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A Self-Oscillating Active Filtering Antenna

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***Abstract* – A self-oscillating active filtering antenna is presented in this work. In the positive feedback path of an oscillator, a two-way filtering power divider is incorporated. One of the output port of the power divider is electromagnetically coupled to an antenna, and the other output port is used for feedback. A 2.45-GHz self-oscillating active filtering antenna with 18 mW DC power consumption has been fabricated and measured for verification. The measured phase noise at 600-kHz offset frequency is –112 dBc/Hz. 50-dB suppression of the second harmonic is also achieved.**

***Index Terms* — Active antennas, Filtering antennas, Filtering power divider, Oscillators.**

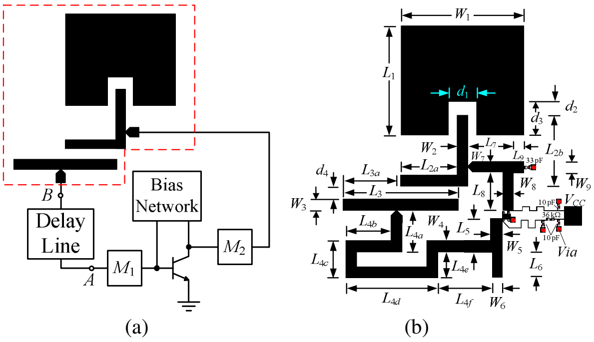
I. INTRODUCTION

Integrated design of microwave circuits attracts people's eyes recently. Filtering antennas, integration of filters and antennas, treat antennas as coupled resonators so that the coupled resonators theory for filter design could be applied. The mismatch problem at the interface between antennas and filters in a conventional design is alleviated [1]. Circuit size is also reduced [2]. An oscillator integrated with a bandpass filter in the feedback path has superior phase noise [3], [4]. Self-oscillating active antennas, integration of passive radiators and active devices for oscillation, also find their applications in radio frequency identification (RFID) systems [5]. Recently, a self-oscillating mixer with resonator-antenna filter is presented [6]. With a two-way filtering power divider in the feedback path, a self-oscillating active filtering antenna is presented in this work.

II. CIRCUIT DESIGN

Block diagram and layout of the proposed circuit are depicted in Fig. 1. It consists of a common-emitter amplifier with a bias network and input/output matching networks (M_1/M_2), a two-way filtering power divider integrated with an antenna (enclosed by the dashed line), and a delay line for feedback. One output port of the two-way filtering power divider is capacitively coupled to a microstrip antenna through a gap [1]. The other output of the power divider is connected to the input of the amplifier through a delay line. With appropriate length of the delay line, a positive feedback of the amplifier is constructed and the amplifier with positive feedback becomes an oscillator [3], [4]. A self-oscillating active filtering antenna is formed.

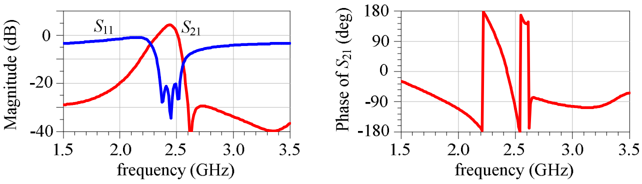
Following the procedure proposed in [1], a filtering power divider integrated with a microstrip antenna is designed. Dimension of the microstrip antenna can be determined from the design formulas in literature [7]. Equivalent circuit model of the antenna can be extracted according to the full-wave simulated results [1]. To design the two-way filtering power divider, the input and output ports of the power divider are modeled by coupled resonators. The filtering power divider is then designed with coupled resonators theory [8]. Distance between the coupled resonators and feed point at the input/output resonator can be determined by the required external quality factors and coupling coefficients which are calculated from the bandpass specifications.



(a) (b)

Fig. 1. The proposed self-oscillating active filtering antenna. (a) Block diagram. (b) Layout.

The common-emitter amplifier is realized with an NXP BFG425W transistor. With the design of matching networks M_1 and M_2 shown in Fig. 1, the amplifier is simultaneously conjugate matched to 50 Ω at the input and output terminals [9]. The output terminal of the amplifier is then connected to the input of the filtering power divider with integrated antenna. S_{21}, the forward transmission parameter from A to B without the delay line in Fig. 1, is simulated and portrayed in Fig. 2. Fig. 2 shows that positive feedback is possible since $|S_{21}|$ is larger than 0 dB at the design frequency $f_0 = 2.45$ GHz. Due to the embedded filter, good return loss is also achieved. The simulated phase of S_{21} is –31.9°. A delay line, implemented by a 50-Ω microstrip line of electrical length $\theta = 328.1°$, is then connected between A and B for positive feedback.



(a) (b)

Fig. 2. Simulated S parameters from A to B without the delay line in Fig. 1. (a) Magnitude of S_{11} and S_{21}. (b) Phase of S_{21}.

