# MICROWAVE OSCILLATORS AND FILTERS BASED ON MICROSTRIP RING RESONATORS

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## Abstract

Tunable microstrip ring resonator oscillators and filters are described. Two alternative techniques for suppression of unwanted higher order modes are reviewed. The practical oscillator has a tuning bandwidth of nearly 30%, and phase noise better than -90dBc, 10kHz from carrier. This is encouraging performance for a compact planar device.

## Introduction

Microstrip ring resonators find applications in microwave filters and oscillators, as well as in their original role as tools for dielectric material characterization. They are particularly useful when a compact planar structure is more important than the very highest possible Q factor.

A simple closed transmission line analysis of the resonator predicts a series of resonances at frequencies for which the mean circumference is a whole number of wavelengths. Introducing a gap at $90^0$ to the feed causes odd modes to be replaced by n+1/2 modes, which can be tuned down in frequency by introducing a variable capacitance across the gap. The even modes are unaffected by this.

This paper reviews recent work [1-4] on methods of suppressing the unwanted modes, and the design of two components, a single resonator filter and an oscillator, using the ring resonator and mode suppression techniques.

## Mode Suppression

The higher order, fixed frequency even modes can be avoided by selective excitation or selective damping. One method of selective excitation is to split the input and/or output feed lines, such that the feed points correspond to nodes in the voltage standing wave pattern [1]. This method relies heavily on exact symmetry in the split feed, and it is difficult to achieve the theoretically predicted suppression in practice. A more successful method is to introduce resistive damping at a point on the ring corresponding to a node in the wanted mode patterns, and an antinode in the unwanted mode patterns [2]. This method is far more tolerant of manufacturing variations, and was adopted in the filter and oscillator designs described below.

## Filter design

The experimental design for a single ring resonator filter [3] is illustrated in Fig. 1. It consists of a single ring with input and output ports formed by open ended microstrip lines at diametrically opposed positions, radial to the ring, on the inside of the ring. A series tuning varactor is mounted across a gap in the ring at $90^0$ to the feeds. The input and output ports have low cost MMIC buffer amplifiers. The n=2 mode is suppressed by means of shunt resistors mounted opposite the tuning diode, on either side of the d.c. blocking capacitor. This position corresponds to a voltage null for the tunable n = 3/2 mode, but a voltage maximum for the nearby, unwanted n=2 fixed frequency mode.

Input and output connections are made from the underside of the board via orthogonal SMA connectors, with the centre conductor fed through a hole in the microstrip substrate.



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The measured response of the resonator, tuned to 1.81GHz, is shown in Fig.2. The resonator has a Q factor of approximately 100, and the net transmission gain is 6.7dB. The n=2 mode is heavily suppressed, and the next significant mode is the n=7/2 mode, tuned to 4.4 GHz.

## Oscillator Design

A similar circuit arrangement was used to form a tunable oscillator, as shown in Fig.3. Here, the buffer amplifiers are joined together via a phase trimming network, which is adjusted empirically to achieve the desired tuning range.

Fig. 4 shows the tuning range using two different varactor diodes. The first varactor diode used was a M/A COM ML4573-186, with a capacitance range of 3.96 pF to 0.44 pF, for a reverse voltage range of 0 to 25 V. The second diode was a Siemens BB811, chosen to give improved linearity over a narrower tuning range. It had a specified minimum tuning range of 1.2 pF to 7.8 pF, over the reverse bias voltage range 1 V to 28 V. The improvement in linearity and the reduction in tuning range are clearly shown in Fig. 4.

Fig. 5 shows the variation of output power with frequency, for both versions of the circuit.

The phase noise of the oscillator was measured for a range of different conditions. The first measurement was performed with the varactor replaced by a fixed 1 pF ceramic chip capacitor, giving an oscillation frequency of 1.83 GHz. Subsequent measurements were performed with the two varactors described above, and with various oscillation frequencies. The results, for a range of offset frequencies, are shown in Table 1.

The table includes a result for the ML4573-186 diode slightly forward biased. This extends the tuning range to nearly 30%, but brings about a degradation in the phase noise. As discussed in [4], this can be understood qualitatively in terms of the increased thermal and shot noise of the forward biassed diode.

The temperature stability of the oscillation frequency, from -20°C to +60°C was measured with a fixed 1 pF chip capacitor in place of the varactor, in order to eliminate bias drift effects. The results are shown in Fig. 6.

## Conclusions and Recommendations

A microstrip ring resonator filter and oscillator have been reviewed. The oscillator shows a tuning range of nearly 30%. Unlike other higher Q types of resonator, these tunable ring resonators are compatible with planar MIC manufacture.

