A Multi-standard 13.56MHz RFID reader system

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1. Introduction

As the great interest in RFID (Radio Frequency Identification) system increased, RFID system has been widely used in a lot of fields such as E-commerce, transportation, and certification and so on. [1-3]

A RFID technology is non-connection methods for information identification technology by using radio frequency. RFID system is communicated between tag and reader by using electromagnetic fields. RFID reader set to a certain electromagnetic frequency and an RFID tag composed of a microchip is connected to an antenna. The microchip is possessed information which is transmitted to the reader whenever the reader within read range sends appropriated signals to an object like an identification data. [5]

RFID systems can be classified according to their carrier frequency. Depending on their carrier frequency, system characteristics and required specifications are changed. For example, using 13.56 MHz, low frequency RFID system, has passive tag, short read range and various applications in smart label tags. [1-3]

In this paper, we consider analyzing 13.56MHz RFID system and generating required specifications of RFID system. Through these processes, we proposed a compatible 13.56MHz RFID reader system.

2. Standards analysis

The international standards for 13.56MHz RFID are ISO14443 A/B, ISO15693, and ISO18000-3. Table 1 shows some key specifications of these standards.

Table 1 Specifications of 13.56MHz RFID standards [1-3]

ISO standard	14443A	14443B	15693	18000-3
Carrier frequency	13.56 MHz ± 7 KHz			
Data coding (Reader to Tag)	ASK 100% Modified Miller	ASK 10% NRZ	PPM (1 out of 256, 1 out of 4)	
Data coding (Tag to Reader)	OOK Manchester	BPSK NRZ-L	One or two subcarrier Manchester	
Data rate	106kbps		6.62 / 6.67 kbps 26.48 / 26.69 kbps	
Subcarrier Frequency	847.5kHz		423.75 / 484.28 kHz	
Read range	~5cm		5~20cm	
Required BW	1.7MHz		1MHz	

In 13.56MHz RFID system, reader should transmit clock, power and data to the RFID tag. In order to offer a continuous power supply to the tag the length of the blanking signal intervals is just 2–3us. Hence, these standards are using that kinds of coded data; modified miller, NRZ and PPM. [5] The transmitter mixed carrier signal with coded digital data. The mixed signal is sent to the tag, the associated RFID chip responds with the requested information, such as an identification number or product date. [5] It was not until arriving mixed signal that the tag is working.

For low power consumption and higher efficiency, data transfer from the RFID tag to the reader uses load modulation with subcarrier. The subcarrier frequency is different according to standards. The modulation with the subcarrier is operated by subcarrier using different coded data. The subcarrier frequency is obtained by the binary division of the carrier frequency. For the 13.56MHz RFID systems, the subcarrier frequencies 847 kHz (13.56MHz / 16) and 424 kHz (13.56 MHz /32) are usually used. Modulated with subcarrier signal is used to switch the load resistance on and off. The advantage of using subcarrier modulation becomes clear when we consider the frequency spectrum generated. [5]

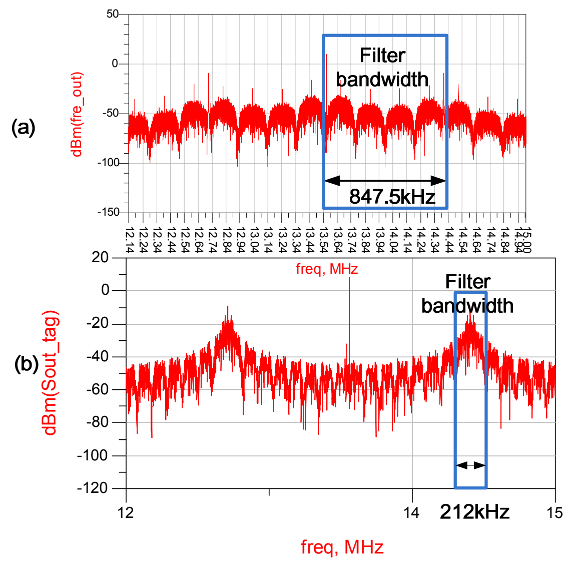

Fig. 1 Transmitter output spectrum of 14443A/B:
(a) ISO1443A spectrum, (b) ISO1443B spectrum

Fig. 1 shows the spectrum of 14443A/B standards. According to Fig. 1, (a) has larger bandwidth than (b).These two standards have only coding type difference in transmitter. It means that the bandwidth is changed from coding type. Considering these 4 standards, maximum required bandwidth is 1.7MHz in transmitter. Thus, receiver should consider 847.5 kHz band signal. Since others have smaller bandwidth than 14443A type, proposed system should not consider other standards about bandwidth.

