Journal of the Korea Academia-Industrial cooperation Society
Vol. 12, No. 6 pp. 2770-2776, 2011

DOI : 10.5762/KAIS.2011.12.6.2770

Study on Coexistence between WiBro and WLAN in DTV Bands

Yan-Ming Cheng[1,2], In-Kyoung Cho[2], Yong-Sup Shim[2] and Il-Kyoo Lee[3*]

[1]Department of Electronic Information, College of Electrical & Information Engineering, Beihua University, China

[2]Department of Information & Communication Engineering, Kongju National University, Korea

[3]Department of Electrical, Electronic & Control Engineering, Kongju National University, Korea

DTV 대역에서 WiBro와 무선랜의 상호공존성에 관한 연구

정연명[1,2], 조인경[2], 심용섭[2], 이일규[3*]

[1]중국 북화대학교 전기및정보공학대학 전자정보공학부

[2]공주대학교 정보통신공학과

[3]공주대학교 전기전자제어공학부

Abstract Mutual Interference scenarios between Wireless Broadband (WiBro) and Wireless LAN (WLAN) in DTV bands are assumed. Co-channel interference and adjacent channel interference are respectively evaluated in terms of carrier to interference ratio (C/I) by using Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) based on the Monte-Carlo simulation method. For the simulation, three frequencies such as 185 MHz, 481 MHz and 687 MHz are chosen. Analysis results indicate that interference situation of using frequency of 185 MHz is the worst case, which requires longer protection distance between WiBro MS and WLAN User Equipment (UE), lower transmit power of WiBro Mobile Station (MS) and WiBro Base Station (BS) and WLAN UE and larger guard band. Comparing to cases of using frequency of 185 MHz and 481 MHz, interference situation of using frequency of 687 MHz is slighter. Therefore, using frequency of 687 MHz is easier for coexistence between WiBro and WLAN. Analysis results can be used as reference and guideline when planning the deployment of WiBro and WLAN in DTV bands.

요 약 본 논문은 DTV 주파수 대역(185 MHz, 481 MHz, 687 MHz)에 WiBro와 무선랜 서비스가 동일 채널 및 인접 채널에 할당되는 시나리오를 가정한 후, Monte-Carlo 기반의 Spectrum Engineering Advanced Monte Carlo Analysis Tool(SEAMCAT)을 이용한 간섭 분석을 통해 최적의 주파수 대역을 제시하였다. 분석 내용으로 WiBro Mobile Station과 무선랜 User Equipment 사이의 요구되는 보호거리 및 보호 대역, WiBro Mobile Station/Base Station 및 무선랜 User Equipment 의 허용 송신 파워를 분석하였다. 분석 결과, 주파수 대역 185 MHz에 할당할 경우가 상대적으로 잠재적 간섭이 가장 큰 경우이고 697 MHz의 할당이 최적의 주파수 대역으로 분석되었다. 본 분석결과는 향후 DTV 주파수 대역에 WiBro와 무선랜의 할당에 유용하게 활용될 것으로 기대된다.

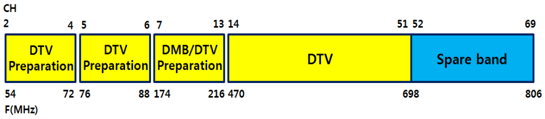
Key Words : WiBro, WLAN, DTV bands, C/I, SEAMCAT, Guard band

1. Introduction

The switch from analog to digital broadcast television is referred to as the Digital TV (DTV) Transition, which is being carried on or has been accomplished in the world. For instance, in U.S., since June 13, 2009, all

*Corresponding Author : Il-Kyoo Lee (leeik@kongju.ac.kr)
Received March 8, 2011 Revised (1st April 20, 2011, 2nd June 6, 2011) Accepted June 9, 2011

full-power television stations have broadcast over-the-air signals in digital only. In Korea, after 2012, frequency arrangement plan is illustrated in Figure 1 for DTV [1], the details are as follows: ① CH 2~6 (5 channels) will be assigned in preparation for DTV, but channeling arrangement will be reserved; ② CH 7~13 (7 channels) will be given priority to terrestrial DMB, and then, if these channels can be reused in some areas, these channels will also be in preparation for DTV; ③ CH 14 ~51(38 channels) will be used for DTV. ④ CH 52~CH 69(18 channels) are spare.



