

Chapter 36

Comparison Between Integrated Transmitter Typologies for Monolithic Wireless Smart Sensors

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Abstract Two different integrated transmitter topologies, each exploiting an on-chip loop antenna and implementing an on–off key (OOK) modulation, have been implemented using a standard 0.35 μm CMOS process. The implemented transmitters use two different directly modulated oscillator topologies, namely a 2.5 GHz complementary cross-coupled LC oscillator and a 1 GHz current-starved ring oscillator, whose outputs are employed respectively to feed their own loop antenna. The cross-coupled LC transmitter and the ring oscillator topology consume, respectively, 22 and 4.4 mW from 3.3 V supply voltage. The average power consumption can be decreased to few tens of microwatt by duty-cycling the transmitters and by increasing the data rate of the packet to be transmitted up to 2 Mbit/s for the cross-coupled LC typology and 1 Mbit/s for the ring oscillator transmitter. The employed integrated small loop antenna radiate sufficient power for few meters communication range.

36.1 Introduction

Smart sensors are rapidly growing in importance in the last years because of the necessity of monitoring several kinds of physical parameters in all applications where electro-mechanical systems must interact with their environment [1]. Furthermore, providing the sensors with a wireless communication channel to transmit the detected information allows to set up networks of wireless nodes, each

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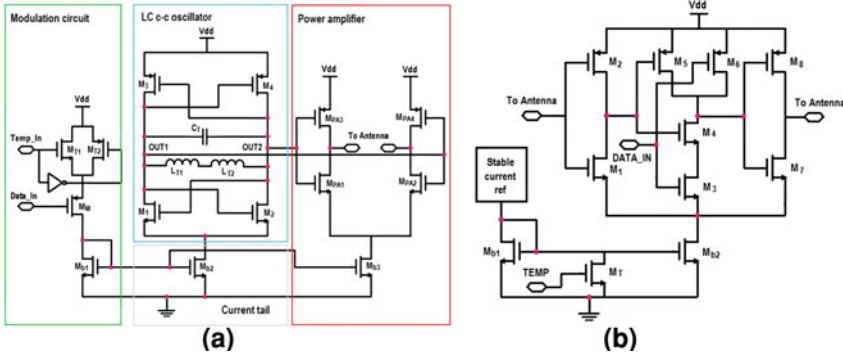


Fig. 36.1 Circuit schematic of the implemented transmitters: **a** LC c-c oscillator based transmitter; **b** ring oscillator based topology

having sensing, computational and communication capabilities. In this context, a fully embedded wireless system for short range applications can be realised exploiting an integrated loop antenna [2, 3].

In this paper the comparison between two different transmitter topologies made with a standard CMOS process, each exploiting an integrated loop antenna and implementing an on-off key (OOK) modulation, are discussed. The circuits can be seen as the RF sections of monolithic smart RFID based sensory systems.

36.2 Transmitter Architectures

A time-varying envelope modulation scheme, such as on-off keying (OOK), can be preferred with respect to a frequency modulation structure for the implementation of low-power transmitters [4]. In this case, in fact, the modulator architecture is usually simple to be implemented and allows to reduce the power consumption.

In this paper, two directly on-off keying (OOK) modulated oscillator based transmitters are proposed. The circuit schematics of the implemented architectures are shown in Fig. 36.1.

The first transmitter topology uses a complementary cross-coupled LC oscillator [5] implemented with standard transistors provided by the four-metal layer AMS CMOS 0.35 μm technology. The resonating circuit employs two 2.6 nH square spiral inductors fabricated in the top layer metallization and a polysilicon capacitor appropriately sized for getting 2.5 GHz oscillation frequency. The transistors pairs, together with the current tail source, have been sized for obtaining the needed negative transconductance for sustaining oscillations and to properly bias the coupled differential buffer, that is connected at the oscillator outputs, at the switching point. The buffer is used to feed the integrated 6.6 mm length loop antenna. A start-up circuit allows for enabling the transmitter and for implementing the OOK modulation.

Table 36.1 Parameters of the implemented integrated antenna

| Parameter | Loop 1 (@ 2.5 GHz) | Loop 2 (@ 1 GHz) |
|-------------------------------|-----------------------|---------------------|
| Area (μm^2) | 1620×1620 | 1520×1088 |
| Trace width (μm) | 20 | 20 |
| Feeding gap (μm) | 139 | 70 |
| G (dB) | -35 | -52 |

The second transmitter is based on a three-stage single-ended current-starved ring oscillator biased by mean of a current sink with high stability over supply voltage fluctuations that alleviates the oscillation frequency variations due to bias current fluctuations [6]. The integrated 5.1 mm length loop antenna is connected between the first inverter stage and the last one to create both the feedback path and the wireless communication channel. The OOK modulation is implemented by exploiting a two inputs NAND gate, one of those is provided with the modulating signal.