Methods of suppressing unwanted, fixed frequency modes have been discussed. Two methods, selective excitation and selective damping were reviewed. Selective damping was found to be more amenable to practical implementation.

Ultimately, for higher frequency applications, where the resonator dimensions would be reduced sufficiently, the technique has potential for MMIC integration. Clearly, in a MMIC the use of orthogonal feeds would be difficult. In the case of a filter it would be reasonable to reposition the feeds on the outside of the ring to facilitate the input and output bond wire connections. In the case of an oscillator, one possibility would be to keep the active components inside the ring, and to extract the output by means of an additional capacitive sensor outside the ring, followed if necessary by a buffer amplifier.

## References


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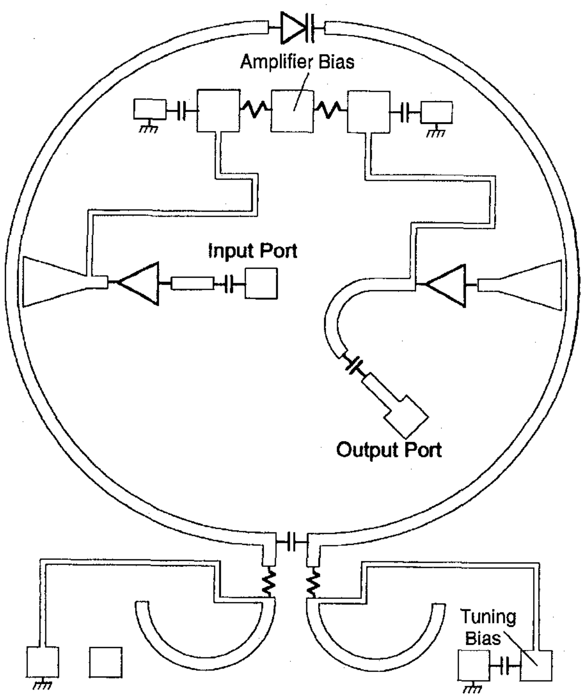


