REQUIREMENT OF ANALOG FRONT END ASIC FOR POWER LINE COMMUNICATION MODEM OF KOREAN INDUSTRIAL STANDARD

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ABSTRACT

Recently, in Korea, the commercialization of power line communication (PLC) is accelerated due to the testing deployment of automatic meter reading (AMR) modem using PLC. As the test site increases, the needs for analog front end (AFE) ASIC for PLC modem, which was previously implemented by printed circuit board (PCB), arise. In this paper, we present the technical requirement of an AFE ASIC for PLC modem which complies the Korean Industrial Standard (KS).

1. INTRODUCTION

Power line communication (PLC) is well-known for its versatile connectivity to every power line network from power outlets to distribution and transmission line. Even though the unique international standard or specification for PLC does not exist, the consistent struggle to make a single standard is conducted by IEEE P1901 [1]. Thus there are several specifications for PLC such as HomePlug, Universal Powerline Association (UPA), Korean Industrial Standard (KS) and etc [2, 3, 4].

The KS specifies both physical (PHY) and medium access control (MAC) layer of broadband PLC [2]. The Korean government makes step forward to contribute KS as an international standard. This active movement comes from the successful deployment of PLC. In Korea, the commercialization of PLC is mainly activated in the area of automatic meter reading (AMR). In 2007, KS-compliant PLC modems were tested at 5000 households in 4 regions in Korea under the supervision of the government-sponsored power company, KEPCO. Successful deployment of AMR using PLC drives the expansion of testing households to 50000 in 2008.

At this stage, the need for cost down of PLC modem arises. The modem for PLC is consists of analog front end (AFE), digital transceiver and coupling part. One of the way to reduce manufacturing cost of PLC modem is to implement the conventional AFE on printed circuit board (PCB) to ASIC. By this, we can achieve not only cost down but also small-sized implementation. We present the KS specification for PLC modem, the electromagnetic emission limit and the parameters for AFE ASIC such as transmitter band pass filter (BPF), transmitter line driver, receiver BPF, receiver gain controller and power dissipation. In this paper, we present the requirement of AFE ASIC for the PLC modem of KS. This paper is organized as follows. We discuss recent KS specification to design AFE ASIC in Section 2. In Section 3, we propose the system parameters of AFE ASIC suitable for KS. The electromagnetic emission limit for AFE ASIC is presented and in Section 4. We conclude the paper in the next Section.

Table 1: KS specification of PHY layer.

Item	**Value**
Bandwidth used (MHz)	$2.15 \sim 23.15$
Tone space (kHz)	97.65625
Sampling frequency MHz)	50
IFFT interval (sample)	512
Cyclic prefix(CP) interval (sample)	128
Roll Off Interval (sample)	16
Symbol interval (sample)	624
Symbol rate (kHz)	80.1282
Symbol Period with CP (μsec)	12.48
Tone modulation	DBPSK, DQPSK D8PSK

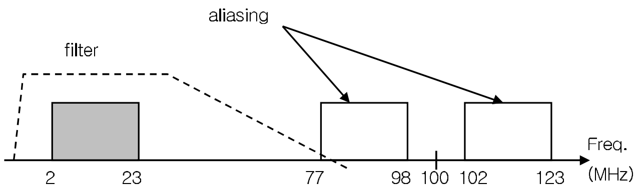

Figure 1: Spectrum of input signal at transmitter.

2. KOREAN INDUSTRIAL STANDARD FOR POWER LINE COMMUNICATION

In 2006, Korean government established KS 'X4600-1' which is the national standard for PLC [2]. This standard provides functional requirements and specification of the physical (PHY) and medium access control (MAC) layers for high speed PLC devices. It also supports the connectivity for in-home and access data network.