In inductively coupled tags are always operated passively. This means that all the power needed for the operation of the microchip has to be provided by the reader. For this purpose, the reader's antenna coil generates a strong electromagnetic field, which penetrates the cross-section of the coil area and the area around the coil. Because the wavelength of the frequency range used (13.56 MHz: 22.1m) is several times greater than the distance between the reader's antenna and the tags, the electromagnetic field may be treated as a simple magnetic alternating field with regard to the distance between transponder and antenna. [5]

Considering bandwidth, power consumption, signal loss and carrier frequency, we can obtain required Q factor of receiver circuit. Thus, receiver should be designed for having about eight degree of Q factor. In order to forecast output power and current, we should calculate matching circuit parameters in made simple model in Fig. 2.

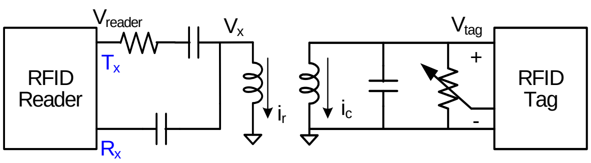

Fig. 2 RFID simple models

According to the Fig. 2, we can calculate induced voltage, required magnetic field strength and required current in equation (1),(2).

$$V_{induced} = 2\pi NSB_0Q_{tag}$$
$$B_0 = \frac{1.8V}{2\pi \times 13.56MHz \times 0.0046 \times 40} = 0.038\,\mu wb/m^2 \quad (1)$$
$$I_{rms} = \frac{2B_0(a^2+r^2)^{3/2}}{\mu a^2 N} = 30mA@10cm \quad (2)$$

Considering the 13.56MHz RFID system, the calculated value is shown in Table 2.

Table 2 Required current and voltage
(Assumption: ohmic-resistance is 5ohm)

ISO standard	14443A/B		15693 18000-3
Read range	~2cm	~10cm	~20cm
I_{rms}	1mA	30mA	220mA
V_p	0.57V	1.7V	3.1V

In order to provide sufficient power to tags, we should offer more than 30mA required current. If the required current is small, tags would not awake.

3. System design

According to generated specifications of 13.56MHz RFID system, transmitter should support 10%, 100% ASK modulator and antenna driver Moreover, rising and falling time of ASK waveform is satisfied presented waveform which is stated in these standards. [1-3]

All of commercial 13.56MHz RFID tags are not complying with these standards. For example, 10% ASK modulator cannot always awake commercial tags. Some of tags are corresponded with 30~50% ASK modulator according to experiment. Thus, the compatible transmitter system should support additional types of ASK modulation. In order to provide multi standard efficiency, mode selection is controlled digitally. And for transmitting higher output power, differential architecture is preferred.

There are a lot of kinds of receiver architecture. Many of these, only three architectures are fit for this RFID system: mixer based method, envelop detector and sigma-delta modulator. Mixer based architecture has the best in sensitivity. However, it needs high-order filter in order to reject harmonics. Sigma-delta modulator has high efficiency and high noise immunity. However, it needs high over sampling ratio such as about 1GHz.

Considering efficiency, envelop detector is the best architecture. Using the envelop detector, signal distortion can be decreased. However, it is weak for small signal. [5]

As shown in Fig. 3, envelop detector based receiver architecture is composed of envelop detector, filter, and comparator.