[Fig. 1] Frequency arrangement plan for DTV in Korea

An important benefit of the switch to all-digital broadcasting is that it freed up parts of the valuable broadcast spectrum for public safety communications (such as police, fire departments, and rescue squads) or unlicensed services. Also, some of the spectrum can now be auctioned to companies that will be able to provide consumers with more advanced wireless services (such as wireless broadband) [2]. As we know that TV bands locate in the VHF and UHF bands, therefore TV bands have several important properties that make them highly desirable for wireless communications as following: ① Excellent propagation, ② Ability to penetrate buildings, ③ Foliage Non-line of sight connectivity, ④ Broadband payload capacity [3]. Therefore, according to frequency arrangement plan for DTV in Korea, some wireless communication systems can be deployed in some frequency bands unused by DTV, and feasibility of coexistence between DTV and wireless systems have been considered[4-6]. However, feasibility of coexistence between wireless systems in DTV bands must be taken into account, thereby, this paper assumes that Wireless LAN (WLAN) and Wireless Broadband (WiBro) operating in DTV bands. WLAN is assumed to operate at 185 MHz, 481 MHz and 687 MHz, respectively. WiBro is assumed to operate at co channel with WLAN or adjacent channel to WLAN. Based on previous assumptions, WLAN and WiBro potentially interfere each other. Therefore, protection distance between WLAN User Equipment (UE) and WiBro Mobile Station (MS), the maximum allowable transmit power of WiBro MS, WiBro Base Station (BS) and WLAN UE and the guard band are respectively analyzed by using Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT)[7].

2. System Descriptions

2.1 WLAN

WLANs are able to provide wireless network communication over short distances using radio or infrared signals instead of traditional network cabling. WLANs are being widely used in private home, business and hotspots (such as coffee shop, conference and airport, etc.). Main parameters of WLAN are summarized in Table 1 [8].

[Table 1] Main parameters of WLAN

Parameter	Value	Units
Frequency	185/481/687	MHz
Reception Bandwidth	22	MHz
Receiver Sensitivity	-55.33	dBm
Interference Criteria(C/I)	10	dB
Noise Floor	-90.41	dB
Antenna Height	Rx 1.5/Tx 2.5	m
Antenna Azimuth	0~360	Degree
Antenna Peak Gain	6	dBi
Antenna Pattern	Omni-directional	
Output Power	23	dBm

2.2 WiBro

WiBro is a wireless broadband Internet technology developed by Korea based on IEEE 802.16e international standard . WiBro supports mobility up to walking speed and vehicle speed and wider coverage. Main parameters of WiBro are assumed in Table 2 according to A technical overview and performance evaluation of mobile WiMAX part [9] and WiMAX forum TWG contribution to development of candidate IMT-Advanced RIT based on IEEE 802.16 [10].

[Table 2] Main parameters of WiBro

Parameter	Value	Units
Frequency	Co-channel/adjacent channel with WLAN	MHz
Bandwidth	10	MHz
Base station (BS)		
Transmit power	33	dBm
Antenna hight	30	m
Mobile Station (MS)		
Transmit power	25	dBm
Antenna height	1.5	m
Noise floor	-107	dBm/MHz
Noise Figure	7	dB
Protection Criteria I/N	-6	dB
S/N	9.4	dB
Sensitivity	-90.6	dBm

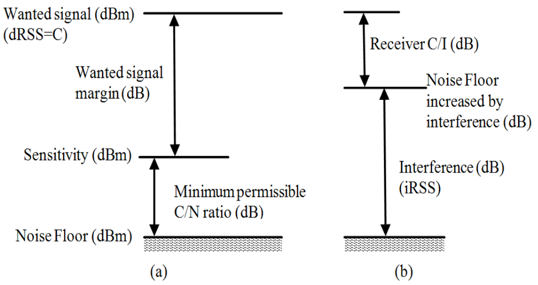
3. Scenarios and Methodology

Indoor deployment environment in urban is chosen and two scenarios will be assumed as following:

Scenario 1, WiBro interferes with WLAN UE, which includes scenario of interference from WiBro MS to WLAN UE and scenario of interference from BS to WLAN UE.

