갈릴레오 수신기 설계를 위한 RF 성능 분석에 관한 연구

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RF performance Analysis for Galileo Receiver Design

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요 약

본 논문에서는 갈릴레오 수신기 구조의 요구사항을 검토한 후 시뮬레이션을 통해 RF 성능 파라미터들이 갈릴레오 수신기 성능에 어떠한 영향을 주는지 알아보았다. 먼저 갈릴레오 시스템의 일반사항과 갈릴레오 수신기의 구조 및 특성에 대해 고찰하였고, 갈릴레오 수신기의 성능 분석을 위해 에질런트사의 ADS(Advanced Design System)를 이용하여 15 % EVM에 상응하는 16 dB C/N의 갈릴레오 수신기 성능 요구 규격에 초점을 맞춰 갈릴레오 수신기를 설계하였다. AGC(Automatic Gain Control) 동작을 확인하기 위해 수신 파워에 따른 출력 IF의 변화량을 확인하였으며, 일정한 IF 출력을 통해 정상적인 AGC 동작을 확인하였다. 수신기 입력 파워에 의한 성능 분석과 수신기 국부 발진기의 위상 잡음 변경에 따른 성능 열화 분석을 통해 -127 dBm의 입력 파워에서 EVM(Error Vector Magnitude) 변화를 알아보았다. 또한 AGC의 이득 범위(-2.5 dB ~ +42.5 dB)에 의해 결정된 -92 dBm ~ -139 dBm의 입력 파워에서 ADC(Analog to Digital Converter)의 비트 변경에 따른 성능 분석을 하였으며, LO의 위상 잡음이 감소하고 ADC의 비트가 증가함에 따라 EVM이 향상됨을 알 수 있었다.

Key Words : Galileo; RF Performance; ADC; AGC; EVM.

ABSTRACT

This paper presents the effects of RF performance parameters on the Galileo receiver design via simulation after reviewing the requirements of the Galileo receiver structure. At first, we considered the general requirements, structure and characteristics of the Galileo system. Then we designed the Galileo receiver focused on performance requirement of 16 dB C/N which is equal to 15 % Error Vector Magnitude(EVM) by using Advanced Design System(ADS) simulation program. In order to verify the function of Automatic Gain Control(AGC)), we measured the IF output power level by changing the input power level at the front - end of the receiver. We analyzed the performance degradation due to phase noise variations of Local Oscillator(LO) in the Galileo receiver through EVM when the minimum sensitivity level of -127 dBm is applied at the receiver. We also analyzed the performance degradation according to variable Analog-to-Digital Converter(ADC) bits within the Dynamic range, -92 ~ -139 dBm, which has been defined by gain range (-2.5 ~ +42.5 dB) in the AGC operation. The results clearly show that the performance of the Galileo receiver can be improved by increasing ADC bits and reducing Phase Noise of LO.

I. Introduction

According to the rapid technical development, portability has been emphasized in the modern society and a demand for the location awareness has been increased. Therefore, the requirements for the Location Determination System are increasing and the Location Based Service industry rocketed to new important industry[1].

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Global Positioning Systems(GPS), represented Global Navigation Satellite System(GNSS), have been applied in various fields by an accuracy of the location and time. The U.S pushes ahead the modernization plan of the GPS to improve the civil Quality of Service(QoS). Meanwhile, the European Union(EU) has declared to build a unique Satellite Navigation System, called Galileo. The Navigation system which provides accurate location and time information has been taken into a new phase. Now that North-East Asia countries like Japan and China have built their own Satellite Navigation infrastructure, we involved in the Galileo project. This means that we can improve the information infrastructure in Korea by GNSS diversity and provide more accurate and stable location information service using Galileo in case of emergency like GPS failure. With the appearance of the Galileo, the Dual-mode with GPS and Galileo will dominate GNSS market in the near future. Therefore, the GNSS required wide-band RF/IF technology which must receive satellite navigation signal of the GPS and Galileo.

In this paper, we have designed and demonstrated the Galileo receiver with various system requirements. First of all, we review requirements of the Galileo receiver structure in Section II. Next, the system performance analysis and results are included in Section III. Finally, the optimum design of the Galileo receiver with the minimum performance requirements of RF/IF components is presented in Section IV.