In this standard, the PHY layer is described separately, classified into two categories of class, A and B. The class A device refers to device suitable for in-home and access data network using the high speed PLC and class B device refers to device suitable for audio/video entertainment network using the high speed PLC. When the two devices co-exist in the same physical network, coexistence should be guaranteed. The class A device should not hinder quality of service (QoS) of class B device. Also, class B device should be able to receive and transmit signals for coexistence with class A device. In this paper, we design an AFE for the class A, which will be primarily used for internet and AMR data transmission.

Table 1 shows the specification of PHY layer (class A) for the KS. The discrete multi tone (DMT) modulation is adopted between 2.15 MHz and 23.15 MHz bandwidth. Each tone has a bandwidth of 97.65625 kHz (theoretical) with the exception of the bandwidth designated as the guard band in accordance with Radio Waves Act [5].

3. PROPOSED SYSTEM

Conventional AFE is consists of digital-to-analog converter (DAC), band pass filter (BPF) and line driver in transmitter path and analog-to-digital converter (ADC), BPF and low noise amplifier(LNA) in receiver path. DS2 company, which leads the UPA specification, produced an AFE ASIC, named DSS7800, which does not include ADC and DAC [6]. At the Homeplug, Intellon produced one chip solution which is a mixture of digital transceiver and AFE [7]. In Korea, the 'XPLC23' chip currently meets the KS and is used for the digital PLC transceiver where ADC and DAC are included [8]. Thus, in this paper, AFE ASIC will be consist of BPF, line driver and low noise amplifier.

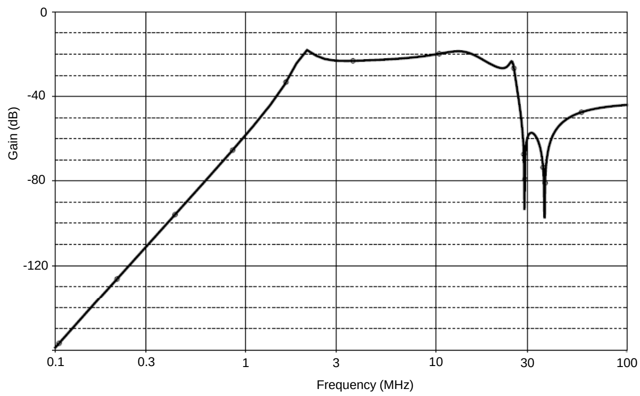

Figure 2: Simulated gain of transmitter's BPF.

3.1. Transmitter

The transmitter part consists of a BPF, amplifier and line driver. The BPF reduces the high frequency component including aliasing noise which is generated by an external DAC in the baseband transceiver. For example, the DAC in XPLC23 operates with 100 MHz sampling frequency and it causes aliasing around the sampling frequency as shown in Fig. 1. Therefore, to unburden the complexity of the filter, the pass band frequency is set at 2 MHz to 23 MHz and the stop band frequency at 77 MHz. The stop band attenuation should be more than 30 dB.

The filter requires a flat magnitude response in the passband and relatively slow transition in gain between the passband and the stopband. Therefore we can select a 3rd-order Butterworth low pass filter (LPF) with cut-off frequency of 23 MHz and 3rd-order Butterworth high pass filter (HPF) with cut-off frequency of 2 MHz. The center frequency of H_H and H_L is 2 MHz and 23 MHz, respectively. The transfer function of the HPF, $H_H(f)$, and the LPF, $H_L(f)$, are shown as follows, respectively:

$$H_H(s) = \frac{s^3}{(s+1)(s^2+s+1)} \tag{1}$$

$$H_L(s) = \frac{1}{(s+1)(s^2+s+1)}. \tag{2}$$

Fig. 2 shows the frquency spectrum of the output signal of the transmitter part.