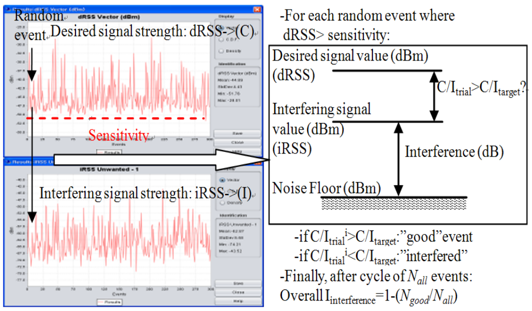
Scenario 2, WLAN UE interferes with WiBro MS SEAMCAT based on the Monte-Carlo simulation method permits statistical modeling of different radio interference scenarios for performing sharing and compatibility studies between radiocommunications systems in the same or adjacent frequency bands. Basic methodology of SEAMCAT is briefly explained as following [11,12]:

The criterion for interference to occur is for the victim receiver (Vr) to have a carrier to interference ratio (C/I) less than the minimum allowable value. In order to calculate the victim's C/I, it is necessary to establish the victim's desired received signal strength(dRSS) corresponding to the C, as well as the interfering received signal strength (iRSS) corresponding to the I. Figure 2 illustrates the various signal levels. Figure 2 (a) represents the situation when there is no interference and the victim is receiving the desired signal with wanted signal margin.



[Fig. 2] The signal levels used to determine whether or not interference is occurring

Figure 2 (b) illustrates what happens when interference occurs. The interference adds to the noise floor. The difference between the wanted signal strength and the interference signal is measured in dB, which is defined as the Signal to Interference ratio. This ratio must be more than the required C/I threshold if interference is to be avoided. The Monte Carlo simulation methodology is used to check for this condition and records whether or not interference is occurring, which is illustrated further in Figure 3.



[Fig. 3] Illustrative summary of the interference criteria computation

4. Simulation Results and Analysis

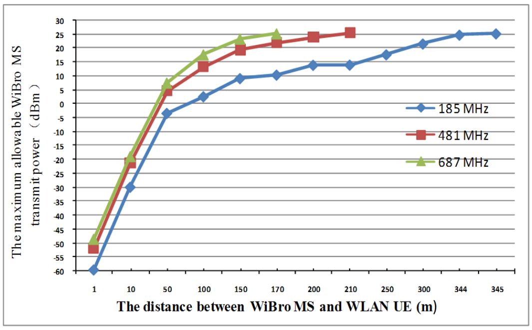
4.1 Scenario of WiBro interfering with WLAN UE

On the basis of previously introduced system parameters, interference scenarios and interference probability of 5% blow is chosen as an acceptable level for performance requirement of WLAN, Co channel and adjacent channel mutual interferences between WiBro and WLAN are evaluated with SEAMCAT, respectively.

4.1.1 Co-channel interference

In the scenario of co channel interference from WiBro to WLAN UE, WiBro and WLAN UE respectively operating at the same frequency of 185 MHz, 481 MHz and 687 MHz is assumed. And then, the protection distance between WiBro MS and WLAN UE and the maximum allowable transmit power of WiBro MS and BS will be evaluated by using SEAMCAT, respectively.

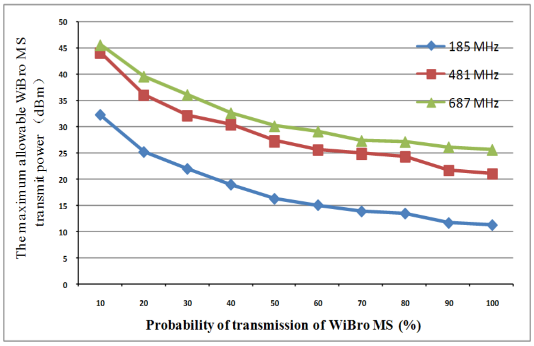
In case of single WiBro MS interfering into WLAN UE, the relationship between the maximum allowable transmit power of WiBro MS and the required protection distance is obtained in Figure 4.



[Fig. 4] The maximum allowable transmit power of WiBro MS vs. the distance between WiBro MS and WLAN UE

Figure 4 shows if the protection distances between WiBro MS and WLAN UE are 345 m, 210 m and 170 m respectively corresponding to 185 MHz, 481 MHz and 687 MHz, the maximum allowable transmit powers of WiBro MS are able to meet the specified transmit power of 25 dBm.

Moreover, in the case of multiple WiBro MSs interfering with WLAN UE, density of transmitter of 10/km^2 and the protection distance of 1m are assumed, respectively. Also probability of transmission of WiBro MS is defined as duty cycle of WiBro MS. Therefore, the duty cycle of WiBro MS from 10 % to 100 % is assumed. The relationship between the maximum allowable transmit power of WiBro MS and duty cycles of WiBro MS is obtained in Figure 5.