Ⅱ. General aspects of the Galileo system and simulation configuration

The Galileo system is the Satellite Navigation system that the EU carried out on their own against GPS of the U.S. It provides the precise location information services which has errors within 1 m in general, 10 cm in commercial and interaction between GPS and GLObal NAvigation Satellite System(GLONASS) which is the Russian version GPS system. The interface between Galileo satellite and Galileo receiver is described in Fig. 1 [2].

Three kinds of independent usable Galileo signal such as E5, E6 and E1 have transmitted from all of the Galileo satellite and especially E5 link is divided into two RF link, E5a and E5b. The Galileo signal transmitted into 4 frequency bands, as shown in Fig. 2, and all of the Galileo frequency bands are included in Radio Navigation Satellite Services(RNSS) spectrum. Especially, E5a, E5b and L1 bands are included in Aeronautical Radio Navigation Services(ARNS) spectrum, too [3].

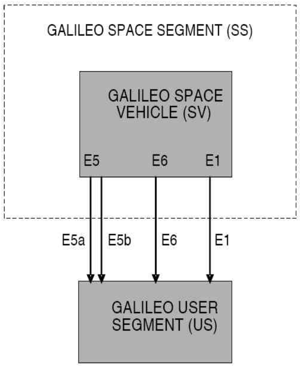

그림 1. 갈릴레오 RF 인터페이스

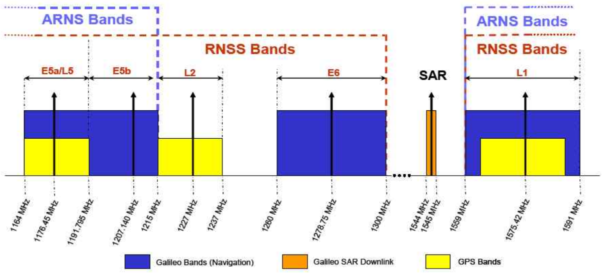

그림 2. 갈릴레오 주파수 계획

Table 1 shows the modulation methods of each Galileo signal bands, chip-rate and spectrum characteristics according to the data-rate and the general Galileo navigation signal parameters.

표 1. 일반적인 갈릴레오 항법 신호

Signal	E5				E6		E1	
Channel	E5a data	E5a pilot	E5b data	E5b pilot	E6B data	E6C pilot	E1B	E1C
Modulation	AltBOC (15,10)				BPSK (5)		BOC (1,1)	
Chip rate [Mcps]	10.23				5.115		1.023	
Symbol Rate [sps]	50	N/A	250	N/A	1000	N/A	250	N/A
User min received power [dBW]	-155				-155		-155	

As a typical Hetero-dyne type, the Galileo receiver is described in Fig. 3 and the receiver performance requirements are represented in Table 2 [4][5].

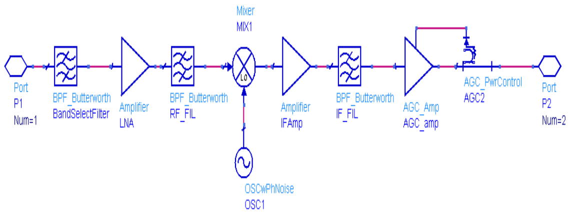

그림 3. 갈릴레오의 헤테로다인 수신기 구조

표 2. 갈릴레오 수신기의 성능 요구 규격

Data rate	125 bps (E1 band)
Noise figure	2 dB
Chip rate	1.023 Mbps
Bandwidth	2 MHz
Received power (min)	-127 dBm

Each Galileo satellites transmit the spread-spectrum signals in the same frequency band with the same size. The minimum Galileo signal received from the earth has -127 dBm signal power with 2 MHz bandwidth at 1.575 GHz. At this point, we can get noise power as follows.

Noise power = Boltzmann' s constant *Temperature*bandwidth
= 8.28 * 10-15 Watts = -141 dBW = -111 dBm (1)

By the equation (1), the Galileo receiver must detect the signal in the noise levels. By using spread-spectrum method, the Galileo receiver can detect the signal. The processing gain makes it possible as follows.

