

논문 2010-2-11

## DTV와 WRAN 시스템 사이의 양립성 분석

## Compatibility analysis between DTV and WRAN systems

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요 약 본 논문에서는, 802.22 WRAN 시스템과 DTV 사이의 주파수 공존 영향에 대해 분석한다. 먼저 간섭에 대한 정의를 명확히 하기 위해, DTV를 간섭원으로, 802.22 WRAN을 피 간섭원으로 설정한다. 두 시스템이 동일한 스펙트럼을 사용했을 때, 두 시스템의 최소 이격 거리를 계산한다. 그리고 잠재적 간섭의 존재 여부를 결정하기 위해, 최소 커플링 손실을 전송 손실과 비교하였다. 최소 이격거리는 전송 손실이 최소 커플링 손실보다 큰 값을 가질 경우 결정된다. 이러한 경우, DTV는 802.22 WRAN 시스템에 아무런 영향도 끼치지 않는 것으로 생각할 수 있다.

**Abstract** In this paper, we analyze an effect co-existence between digital television (DTV) and 802.22 wireless regional area network (WRAN) systems. We set DTV as an interfering system and 802.22 WRAN as a victim system. When they share the same spectrum, we calculate the minimum separation distance. In analysis, we compare a minimum coupling loss (MCL) with a transmission loss (TL) for determining whether there exists the potential interference or not. The minimum separation distance is determined when the TL is larger than the MCL. In this case, the DTV system does not affect any harmful effect to 802.22 WRAN.

**Key Words :** Digital television (DTV), Minimum coupling loss (MCL), 802.22 WRAN

## I. INTRODUCTION

Allowable interference for protecting an incumbent service is known as the protection ratio (PR)<sup>[1]</sup>. In previous studies<sup>[2-4]</sup>, the PR among TV broadcast services using exclusively TV bands was obtained by measurement. Such measurement requires prototype hardware, an investment of time, and other costs. In the near future, TV bands may be used for other kinds of communication systems, such as cognitive radio (CR). CR technology is attracting growing interest from academics, regulation and standardization bodies (such as IEEE 802.22), and industry. Regarding coexistence feasibility, PR was assumed in<sup>[5]</sup>, and it

was further assumed that the impact of CR signal on digital TV (DTV) broadcasting would be similar to that of DTV signal. However, few studies have suggested how to protect TV broadcast services. Also, the required PR has not yet been determined through measurement or simulation.

In this paper, we analyze the compatibility between DTV systems and 802.22 wireless regional area network (WRAN). The same spectrum belongs to both systems. Accordingly, we estimate the minimum separation distance which is necessary for DTV systems to be consistent with 802.22 WRAN. We assume that an existing system is 802.22 WRAN and a newly introduced system is DTV. So DTV systems are set to be the interfering systems. And 802.22 WRAN are set at the victim systems.

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접수일자 2010.2.11, 수정일자 2010.3.31

The remainder of this paper is organized as follows. System parameters of DTV systems and 802.22 WRAN, which are employed for the compatibility analysis, are shown in Section 2. And in Section 3, the compatibility analysis procedure is described. In Section 4, the simulation results are presented. Finally, conclusion remarks are made in Section 5.

## II. SYSTEM PARAMETERS

### 1. IEEE 802.22 WRAN

The IEEE 802.22 standard defines a system for a wireless regional area network (WRAN) that uses unused or white spaces within the television bands between 54 and 862 MHz, especially within rural areas where usage may be lower. To achieve its aims, the 802.22 standard utilises cognitive radio technology to ensure that no undue interference is caused to television services using the television bands. In this way 802.22 is the first standard to fully incorporate the concept of cognitive radio.

The IEEE 802.22 WRAN standard is aimed at supporting license-exempt devices on a non-interfering basis in spectrum that is allocated to the TV Broadcast Service. With operating data rates comparable to those offered by many DSL / ADSL services it can provide broadband connectivity using spectrum that is nominally allocated to other services without causing any undue interference. In this way IEEE 802.22 makes effective use of the available spectrum without the need for new allocations.

There are a number of elements that were set down for the basis of the 802.22 standard. These include items such as the system topology, system capacity and the projected coverage for the system. By setting these basic system parameters in place, the other areas fall into place.

1) *System Topology*: The system is intended to be a point to multipoint system, i.e. it has a base

station with a number of users or Customer Premises Equipments, CPEs located within a cell. The base station obviously links back to the main network and transmits the data on the downlink to the various users and receivers data from the CPEs in the uplink. It also controls the medium access and addition to these traditional roles for a base station, it also manages the "cognitive radio" aspects of the system. It uses the CPEs to perform a distributed measurement of the signal levels of possible television (or other) signals on the various channels at their individual locations. These measurements are collected and collated and the base station decides whether any actions are to be taken. In this way the IEEE 802.22 standard is one of the first cognitive radio networks that has been defined.