III. MEASUREMENT

A 2.45-GHz self-oscillating active filtering antenna has been fabricated on an FR-4 substrate with dielectric constant of 4.33, loss tangent of 0.022, and height of 1.6 mm. Values of the layout parameters shown in Fig. 1(b) are (unit: mm): $L_1 = 29.18$, $L_{2a} = 15.82$, $L_{2b} = 18.9$, $L_3 = 32.33$, $L_{3a} = 15.03$, $L_{4a} = 11.09$, $L_{4b} = 12.65$, $L_{4c} = 10.01$, $L_{4d} = 25.75$, $L_{4e} = 6.91$, $L_{4f} = 15.24$, $L_5 = 8.89$, $L_6 = 6.6$, $L_7 = 12.69$, $L_8 = 10.35$, $L_9 = 2.94$, $W_1 = 34.5$, $W_2 = W_3 = 3.08$, $W_4 = 3.1$, $W_5 = 3.3$, $W_6 = W_7 = 2.8$, $W_8 = 3.0$, $W_9 = 3.1$, $d_1 = 7.8$, $d_2 = 3.66$, $d_3 = 8.95$, and $d_4 = 3.38$. Diameter of each via is 1.0 mm. 0603 surface mounted resistors and capacitors are used with their values illustrated in Fig. 1(b). The circuit size is approximately 67×68 mm^2. To verify that the oscillator is active and radiates power through the antenna, another microstrip antenna operated at 2.45 GHz is designed for receiving the radiated power. Fig. 3(a) shows photograph of the initial measurement setup and the measured receiving spectrum. The self-oscillating active filtering antenna is biased with a DC power supply of voltage 3 V and current 6 mA. The receiving antenna which is placed in the broadside of the radiating antenna with identical polarization is connected to a signal analyzer Agilent CXA N9000A. The distance between two antennas is about 5.1 cm. Although radiated power near 2.42 GHz is measured, severe nearby spurious radiation is also observed. The spurious emission may be caused by radiation of the feedback delay line and could be reduced if the feedback path is covered by a metallic plate, as shown in Fig. 3(b). A paper is also inserted between the feedback microstrip line and metallic plate for insulation. Fig. 3(b) shows the measured radiation spectrum centered at 2.453 GHz with 1.5 MHz frequency span. It reveals that the purity of radiation is greatly improved. The received power is –17.6 dBm at 2.453 GHz. Fig. 4(a) shows the measured phase noise at 600-kHz offset frequency is $L(\Delta f) = -112$ dBc/Hz. 50-dB suppression of the second harmonic at 4.91 GHz is also measured, as shown in Fig. 4(b).

IV. CONCLUSION

With an embedded two-way filtering power divider integrated with an antenna in the feedback path, a 2.45-GHz self-oscillating active filtering antenna has been realized and validated. With the required bandpass specifications, a systematic approach could be utilized to design the circuit. The proposed structure with properly designed frequency could be applied in wireless communication systems with the requirement of low-cost and unmodulated RF sources.

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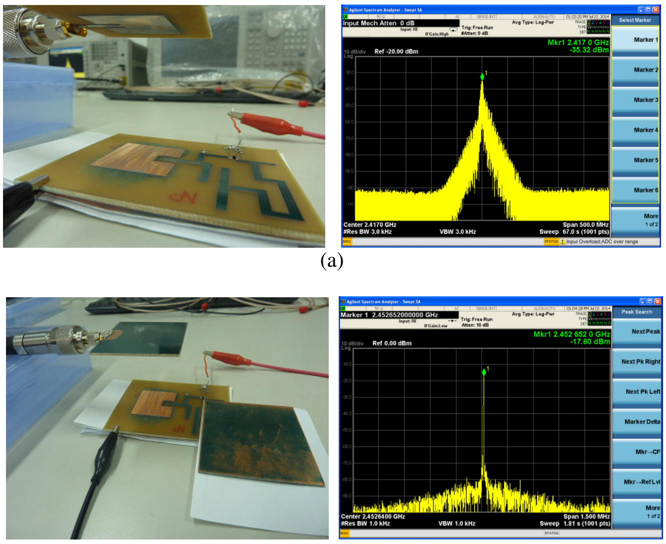
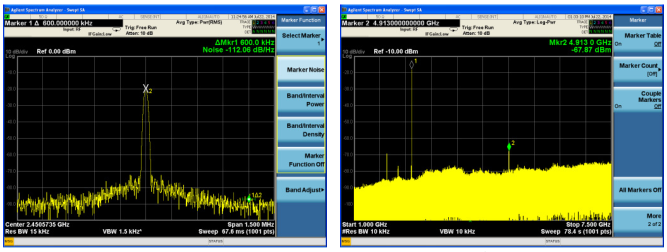


(a)

(b)

Fig. 3. Measured radiation spectrums. (a) The feedback delay line is not shielded. (b) The feedback delay line is shielded with a metallic plate.



(a)

(b)

Fig. 4. (a) Phase noise measurement at 600-kHz offset frequency. (b) Measurement of harmonic emission.

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