Processing gain =chip_rate/data_rate
= (1.023*106)/data_rate = 8.184*103 = 39 dB (2)

In the received signal power, the actual received signal power is presented as
Actual received signal power = received signal + processing gain

= 127 dBm + 39 dB= 88 dBm (3)

where, the processing gain is calculated from (2).
It shows that the Galileo signal can be easily detected even though it is under noise level.
The sensitivity of the Galileo receiver can be written as follows [6].

Sensitivity = noise floor (dB) + C/N (dB) + 10logBW (Hz) + Noise figure (dB) + implementation margin (4)

where
- Noise floor = Boltzmann' s constant * Temp * BW (Hz)
- C/N (required signal to noise ratio) = 20log(EVM/100%)
- BW : typically defined by the IF filter
- Noise Figure : system noise figure = 2 dB
- Implementation margin = 5 dB

Substituting (3) into (4), we can achieve
- 88 dBm = -174 dBm + C/N (dB) + 63 dB + 2 dB+ 5 dB
C/N = 16 dB = 20log (EVM/100%).
EVM ≈ 15 % (5)

Equation (5) shows that the Galileo receiver required below 15% of EVM to meet 16 dB C/N as the system performance requirement. In order to achieve this goal, we need to allocate sketched gain and loss to each of system blocks in the Galileo receiver by using RF components provided by vendors. And in view of the non-linearity characteristics of the Mixer, we choose RF amplifiers that a gain does not exceed 25 dB. Also we select the RF filters which have the Insertion loss, below 3 dB. Table 3 shows the RF component parameters used for the design of Galileo receiver.

표 3. RF 부품 파라미터

	Parameters				
Block	**Gain (dB)**	**NF (dB)**	**IP3 (dBm)**	**IL (dB)**	**Atten (dB)**
LNA	16	1.5	39		
BPF		2.5		2.5	55
AMP	17	3.5	32		
AMP	22	5	42		
BPF				2.5	55
Mixer	-6	6	17		
BPF				1	40
AMP	18	5	35		
AMP	20	5	41		
SAW		25		25	45
AMP	45	7	24		
AGC	20	1.73	40		

We designed and simulated the Galileo receiver using Advanced Design System(ADS), system simulation program by Agilent. The major blocks such as Signal generation, Transmitter, Channel, Receiver, ADC, Interference signal generation and Performance measurement are designed and it is described in Fig. 4 [7][8].

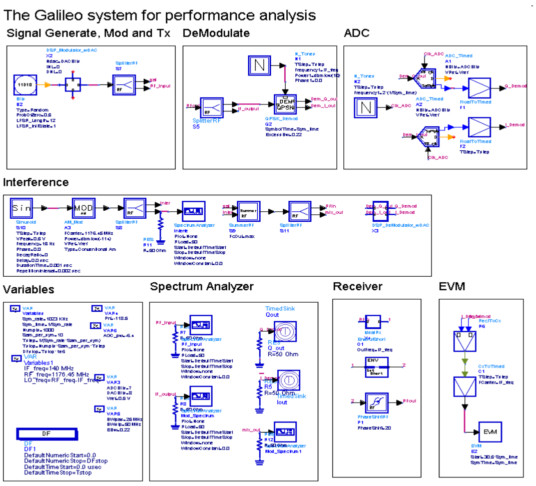

그림 4. ADS를 이용하여 설계한 갈릴레오 수신기

Ⅲ. Performance analysis of the Galileo receiver

We reviewed Automatic Gain Control(AGC), Error Vector Magnitude(EVM) variation by changing Analog to Digital Converter(ADC) bits and constellation in order to analyze the receiver performance of the Galileo system. Also, we analyzed performance degradation due to interference like DME/TACAN.

1. AGC operation

In order to make sure the performance of the AGC, we apply variable input power, from -90 ~ -140 dBm, to the Galileo receiver. Fig. 5 and Fig. 6 show the output power of the AGC and EVM variations on E1 signal ID.