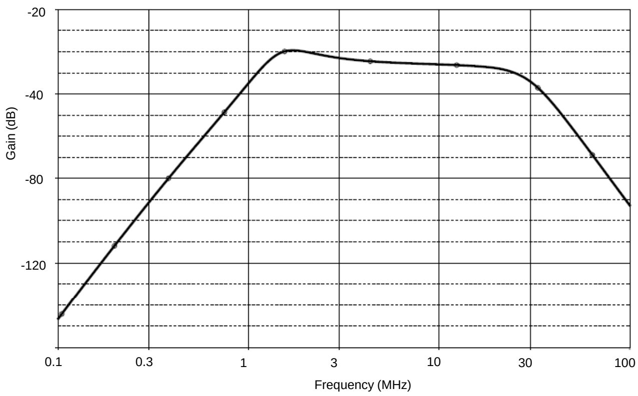

Figure 3: Simulated gain of receiver's BPF.

3.2. Receiver

The receiver part consists of a BPF and AGC amplifier. Dissimilar to the BPF of transmitter, the BPF of receiver needs a fast transition in gain between the passband and the stopband. Therefore, the combination of the elliptic low pass filter and the Butterworth high pass filter will be appropriate. We verified that more than 30 dB suppression occurs at 27 MHz which is caused by the elliptic low pass filter [9].

The practical receiver can be designed as follows. The receiver part consists of a 10th-order BPF, two stage variable gain amplifier and output amplifier. It is necessary for the BPF to eliminate noise components outside the signal bandwidth of 2 MHz∼23MHz. This means that the filter has a fast transition in gain between the passband and the stopband. Therefore, we selected the 5th-order elliptic low pass filter and the fifth-order Butterworth high pass filter,

$$H(s) = \frac{s}{s+1} \times \frac{s^2}{s^2 + 1.618s + 1} \times \frac{s^2}{s^2 + 0.618s + 1}. \quad (3)$$

Fig. 3 shows the simulated frequency spectrum of output signal of the 10th-order BPF. We can observe that more than 30 dB suppression occurs at 27 MHz which is caused by the elliptic low pass filter. The variable gain amplifier (VGA) controls the signal magnitude to make signal levels constant regardless of the signal variation in the input stage.

3.3. ASIC Technology

The technology of the AFE ASIC is not restricted but the supply voltage is directly related with power consumption. It should be emphasized that the standby power consumption is critical and nationwide issue to the PLC module for AMR since they will be deployed with numerous units. For example, DSS7800 operates with 5V supply voltage which have power consumption 1.7 Watt in transmit with its line driver active, 685 mWatt in receive mode, and 15 mWatt in standby mode [6]. The reduction of standby power can be achieved either an adoption of the high technology of ASIC or sophisticated control of AFE from the digital transceiver.

Table 2: Specification of proposed AFE ASIC.

Block	Specification

TX BPF	- Passband: 2 MHz∼23 MHz
	- Insertion loss: < -3 dB (wp)
	- Ripple: +/-1 dB (within passband)
	- Stopband
	  - Low frequency: 1 MHz
	  - High frequency: 77 MHz

TX Line Driver	- Passband: 2 MHz∼23 MHz - Output Impedance : 50 Ω

RX BPF	- Passband: 2 MHz∼23 MHz
	- Insertion loss: < 6 dB (wp)
	- Ripple: +/-1 dB (within passband)
	- Stopband
	  - Low frequency: 1 MHz
	  - High frequency: 77 MHz

RX AGC Amplifier	- Passband: 2 MHz∼23 MHz - Gain : 32 dB

Table 2 shows the specification for AFE chip. This specification comes from the circuit design of AFE with PCB type [9]. Both of BPFs have more than 40dB suppression in the stopband. Since the transmitted signal has a bandwidth from 2 MHz to 23 MHz, each filter must guarantee less distortion in that bandwidth. Both of BPF filters can be designed using Gm-C filter. By using the fusing control for Gm-C filter, when the prototype AFE ASIC is implemented we can tune the deviation of the passband filter.