[Fig. 5] The maximum allowable WiBro MS transmit power vs. duty cycle of WiBro MS

Figure 5 shows interference situation from WiBro MS to WLAN UE is the worst case when duty cycle of WiBro MS is 100%. In consequence, the maximum allowable WiBro MS transmit power of 11.2 dBm, 21 dBm and 25.5 dBm can be respectively figured out to correspond to 185 MHz, 481 MHz and 687 MHz.

When the scenario of WiBro BS interfering with WLAN UE is analyzed , Multiple WiBro BSs interfering into WLAN UE only is taken into account, namely, closest seven BSs interfering with WLAN UE is assumed. The maximum allowable transmit power of WiBro BS is figured out in Table 3.

[Table 3] The maximum allowable transmit power of WiBro BS

Frequency	185 MHz	481 MHz	687 MHz
Maximum allowable transmit power of WiBro BS	-7.84 dBm	-4.96 dBm	-2.56 dBm

Table 3 indicates that the maximum allowable transmit power of WiBro BS should not be more than -7.84 dBm, -4.96 dBm and -2.56 dBm corresponding to 185 MHz, 481 MHz and 687 MHz, respectively to meet interference probability of 5%.

4.1.2 Adjacent channel interference

In scenario of Adjacent channel interference from WiBro to WLAN, the case of multiple WiBro MSs interfering with WLAN UE is taken into account. Density of interferes/km^2 of 50, 100, 150 and 200 and the protection distance of 1m are assumed. And then, according to different required guard bands, the maximum allowable transmit power of WiBro MS is evaluated through simulation. The results are summarized in Table 4.

[Table 4] The maximum allowable WiBro MS transmit power vs. the appointed guard band

Appointed guard band (MHz)	Maximum allowable transmit power of WiBro MS (dBm)											
	WLAN:185 MHz WiBro:201 MHz+guard band				WLAN:481 MHz WiBro:497 MHz+guard band				WLAN:687 MHz WiBro:671 MHz-guard band			
	Density of interferers/km^2				Density of interferers/km^2				Density of interferers/km^2			
	50	100	150	200	50	100	150	200	50	100	150	200
0	17.1	14.1	12.0	8.4	27.0	22.5	19.3	17.7	29.6	25.2	22.2	19.8
2	22.5	19.3	16.8	14.7	32.7	28.2	25.8	23.4	34.8	29.6	27.6	25.2
4	25.8	21.1	19.5	17.5	34.0	29.8	27.2	25.2				
5	26.0	22.3	19.9	18.1								
10	31.4	26.8	25.5	22.5								
13	33.8	29.2	27.1	24.9								

Table 4 shows that when density of interferers equals to 200, interference situation of WiBro MS interfering with WLAN UE is the worst case. Therefore, the guard bands are more than 13 MHz, 4 MHz and 2 MHz respectively corresponding to 185 MHz, 481 MHz and 687 MHz for meeting the specified transmit power of WiBro MS of 25 dBm.

In the case of multiple WiBro BSs interfering with WLAN UE, according to different required guard bands, the maximum allowable transmit power of WiBro BS is evaluated through simulation. The results are summarized in Table 5.

[Table 5] The maximum allowable WiBro BS transmit power vs. the appointed guard band

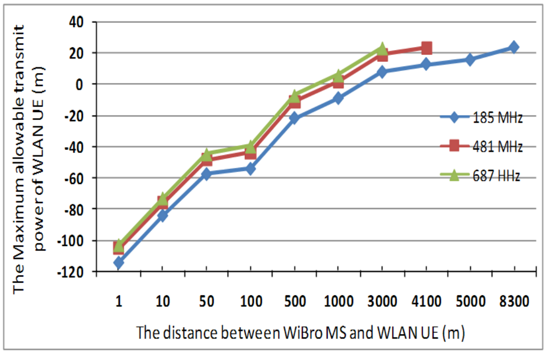
Appointed guard band(MHz)	Maximum allowable transmit power of WiBro BS (dBm)		
	WLAN:185 MHz WiBro:201 MHz+guard band	WLAN:481 MHz WiBro:497 MHz+guard band	WLAN:687 MHz WiBro:671 MHz-guard band
0	14.5	16.8	19.2
5	17.22	19.5	21.6
10	18.96	21.12	22.8
15	21.36	23.46	25.62
20	31.0	33.0	34.8
25	31.5		
35	31.5		

Table 5 shows that the guard band of 20 MHz for both 481 MHz and 687 MHz are able to meet the specified transmit power of WiBro BS of 33 dBm. But in the case of the guard band of 20 MHz for 185 MHz, transmit power of WiBro BS should be reduced to 31 dBm.