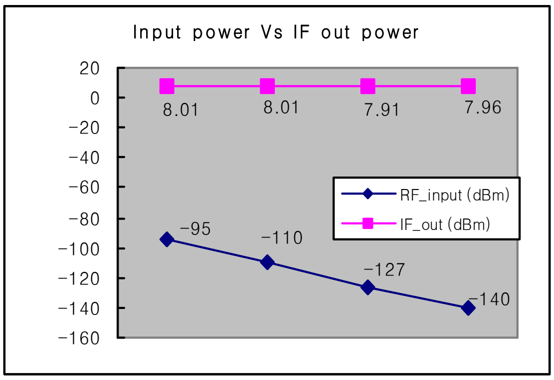

그림 5. 입력 파워에 따른 AGC의 출력 파워

In Fig. 5 we recognized that the output power of the AGC kept up its magnitude, around 8 dBm within the various input power. It means that the AGC works normally within the minimum input power. The EVM maintains 3 to 6 % in the minimum input power, -127 dBm, however it drops dramatically to 18 % when the input power of -140 dBm is applied.

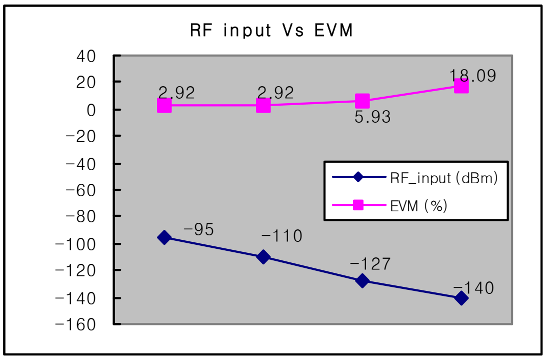

그림 6. 입력 파워의 변화에 따른 EVM

2. LO Phase Noise

In this section, we analyzed the effects caused by LO Phase Noise of the Galileo receiver on E1 signal ID. Table 4 shows the added LO Phase Noise, and the result showed in Fig. 7.

표 4. LO 위상 잡음 파라미터

Offset(KHz) / Times	LO Phase Noise (dBc)		
	1	10	100
Case 1	-80	-90	-100
Case 2	-70	-80	-90
Case 3	-60	-70	-80

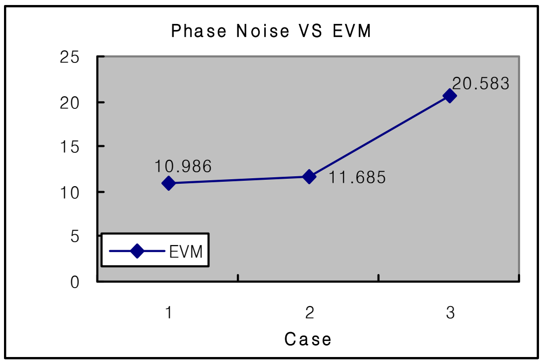

그림 7. LO 위상 잡음 변화에 따른 EVM

Ⅳ. Conclusion

In this paper, we studied the effects of RF parameters on the performance of Galileo receiver. For the performance analysis of the Galileo receiver, we designed the Galileo receiver focused on the performance requirements which is 16 dB C/N equal to 15 % EVM by using ADS simulation program. To ensure the AGC operation, we measured the IF output power by changing received power. To review the effect of LO Phase Noise on the receiver performance we look into EVM changing at the received power of -127 dBm which is the minimum sensitivity of the Galileo receiver. We also analyze the performance according to the variable ADC bits within the Dynamic range, -92 ~ -139 dBm. In order to analyze the interference impact, we added same and higher interference signal (-127 and -117 dBm) to the Galileo receiver. The EVM as performance measure is improved to below 15 % as changing ADC bits and reducing LO Phase Noise. The results clearly show that the efficiency of the Galileo receiver can be improved by changing ADC bits and LO Phase Noise and other RF components requirements.

The analyzed results would be helpful in implementing a receiver for the Galileo system.

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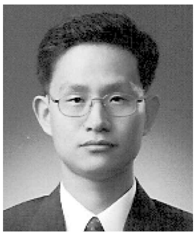

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