4. REQUIRED EMISSION LIMIT

In Korea, government permitted the use of bandwidth from 9 kHz to 30 MHz for PLC through the Radio Waves Act [5]. For 9 kHz ∼ 450 kHz, the permissible emission is under 225/f (f is frequency in MHz). For the electric field emission of frequency range between 450 kHz and 30 MHz, electric field strength must be lower than 54dBV/m @ 3m (500μV/m @ 3m). Addi-

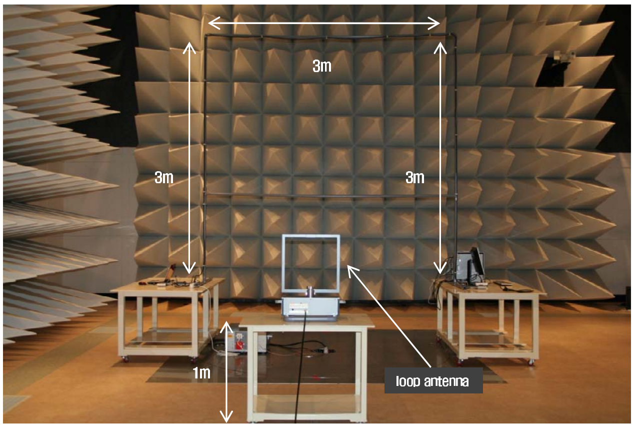

Figure 4: Experimetal setup for emission test in anechoic chamber.

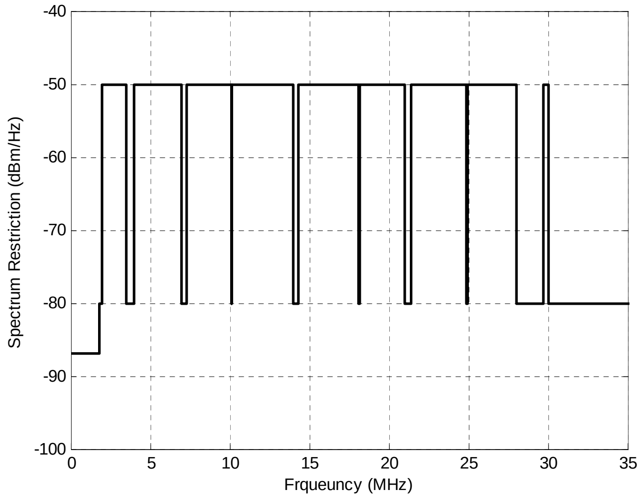

Figure 5: Transmission Spectrum Restriction of KS.

tional restrictions exist for AM broadcasting and amateur radio in the frequencies from 450 kHz to 30 MHz. PLC modems with AFE ASIC will be tested for EMC in an anechoic chamber as shown in Fig. 4. Two test modems are connected through 3m(H) x 3m(L) x 3m(H) unshielded power cable. The loop antenna is 1 m tall from the ground and at 3 m distance from the test modem. The radiated emissions are measured in dBμV/m by using quasi-peak levels through this antenna. The mode of the modems is set to normal operation.

The transmission spectrum of class A device shall not go beyond the range shown in Fig. 5. In this figure, only AM broadcasting and amateur HAM guard bands are displayed. Except -87 dBm/Hz for lower 1.8 MHz of frequency range, the spectrum is restricted to -80 dBm/Hz for the AM broadcasting and the amateur HAM guard bands. The bandwidth designated in the prohibited bandwidth proclaimed by the Minister of Information and Communication in accordance with Article 58(4) of Radio Waves Act, shall be additionally guarded [5].

5. CONCLUSION

Conventional PLC AFE for KS has been implemented with op amp and passive elements. To solve a difficulty of implementation for a small-sized and cheaper modem, ASIC implementation is essential. We proposed the design of AFE ASIC for PLC which is composed of transmitter/receiver BPF, line drive amplifier and variable gain amplifier. The power consumption, ASIC technology and other related issues are also presented.

6. REFERENCES

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