Determination of Receiver Selectivity and Transmit Frequency Using a Common Resonator

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***Abstract*—In this letter, determination of receiver selectivity and transmit frequency using a common resonator is presented for a 5.3 GHz transceiver employing a time division duplex, on–off keyed modulation format. The microstrip circuit is fabricated on Rogers RO4003®, a high frequency laminate. In receive mode, a 3 dB passband of 35 MHz and a small-signal gain of 26 dB has been achieved. In transmit mode, an output power of +7 dBm for the fundamental, −15.0 dBm for the second harmonic, −18.0 dBm for the third harmonic, and −35.0 dBm for the fourth harmonic has been achieved.**

***Index Terms*—Dielectric resonator, microstrip circuits.**

I. INTRODUCTION

DIELECTRIC resonators offer a significant performance advantage in the design of microwave oscillators and filters. Although oscillator and filter applications employing dielectric resonators are well known in the art, an efficient means using a single circuit has not been identified to provide both the narrow-band receiver selectivity and the transmitter frequency using a common resonator. If the same dielectric resonator is used to determine both the narrow-band receiver selectivity and the transmitter frequency in a microwave transceiver, then a significant reduction in material cost, manufacturing cost, and complexity can be achieved. Moreover, a single resonator will eliminate any frequency error differences between the receive and transmit modes. If the substrate material has sufficiently low dissipation, such as alumina (AL_2O_3) or low temperature cofired ceramic (LTCC), then a printed resonator, which can be laser-trimmed, may be employed. If the substrate material is more lossy, such as the Rogers RO4003® high frequency laminate material, then a resonator made of a high-permittivity dielectric material may be coupled to microstrip lines. Challenges in implementing the single-resonator solution include either adapting or compromising the resonator Q so that it is appropriate for both the filter and oscillator functions.

II. CIRCUIT PRINCIPLE

An oscillator configuration using a resonator as a parallel feedback element located between orthogonal drain and gate transmission lines connected to an amplifier device is the subject of U.S. Patent 4, 357, 582, Ishihara *et al.* For bandpass filters, microstrip lines coupled to the resonator are commonly employed and known in the art. However, an efficient means has not been identified to provide both the narrow-band receiver selectivity and the transmitter frequency using a common resonator.

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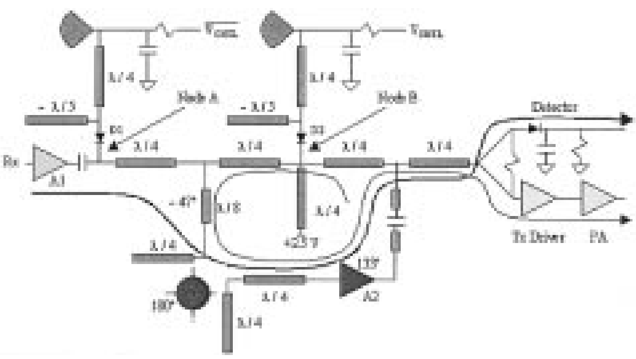

Fig. 1. Block diagram of common resonator system.

Shown in block diagram form in Fig. 1 is the common resonator system which employs a single pair of orthogonal transmission lines coupled to a dielectric resonator to determine both receiver narrow-band selectivity and transmit frequency. An initial configuration, which used two pairs of co-located orthogonal transmission lines coupled to the resonator for independent receive and transmit paths, left insufficient room around the resonator to implement electrical tuning. Even though the separate signal paths provided a convenient means to achieve different resonator loaded quality factors (Q), lab measurements indicated that a shift in center frequency could result when switching between the different loaded Qs. For the solution disclosed, the proper gain and phase conditions required for oscillation when the resonator Q defines a receiver passband of 35 MHz has been addressed.

The disclosed solution uses PIN diodes D1 and D2, with a reverse bias of +2.5 V, to change the load reactance presented to Nodes A and B in Fig. 1, respectively. The narrow-band filter mode is enabled by setting V_{CNTL} to +5 V, which defines a high impedance at Node A and a low impedance at Node B. The received signal is amplified by A1, passed through the first $\lambda/4$ segment, and blocked from entering Node B by a second $\lambda/4$ segment. The signal is then coupled to the resonator, amplified by A2, and for the particular application illustrated in Fig. 1, detected by the diode detector since it is blocked from Node B by the second $\lambda/4$ segment.

The oscillator mode is enabled by setting V_{CNTL} to 0 V which defines a low impedance at Node A and a high impedance at Node B. In this mode, amplifier A1 is isolated from the circuit and a feedback path through the resonator is created. Stable oscillation is achieved when the delay of the resonator, the amplifier, and all the transmission lines sum to an integer multiple of 360° [1] and the open-loop small signal gain exceeds unity. For the configuration shown in Fig. 1, summing the approximate 47° delay of the $\lambda/8$ segment, the 180° delay of the resonator, the 133° delay of amplifier A2, the 270° delay of the three $\lambda/4$

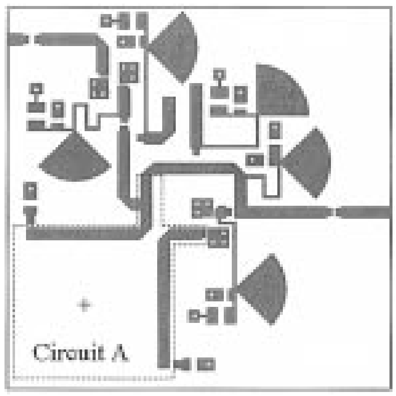

Fig. 2. Printed circuit board layout.

segments, and the delay of the miscellaneous 50 Ω segments and PIN diode phase offsets results in a total delay of 720°.