4.2 Scenario of WLAN UE interfering with WiBro MS

4.2.1 Co-channel interference

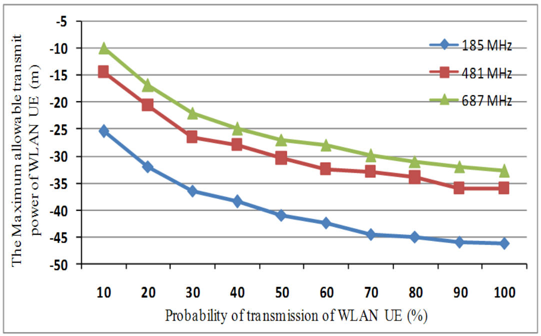
In case of single WLAN UE interfering into WiBro MS, the relationship between the maximum allowable transmit power of WLAN UE and the required protection distance is obtained in Figure 6.



[Fig. 6] The maximum allowable transmit power of WLAN UE vs. the distance between WiBro MS and WLAN UE

Figure 6 shows if the protection distances between WiBro MS and WLAN UE are 8.3 km, 4.1 km and 3 km respectively corresponding to 185 MHz, 481 MHz and 687 MHz, the maximum allowable transmit powers of WLAN UE are able to meet the specified transmit power of 23 dBm.

In the case of multiple WlAN UEs interfering with WiBro MS, density of transmitter of 10/km^2 and the protection distance of 1m are assumed. Also probability of transmission of WLAN UE is defined as duty cycle of WLAN UE. Therefore, the duty cycle of WLAN UE from 10 % to 100 % is assumed. Then the maximum allowable transmit power of WLAN UE is evaluated through simulation to meet different duty cycles of WLAN UE. The relationship between the maximum allowable transmit power of WLAN UE and duty cycles of WLAN UE is shown in Figure 7.



[Fig. 7] The maximum allowable transmit power of WLAN UE vs. duty cycle of WLAN UE

Figure 7 shows interference situation from WLAN UE to WiBro MS is the worst case when duty cycle of WLAN UE is 100%, and consequently the maximum allowable WLAN transmit power of -46.2 dBm, -36 dBm and -32.8 dBm can be respectively figured out to correspond to 185 MHz, 481 MHz and 687 MHz.

4.2.2 Adjacent channel interference

In scenario of Adjacent channel interference from WLAN to WiBro, the case of multiple WLAN UEs interfering with WLAN UE is taken into account. Density of interferes/km^2 of 50, 100, 150 and 200 and the protection distance of 1m are assumed. And then, according to different required guard bands, the maximum allowable transmit power of WLAN UE is evaluated. The results are summarized in Table 6.

[Table 6] The maximum allowable transmit power of WLAN UE vs. the appointed guard band

Appointed guard band (MHz)	Maximum allowable transmit power of WLAN UE(dBm)											
	WLAN:185 MHz WiBro:201 MHz+guard band				WLAN:481 MHz WiBro:497 MHz+guard band				WLAN:687 MHz WiBro:671 MHz-guard band			
	Density of interferers/km^2				Density of interferers/km^2				Density of interferers/km^2			
	50	100	150	200	50	100	150	200	50	100	150	200
0	-40.8	-44.5	-47.0	-49.5	-30.7	-35.0	-37.7	-41.5	-27.0	-32.0	-34.5	-38.2
5	-38.0	-42.0	-44.5	-46.8	-28.5	-34.0	-35.7	-38.5	-24.7	-29.5	-33.0	-34.7
10	-30.5	-34.5	-38.0	-39.7	-20.5	-25.0	-28.0	-31.0	-18.1	-21.9	-25.4	-26.5
15	-19.0	-23.0	-25.7	-27.0	-9.0	-14.0	-16.7	-19.2	-5.4	-10.6	-13.3	-15.4
20	-13.2	-17.5	-20.2	-22.0	-4.25	-7.7	-10.6	-12.8	-0.4	-5.4	-8.2	-10.5
25	0	-3.9	-6.7	-8.5	9.3	5.4	1.8	-1.0	12.6	8.0	4.6	3.0
30	0	-4.2	-6.9	-8.8	9.4	5.7	2.4	-0.5	12.6	8.0	4.8	3.0

Table 6 indicates that transmit power of WLAN UE is difficult to be up to 23 dBm although the guard band already is 30MHz between WLAN and WiBro.

