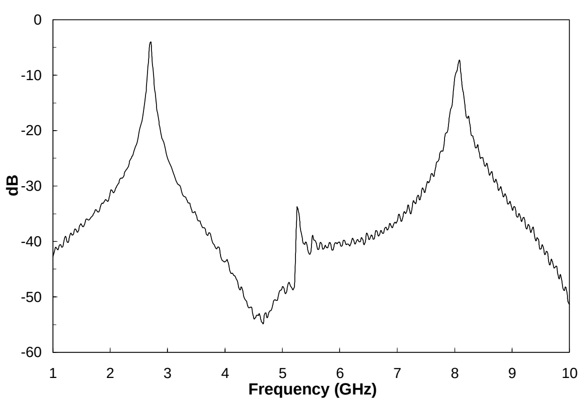


Fig. 5. Frequency response of square ring resonator constructed from corrugated couplers.

Of significant interest in this plot is the diminished response at the first harmonic frequency, 5.4 GHz. In contrast to the ordinary ring, the response of this ring at the first harmonic reaches a maximum of -30 dB with respect to the fundamental peak. This represents a 26 dB increase in rejection of the harmonic frequency.

## CONCLUSIONS

A microstrip ring resonator implemented with corrugated couplers connected in a square configuration has been investigated. The methodology for designing the ring and its constituent couplers is given. The properties of the corrugated coupler are shown experimentally to result in a ring resonator implementation which exhibits increased quality factor and suppression of the first harmonic.

## REFERENCES


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