Mixing Behavior of a Dual-Patch Active Antenna Oscillator at 1.2 GHz

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Introduction

Active antennas have received attention in the literature for the size, weight, and cost improvements they allow [1]. Of interest for communications purposes are self-oscillating mixer active antennas. These systems use a single active device to perform both oscillation and mixing functions, and have been based on the resonant tunneling diode [2], FET [3]-[4], and Gunn diode [5] devices. These systems exhibit isotropic conversion gains of -3.7 dB [5], 2.74 dB [3], and 10 dB [2]. In this paper we report the significant mixing gain of a dual-patch active antenna oscillator based on a MMIC RF amplifier and operating at 1.2 GHz.

Antenna Configuration

The oscillator uses the Mini-Circuits ERA-2SM RF amplifier. The biasing circuit consists of a 100 Ω resistor and an RF blocking inductor and operates on a supply voltage of 7.5 V. It is constructed by connecting the input and output of the amplifier to two symmetric microstrip patch antennas between Port2 and Port 1 (cf. Fig. 1). The two microstrip patches are two gap-coupled TM resonators, and the loop around which oscillation occurs consists of the amplifier and these patches. Oscillation occurs close to the resonant frequency of the patches. A linear model of this oscillator was developed in [6]. It uses the amplifier and antenna *S*-parameters in order to predict the resonant frequency.

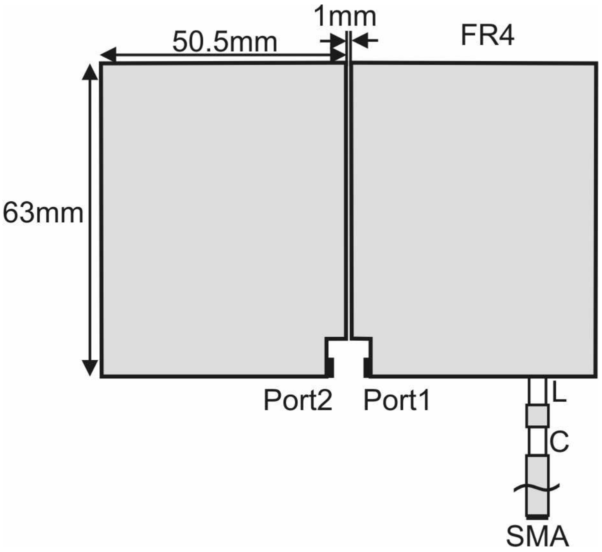

Fig. 1. Active antenna geometry; the amplifier input is connected to Port2 and the amplifier output is connected to Port1; the biasing circuit is not shown.

Inherent in the loop impedance technique for oscillator design is that stable oscillation occurs when the amplifier produces just enough gain to exactly cancel the loss around the rest of the loop. Simulations done with Ansoft Designer v. 2.0 predict passive loop loss of approximately 8-10 dB at the oscillation frequency. Therefore, the amplifier is providing 8-10 dB of gain when stable oscillation is achieved; the small-signal gain of the amplifier is 15.8 dB at the predicted oscillation frequency. The gain provided at oscillation is smaller than the small-signal gain, so the amplifier is typically operating under conditions that cause gain compression of about 7 dB. We hypothesize that the oscillating amplifier is operating in a weakly non-linear region that gives rise to higher-order effects such as mixing. This is confirmed experimentally by the insignificant power of higher-order harmonics of the fundamental oscillator frequency.

Experimental Results

The vertically-polarized antenna, shown in Fig. 1, receives RF power from an external radiating source and mixes this signal with the local oscillator provided by the antenna itself. The intermediate frequency (IF) is delivered to an SMA connector at the end of the microstrip line attached to the right-hand patch shown in Fig. 1. The inductor and capacitor block RF and DC power, respectively, from reaching the SMA connector.

To investigate the mixing effect, an experiment was conducted at 3 different supply voltages. First, the oscillating frequency of the active antenna was measured. Then, a RF signal at a slightly higher frequency was used to illuminate the active antenna and a reference antenna of 5 dB gain. The power received by the reference antenna and the power present in the IF signal generated by the antenna were measured using a Tektronix 2755AP spectrum analyzer. After correcting for the gain and impedance mismatch of the reference antenna, the active antenna isotropic conversion gain was found according to [7]

$$G_{\mathrm{iso}} = \frac{P_{\mathrm{IF}}}{P_{\mathrm{iso}}} \tag{1}$$

where P_{IF} is the total IF power and P_{iso} is power received by a fictitious isotropic antenna at the same location. The active antenna exhibited conversion gain of -5.41 to 5.54 dB, as shown in Fig. 2.