2) *Coverage Area*: The coverage area for the IEEE 802.22 standard is much greater than many other IEEE 802 standards - 802.11, for example is limited to less than 50 metres in practice. However for 802.22, the specified range for a CPE is 33 km and in some instances base station coverage may extend to 100 km. To achieve the 33 km range, the power level of the CPE is 4 Watts EIRP (effective radiated power relative to an isotropic source).

3) *System Capacity*: The system has been defined to enable users to achieve a level of performance similar to that of DSL services available. This equates to a downlink or download speed of around 1.5 Mbps at the cell periphery and an uplink or upstream speed of 384 kbps. These figures assume 12 simultaneous users. To attain this overall system capacity must be 18 Mbps in the downlink direction.

In order to be able to meet these requirements using a 6 MHz television channel spectral efficiency of around 3 bits / sec / Hz are required to give the required physical layer raw data transfer rate.

## 2. IEEE 802.22 Air Interface

The physical layers of the IEEE 802.22 system have been designed to enable a sufficient level of performance to be obtained along with the requirement to ensure the system is able to maintain its use of "free" or white space within the television spectrum. To achieve this system requires a considerable degree of flexibility as well as the implementation of many cognitive radio techniques.

Table I. System Parameters of IEEE 802.22 WRAN

표 1. IEEE 802.22 WRAN의 시스템 파라미터

Parameter	Specification
Typical cell radius (km)	30 - 100 km
Methodology	Spectrum sensing to identify free channels
Channel bandwidth (MHz)	6, (7, 8)
Modulation	OFDM
Channel capacity	18 Mbps
User capacity	Downlink: 1.5Mbps Uplink: 384 kbps

1) *Physical Layer*: In order to meet the requirements for the overall 802.22 system, the physical layer maintains a high degree of flexibility. This is built in to the basic specification of the system. One of the first characteristics is the modulation scheme. An OFDM scheme has been adopted because the 802.22 WRAN system to provide resilience against multipath propagation and selective fading as well as a high level of spectrum efficiency and sufficient data throughput. To provide access for multiple users, OFDMA is used for both upstream and downstream data links. IEEE 802.22 allows a variety of modulation schemes to be used within the OFDMA signal: QPSK, 16-QAM and 64-QAM can all be selected with convolutional coding rates of 1/2, 3/4, and 2/3. The required modulation and error correction rates are chosen according to the prevailing conditions. In order to meet the requirements for

the individual users that may be experiencing very different signal conditions, it is necessary to dynamically adapt the modulation, bandwidth and coding on a per CPE basis.

In order to be able to obtain the required level of performance, it has been necessary to the IEEE 802.22 to adopt a system of what is termed "Channel Bonding." This is a scheme where the IEEE 802.22 system is able to utilise more than one channel at a time to provide the required throughput. Often it is possible to use adjacent channels because in many countries the regulatory authorities and frequency planners allow two or more empty channels between stations transmitting high power signals as this prevents interference on the TV signals. These multiple free channels allow the use of contiguous channel bonding. In practice the maximum number of channels that are bonded is likely to be limited to three as a result of the frontend bandwidth limitations. To provide access for both upstream and downstream data, the form of duplex scheme that has been adopted is TDD. This has several advantages. First it only requires one channel to be used - FDD would not be viable because it would be more difficult to control two channels with sufficient transmit / receive spacing. Secondly the use of TDD enables dynamic change of the upstream and downstream capacity.

2) *Medium Access Control*: The fact that the IEEE 802.22 standard is so flexible brings a number of new challenges to the practical implementation of the system. Accordingly the MAC has been designed to provide flexibility and to incorporate these new ideas: In the first instance the initialisation and network entry needs to accommodate the elements of the spectrum usage flexibility. As there is not fixed channel for the system, and no pilot channel can be broadcast, any CPE when turning on and initialising needs to be able to find the signals. Accordingly, when initialising, any CPE first scans the available

spectrum to look at channel occupancy. It will detect those channels free of television transmissions. In the remaining empty channels it will then scan for base station pilot signals and acquire any network information. Once it has acquired the correct network it can then proceed to connect to the network.

It is also necessary to have a defined format for the data. To enable the data to be suitably structured, the transmission is formatted into frames and super frames. The super frame is built up from the smaller frames. The super-frame is used to provide overall synchronization for the system, and in particular provides the initial network access / entry initialization. At the beginning of each super frame, there is a preamble known as the Super frame Control Header, SCH. The SCH contains the information needed for any new CPEs that need to access the base station. The super frame is built up from frames. These frames are split into two elements: the upstream subframe (US) and the downstream subframe (DS). The boundary between these two subframes is variable and can be adapted to accommodate changes on the levels of upstream and downstream capacity required.