**Fig.1** Resonator layout

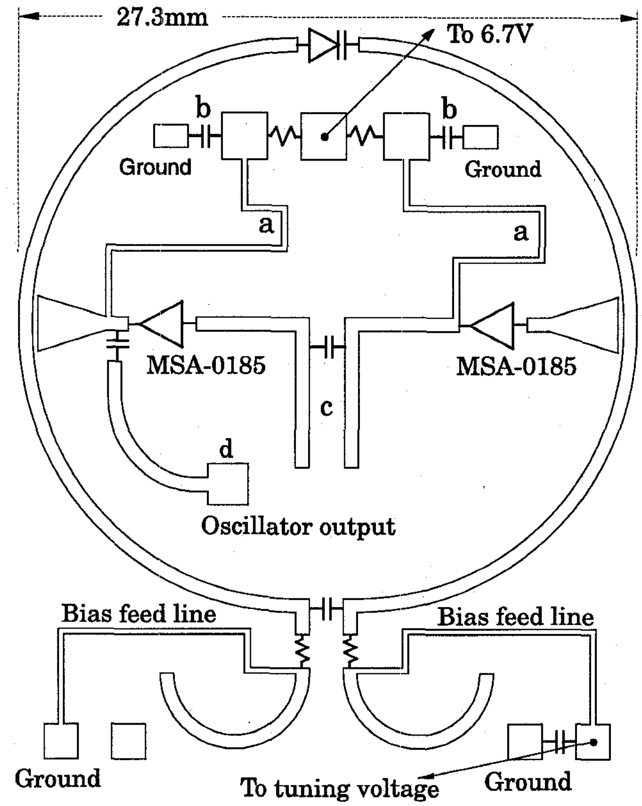


**Fig. 3** Layout of the microstrip ring resonator oscillator

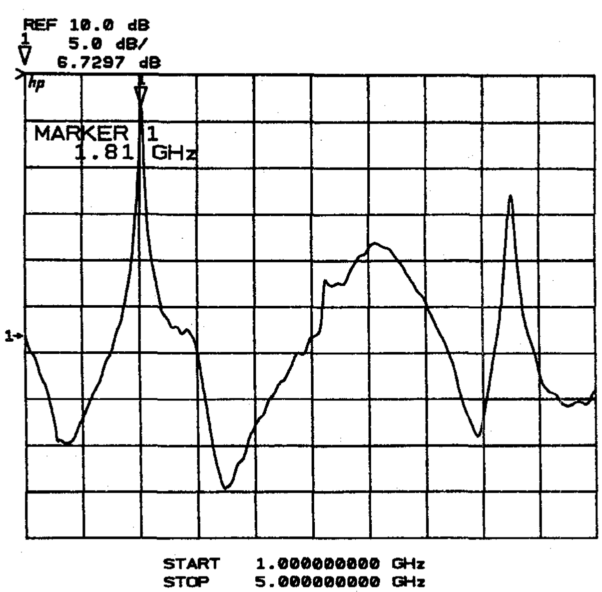


**Fig.2** Measured response of the resonator

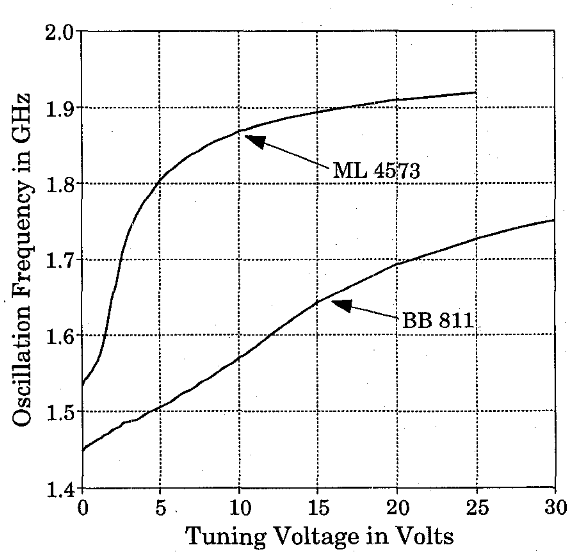


**Fig.4** Oscillation frequency vs. tuning voltage

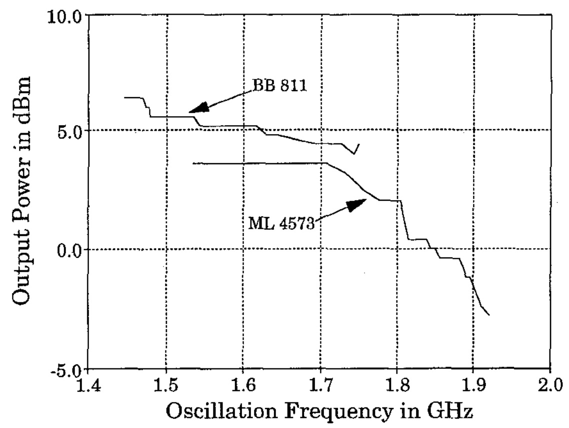


**Fig.5** Output power vs. oscillation frequency

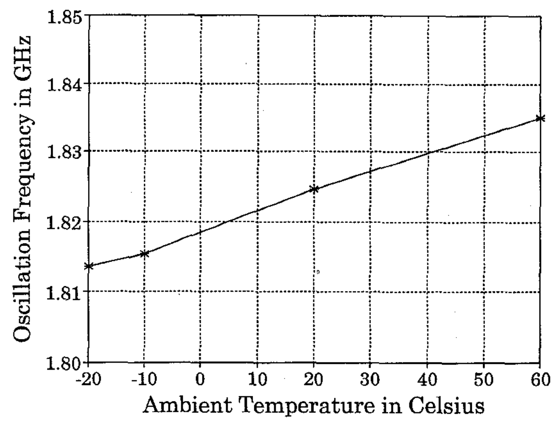


**Fig. 6** Oscillation Frequency Variation with Ambient Temperature

**Table 1 :** Phase Noise Measurements Results

| **Phase Noise in dBc/Hz for :** | **Offset Frequency** | | | | | |
|---|---|---|---|---|---|---|
| | 10 kHz | 20 kHz | 50 kHz | 100 kHz | 500 kHz | 1 MHz |
| Fixed 1pF chip Cap. : 1.83 GHz | -100 | -107 | -117 | -123 | -137 | -141 |
| ML 4573 : 1.53 GHz | -94 | -100 | -111 | -117 | -133 | -138 |
| ML 4573 : 1.8 GHz | -97 | -105 | -114 | -122 | -135 | -141 |
| ML 4573 : 1.47 GHz | -90 | -94 | -103 | -110 | -124 | -130 |
| Siemens BB 811 : 1.45 GHz | -95 | -102 | -112 | -119 | -125 | -140 |
| Siemens BB 811 : 1.66 GHz | -90 | -96 | -106 | -113 | -129 | -134 |


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