The free-running oscillator frequencies were 1.181 GHz for 6 V supply voltage, 1.180 GHz for 7.5 V, and 1.179 GHz for 9 V. Applying a lower supply voltage of 6 V apparently strengthens the mixing effect; this is indicated by the higher conversion gains when a 6 V supply was used. It should be emphasized that the mixing effect takes place outside the injection-locking bandwidth of the antenna. As a result, intermediate frequencies below 1 MHz may not be used.

Measured RF Power [dBm]			
Vsupply[V]	6	7.5	9
IF [MHz]	▨	▨	▨
25	-45.6	-47.6	-48.0
20	-46.8	-47.2	-48.0
15	-45.2	-45.6	-44.0
10	-44.8	-43.6	-44.0
5	-42.4	-40.4	-42.4

Antenna Correction [dB]			
Vsupply[V]	6	7.5	9
IF [MHz]	▨	▨	▨
25	-3.84	-3.84	-3.84
20	-3.86	-3.86	-3.86
15	-3.94	-3.94	-3.94
10	-4.07	-4.07	-4.07
5	-4.19	-4.19	-4.19

IF Power [dBm]			
Vsupply[V]	6	7.5	9
IF [MHz]	▨	▨	▨
25	-46.0	-50.0	-50.8
20	-46.0	-50.0	-50.0
15	-43.6	-49.2	-50.0
10	-44.0	-48.4	-49.6
5	-47.2	-50.0	-50.0

Isotropic Mixer Gain [dB]			
Vsupply[V]	6	7.5	9
IF [MHz]	▨	▨	▨
25	3.44	1.44	1.04
20	4.66	1.06	1.86
15	5.54	0.34	-2.06
10	4.87	-0.73	-1.53
5	-0.61	-5.41	-3.41

Fig. 2. Measured RF power at reference antenna, reference antenna power correction, IF power received, and isotropic mixer gain for three supply voltages.

Theoretical Consideration

The ERA-2SM is nearly ideal in operation; it maintains matching at its input and output ports over a large frequency range and has very low feedback gain. We assume that the output voltage of the amplifier, V_{Out} in a weakly non-linear region is given by

$$V_{\text{Out}} = AV_{\text{In}} + BV_{\text{In}}^{2} \tag{2}$$

The amplifier S_{11}, S_{12}, and S_{22} parameters have very small magnitudes and so may be assumed to be zero without adversely affecting the oscillation theory predictions. At small input voltages, the BV_{In}^{2} term may be ignored and the amplifier's output is linearly related to the input voltage by the factor A. Thus, A is equal to the linear, small-signal voltage gain of the amplifier, or the magnitude of S_{21}, i.e.

$$A = \left| \left[S_{\text{Amp}} \right]_{21} \right| \tag{3}$$

Next, using given input and output voltages at the 1-dB compression point, we can calculate the value of the coefficient B

$$B = \frac{-0.09692 \left| \left[S_{\text{Amp}} \right]_{21} \right|^{2}}{V_{\text{Out,1dB}}} \tag{4}$$

Thus, equation (2) can be used to estimate the desired mixing signal once the amplitudes of the local oscillator signal, V_{LO}, and the injected RF voltage, V_{RF}, are known. While it is perhaps reasonable to assume that the amplitude of the local oscillator signal, V_{LO}, is equal to the input voltage of the stable oscillation compression point, estimating the magnitude of the injected RF voltage is not trivial. This difficulty necessitated the development of the isotropic conversion gain of [7]. This is an open question and additional research is needed in this area.

Conclusion

For an RF amplifier-based active antenna at 1.2 GHz, the isotropic mixer conversion gain of -5.41 to 5.54 dB is reported; the conversion gain depends on the supply voltage of the amplifier and the IF chosen. The present setup uses only four discrete components and could be used as a front-end for a simple FM receiver.

References

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