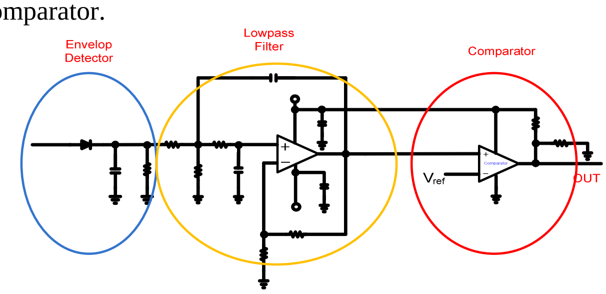

Fig. 3 RFID simple models

Considering performance of envelop detector, we should decide parallel resistance and capacitance. Ripple voltage and falling time are laid in trade off. If RC value is increasing, drop time become larger and ripple degree become smaller. Hence, we should select optimal RC value with considering of performances. Ripple voltage and falling time in envelop detector can be expressed as following (3) and (4).

$$V_{ripple} = \frac{V_p}{f_c RC} \quad (3)$$
$$t_{falling} = RC(\ln V_p - \ln V_{drop}) \quad (4)$$

According to equation (3) and (4), ripple voltage and falling time are laid in trade off. If RC value is increasing, drop time become larger and ripple degree become smaller. Hence, we should select optimal RC value with considering of performances. According to experimental results, ripple voltage is more critical than falling time. Because the output of low-pass filter is not eliminated all of high frequency noise. Therefore, the larger ripple voltage is demanded the more condition satisfied. In the point of total system, smaller ripple voltage is more efficient.

According to second section, required bandwidth is 1.7MHz, the low-pass filter in receiver is suppressing high frequency noise and carrier with 847.5 KHz cutoff frequency and more than second order.

In order to satisfy four standards of 13.56MHz RFID, reference voltage of comparator should be controlled in digital base band. Because voltage levels of tags responding signal are different in different standards. Hence, reference voltage of comparator should be changed according to supporting standard.

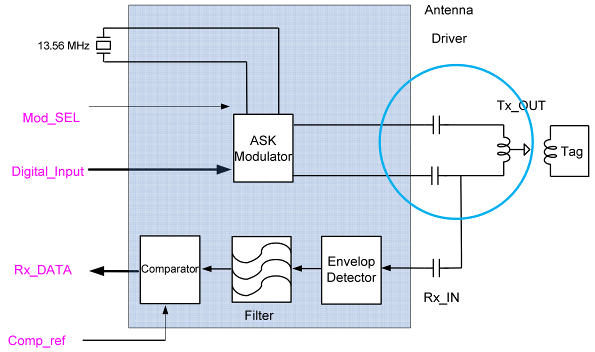

Fig. 4 Proposed RFID reader system

Fig. 4 shows proposed 13.56MHz RFID system block diagram. ASK modulator can be controlled in digital domain and supported not only 10%, 100% ASK but also 30~50% ASK. Antenna driver circuit should be considered calculated Q factor. In receiver part, maximum received signal bandwidth is 1.7MHz. Thus, LPF (low pass filter) has 847.5 kHz cutoff frequency. Lastly, comparator is also controlled in digital baseband for compatible.

4. Experimental results

By using obtained specifications, we implement a board of the system in order to verify proposed RFID system by connecting with FPGA board. By using this, we could awake commercial 13.56MHz RFID tags.

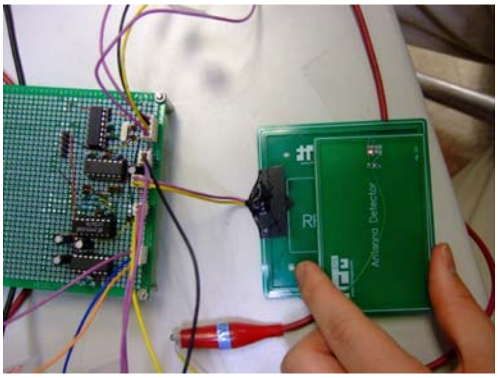

Fig. 5 RFID test board

Fig. 5 is showing the process of RFID board test. According to this process, we can measure the minimum voltage level of awaking tags.

Fig. 6 shows simulated transmitter output voltage waveforms through the antenna for 100% and 10%ASK mode corresponded to digital input.