5. Conclusions

This paper presented mutual interference scenarios between WiBro and WLAN in DTV bands and an analysis methodology SEAMCAT to evaluate co channel and adjacent channel interference between WiBro and WLAN. Simulations were conducted through SEAMCAT to figure out the protection distance, the maximum allowable transmit powers of WiBro MS, BS and WLAN UE as well as the guard band, respectively.

As results of this study, mutual interference scenarios between WiBro and WLAN at the frequency of 185 MHz, 481 MHz and 687 MHz were considered. The frequency of 185 MHz is the worst case, which requires longer protection distance between WiBro MS and WLAN UE, the lower transmit power of WiBro MS and WiBro BS and WLAN UE is necessary, and also the larger guard band is needed. However, it is obvious that comparing to the cases of using the frequency of 185 MHz and 481 MHz, the interference situation of using 687 MHz is slighter. Therefore, using frequency of 687 MHz is easier for coexistence between WiBro and WLAN. Analysis results of this paper can provide reference and guideline to make spectrum plan for deploying WiBro and WLAN in DTV bands.

References

[1] "Frequency policy & using technology workshop", Korea Information & Communications Society, pp.8,15, 5th Jun. 2009.

[2] http://www.dtv.gov/whatisdtv.html

[3] White Spaces Report 2Q 2010: "United States TV White paces: Usage & Availability Analysis", *Spectrum Bridge, Inc,* pp.1-5.

[4] Yan-Ming Cheng,"A Study on Compatibility between DTV and CDMA system",The Institute of Webcasting, Internet and Telecommunication, pp75-82, June, 2010.

[5] Hyun-Jin Hong,"The Impact of Radio Microphone on

DTV in Korea",Proceeding of International Conference on Information and Communication Technology (ICICT 2009), pp75-79, August, 2009.
[6] Gordon L. Stu¨ber,"Interference Analysis of TV-Band Whitespace", Proceedings of the IEEE, pp741-754, April, 2009.
[7] Artūras Medeišis, "Spectrum Engineering Advanced Monte Carlo Analysis Tool For Optimisation of Radio Spectrum Usage", European Radio- communications Office, October, 2006.
[8] Seong-kweon Kim, "Interference Analysis based on the Monte-Carlo Method", The Kroea Institue of Electronic Communication Science, pp.61, 8th April, 2008.
[9] Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation, pp31~pp34, WiMAX Forum, August, 2006.
[10] Wonil Roh,"WiMAX Forum TWG Contribution to development of Candidate IMT-Advanced RIT based on IEEE 802.16", IEEE L802.16-09/0085r1, pp9,16, August, 2009
[11] SEAMCAT Handbook, January 2010, ECO.
[12] ERC REPORT 68,"Monte-carlo simulation methodology for the use in sharing and Compatibility studies between different radio services or systems", European Radiocommunications Committee (ERC), February, 2000.

Yan-Ming Cheng [Associate member]

- Jun. 2000 : Jilin Institute of Technology Electric Engineering, BS
- Feb. 2007 : Kongju National Univ., Korea, MS
- Feb. 2007 ~ current: Kongju National Univ., Korea, PhD course
- Feb. 2000 ~ current : Department of Electronic Information , College of Electrical & Information Engineering, Beihua Univ., China, Lecturer

<Research Interests>
Wireless communication, Spectrum Engineering, RF system

In-Kyoung Cho [Associate member]

- 2009 : Kongju National Univ., Korea, BS
- 2010 ~ current : Kongju National Univ., Korea, MS course

<Research Interests>
RF system, Spectrum Engineering, wireless communication

Yong-Sup Shim [Associate member]

- 2005 : Kongju. National Univ., Korea, BS
- 2010 : Kongju National Univ., Korea, MS
- 2010 ~ current : ETRI, researcher
- 2011 ~ current : Kongju National Univ., Korea, PhD course

<Research Interests>
RF system, EMI, EMC

Il-Kyoo Lee [Regular member]

- 1994 : Electronic Engineering, Chungnam National Univ., MS
- 2003 : Electronic Engineering, Chungnam National Univ., PhD
- 1997 ~ 2004: ETRI, Senior researcher
- 2004 ~ current : Department of information communication, Kongju National Univ., Associate professor

<Research Interests>
RF system, Spectrum Engineering, Wireless communication