A single turn small loop antenna topology has been chosen to be implemented directly on chip mainly because it can surround the whole chip and, consequently, maximize its area. In particular, two separate radiating elements have been implemented. Table 36.1 contains the geometrical parameters of the radiating structures and their theoretical gain, calculated as reported in [7].

36.3 Experimental Results

The implemented transmitters have been characterized using a logarithm periodic dipole antenna connected to a R&S FSV signal and spectrum analyzer acting as receiver. The experimental measurements show a carrier frequency of the complementary cross-coupled LC oscillator based transmitter of about 2.57 GHz with a phase noise of -87 dBc/Hz at 1 MHz offset. The ring oscillator based topology has a carrier frequency of about 1 GHz with a phase noise of -71 dBc/Hz at 1 MHz offset. The carrier frequencies of the implemented transmitters are shown in Fig. 36.2.

The cross-coupled LC transmitter and the ring oscillator topology consume, respectively, 22 and 4.4 mW from 3.3 V supply voltage. The average power consumption can be decreased to few tens of microwatt by turning on the transmitters only for a packet transmission in a second and by increasing the data rate of the data to 2 Mbit/s for the cross-coupled LC topology and 1 Mbit/s for the ring oscillator transmitter.

The loop antennas radiate a power of about -58 dBm at 10 cm that allows to enable a few meters communication range.

Finally, the capabilities of the discussed circuits to transmit an OOK modulated packet of data have been tested using an 8-bit digital code. Figure 36.3 shows the received signal, demodulated using the AM demodulation mode of the R&S FSV spectrum and signal analyzer.

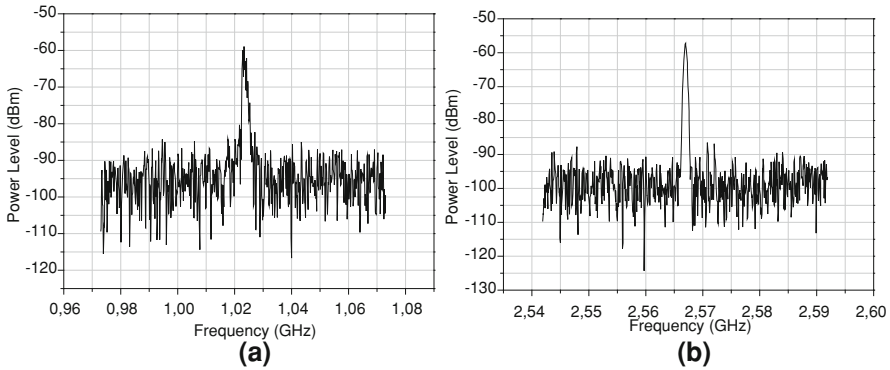


Fig. 36.2 Carrier frequencies of the implemented transmitters **a** RO based topology; **b** c-c LC oscillator based topology

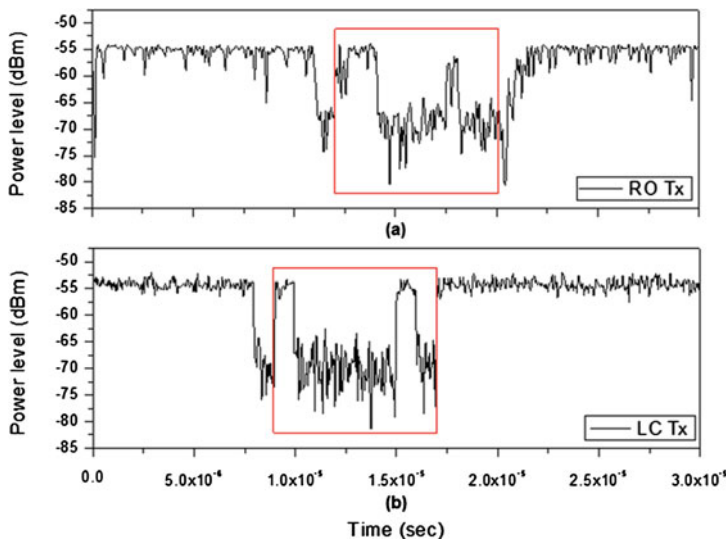


Fig. 36.3 Demodulated 625 kbit/s signal: **a** transmitted using the RO based topology (11000100); **b** transmitted using the c-c LC oscillator based topology (10000010)

36.4 Conclusions

Two fully integrated OOK transmitter topologies, made with a standard 3.3 V CMOS 0.35 μm process, have been presented. The systems are provided with an RF communication channel realized by mean of two single turn small loop antennas, implemented using the top metal layer of the CMOS technology. The radiated power is sufficient for a few meters communication range, thus the transmitters represent an effective solution for the realization of monolithic wireless systems, such as smart sensors.

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