In Fig. 7, the chip was designed and fabricated by using a TSMC 0.18um one poly-six metals CMOS process. Fig. 5 shows the layout of the fabricated single chip, 13.56 MHz RFID reader.

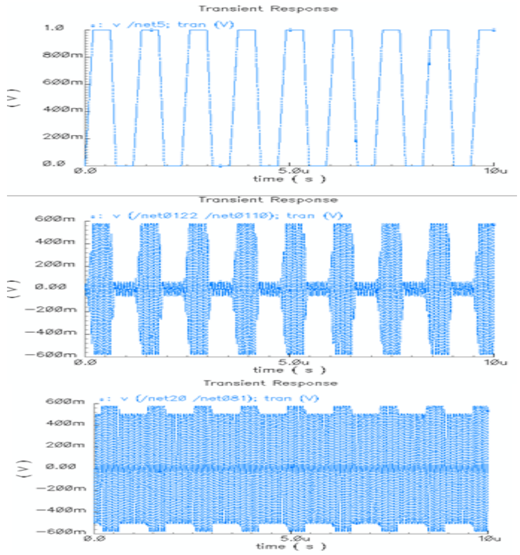

Fig. 6 Waveform of transmitted signal

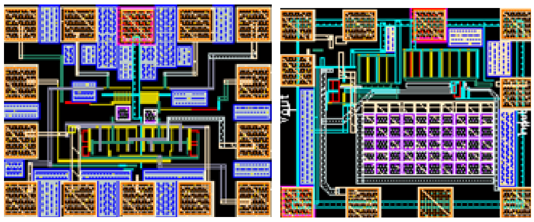

Fig. 7 Layout of 13.56MHz RFID reader

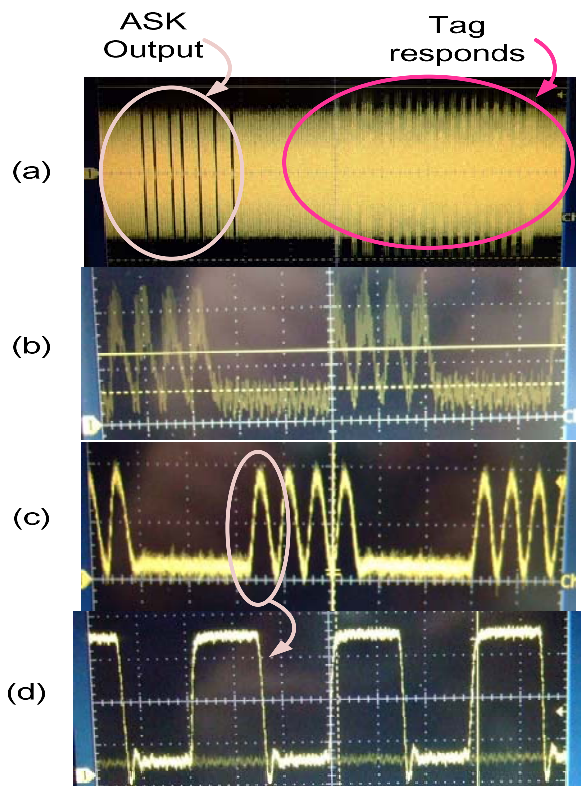

Fig. 8 Measure waveform

Fig. 8 shows reader output waveform and responding waveform of the tag.

(a) Showing followed tag responding signal from reader command.
(b) Showing the output waveform of envelop detector. It still has large power carrier frequency.
(c) LPF output. According to this waveform high frequency noise is suppressed.
(d) Showing comparator output. Duty cycles of these are 1.18us (1/847.5 kHz).

5. Conclusion

We considered 13.56MHz RFID system analysis and obtaining required specifications of transmitting section and receiving section of the RFID reader. Through these processes, we proposed a compatible 13.56MHz RFID reader system.

All of Commercial tags are not complying with standards of 13.56MHz RFID. Hence, general purpose reader should offer various types of ASK modulation and controllable reference voltage is needed.

Proposed total 13.56MHz RFID system should support multi standards, size effective and higher efficient. Through the results of implemented board, we can verify that proposed system has met the specifications of each standard.

References

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