III. Analysis

A series of simulations of the common resonator circuit were completed to determine the proper gain and phase conditions required for oscillation with the resonator Q defining a receiver passband of 35 MHz. Dielectric resonators are generally coupled to transmission lines by locating the dielectric puck either a quarter-wavelength from an open or a half-wavelength from a short circuit. Radiation loss from the termination of a coupled transmission line can introduce Q degradation that can be significant for low-loss applications. For this application, the effective electrical lengths of the transmission lines have been adjusted to achieve the desired Q. A test circuit, outlined with a dotted line in Fig. 2, comprising the resonator, orthogonal-coupled transmission lines, and the $\lambda/8$ and approximate $\lambda/4$ segments in a layout identical to the final circuit was first fabricated to generate S-parameter data of the dielectric resonator thereby eliminating the need to model the dielectric resonator. Measured S-parameter data of the test circuit was then post-processed to extract the SMA connector phase length and imported into MDS as a two-port block. Using Momentum, S-parameter data of the remaining traces and copper structures were generated and incorporated into the MDS simulation as a multi-port block. The final MDS simulation comprises the post-processed resonator S-parameter data, Agilent-supplied MGA86563 GaAs MMIC amplifier S-parameter data, a device model of the PIN diodes, Momentum generated S-parameter data of the remaining layout, and AVX-supplied resistor and capacitor device models. The required 0° phase shift at resonance for stable oscillation was verified via simulation by adjusting the electrical length of the feedback path and measuring the predicted open-loop phase response using the MDS oscillator probe device. Particular attention and adjustments were made to account for the phase shift of the amplifier's input matching network and circuit interaction with the PIN diode switches. Refer to Fig. 2 for the complete layout of the system.

The disclosed solution uses two Alpha Industries SMP1320 PIN diodes available in the SC-70 package. The reverse bias voltage applied to the anode of the diode was increased from 0 V to 2.5 V due to concern over maintaining a low conductance when a RF signal is applied. According to capacitance versus reverse bias curves for microwave applications at 5 GHz, a negligible reduction in capacitance will be achieved with a reverse bias greater than 0 V [2]. Each PIN diode switch was biased with a forward current of 1.5 mA, and an open stub was used to resonate the package inductance.

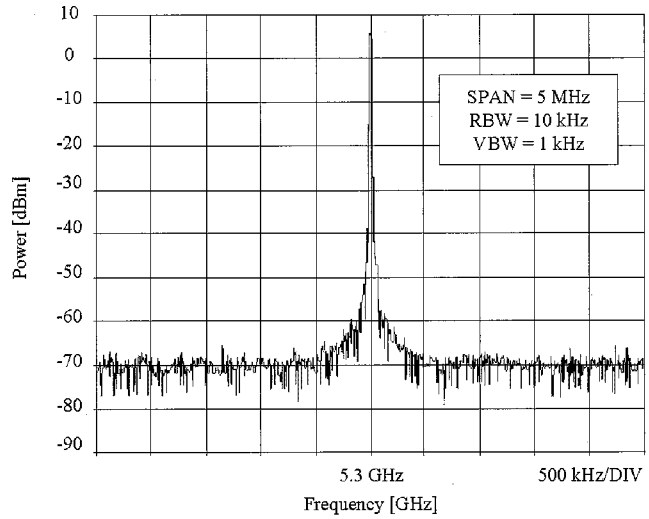

Fig. 3. Output spectrum of the oscillator at 5.3 GHz.

IV. Experimental Results

Using two Agilent Technologies MGA86563 GaAs MMIC LNAs with a small-signal gain of approximately 16 dB each, a 3 dB passband of 35 MHz and a forward gain of 29 dB was measured from the input of the first amplifier to the input to the power splitter in receive mode. Refer to Fig. 1 for a block diagram of the common resonator system. The insertion loss of the dielectric resonator and the switches is 1.5 dB and 1.5 dB, respectively. In transmit mode, the measured oscillator output power is $+7.0$ dBm for the fundamental, -15.0 dBm for the second harmonic, -18.0 dBm for the third harmonic, and -35.0 dBm for the fourth harmonic. Shown in Fig. 3 is the measured oscillator output.

V. Conclusion

An efficient means to provide both the narrow-band receiver selectivity and the transmitter frequency using a common resonator has been demonstrated. The proper gain and phase conditions required for oscillation with the resonator Q defining a receiver passband of 35 MHz has been achieved. To expedite the development of an accurate circuit model, S-parameter measurements were collected for the dielectric resonator and associated orthogonal-coupled transmission lines and incorporated into the circuit model as an S-parameter block. Using PIN diodes to switch between modes, a 3 dB passband of 35 MHz has been demonstrated in receive mode and an output power of $+7.0$ dBm has been demonstrated in transmit mode.

References

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