IEEE 802.22 equipment is designed to ensure that no undue interference is caused to existing television services. As a result the whole system has to be adaptive to ensure that the system avoids channels that are in use while still maintaining the required throughput. It even has to adapt to changes in radio propagation that may occur from time to time. As a result the cognitive radio and cognitive network technology has been incorporated to ensure this requirement is met.

### 3. DTV Systems

The Digital Television Standard describes a system designed to transmit high quality video and audio and ancillary data over a single 6 MHz channel. The system can deliver reliably about 19 Mbps of throughput in a 6 MHz terrestrial broadcasting channel

and about 38 Mbps of throughput in a 6 MHz cable television channel. This means that encoding a video source whose resolution can be as high as five times that of conventional television (NTSC) resolution requires a bit rate reduction by a factor of 50 or higher. To achieve this bit rate reduction, the system is designed to be efficient in utilizing available channel capacity by exploiting complex video and audio compression technology.

The objective is to maximize the information passed through the data channel by minimizing the amount of data required to represent the video image sequence and its associated audio. The objective is to represent the video, audio, and data sources with as few bits as possible while preserving the level of quality required for the given application.

Although the RF/Transmission subsystems described in this Standard are designed specifically for terrestrial and cable applications, the objective is that the video, audio, and service multiplex/transport subsystems be useful in other applications.

Currently, there are three main DTV standard groups.

- 1) *The Advanced Television Systems Committee (ATSC)*: a North America based DTV standards organization, which developed the ATSC terrestrial DTV series of standards. In addition, the North American digital cable TV standards now in use were developed separately, based on work done by Cable Television Laboratories (CableLabs) and largely codified by the Society of Cable Telecommunications Engineers (SCTE).
- 2) *The DVB Project*: a European based standards organization, which developed the DVB series of DTV standards, standardized by the European Telecommunication Standard Institute (ETSI).
- 3) *The ISDB standards*: a series of DTV standards developed and standardized by the Association of Radio Industries and Business (ARIB) and by the Japan Cable Television Engineering Association (JCTEA).

DTV is rapidly becoming obsolete. Toshiba for example no longer makes DTV sets, only HDTV.

- 1) *Clearer Picture*: Digital transmission automatically removes static. Not all the channels you get will be

Table II. System Parameters of DTV Systems  
표 2. DTV 시스템의 시스템 파라미터

Parameter	Specification
Frequency	57MHz
Transmit power	1MW
Channel bandwidth (MHz)	6MHz
Receiver bandwidth (MHz)	67.78dB
Carrier to noise ratio C/N	19.5dB
Antenna Gain	11.65dB
DTV receiver sensitivity	-64dBm

digital. Typically there will be a digital or HDTV equivalent for only a fraction of the old analog channels. This means the analog channels will see no improvement over your old analog cable service. Old TV shows are blurry or have poor contrast or colour because of the quality of the original film. Digital transmission can't help them. For most channels you will not notice any improvement. It is not so much that the images are all that much better than analog, it is the consistency. They are always clear. The place you most notice the increased clarity is nature shows. Even partner, who is rather scornful of digital TV, acknowledges the nature shows are much more impressive on DTV, particularly David Attenborough's the Life of Birds and Planet Earth series.

- 2) *Wider Picture*: Theatre format  $16 \times 9$  (aka widescreen or letterbox) rather than TV's box aspect ratio of 4:3 for HDTV only. DTV uses the same old analog style 4:3. HDTV channels don't always broadcast HDTV size images. Sometimes they broadcast DTV-size when a wide feed is not available for a given show. Modern TVs will stretch and chop the old square broadcast to fit the wide screen TV.

- 3) *More Channels*: DTV makes more efficient use of bandwidth because DTV takes only as much bandwidth as needed for a given resolution so more channels can be packed into the same cable. Over the next years it should see more and more channels available. The old unused analog bandwidth will be freed up for used by police and emergency communications and for cell phones. There are in theory ten times as many available channels, numbered: 1, 1.1, 1.2... adapter box may convert channels to round numbers.

- 4) *Interactive Schedule*: digital box lets look at the schedule for days into the future. It doesn't have to wait for the channel of interest to roll around. It can scroll.

The USA was officially switching on 2009-02-17 from analog NTSC to digital and dropping analog, however they have delayed it to 2009-07, though some stations have already switched. Your analog VCR will stop working too. Thereafter you will need to buy an analog to digital converter to make current TV work. The current VHF channels will be recycled for things like cell-phones, Internet transmissions, pagers etc. However, most cable and satellite services will continue to offer the old analog connection.

### III. COMPATIBILITY ANALYSIS METHOD

All the interference calculations are based on establishing a Minimum Coupling Loss (MCL) which is defined as the minimum power loss between the system and its interferer for maximum tolerable interference level.

$$MCL = P_i + 10 \log \left( \frac{BW_s}{BW_i} \right) - I_s, \quad (1)$$

where  $P_i$  is the interferer signal power,  $BW_s$  and  $BW_i$  are the respective bandwidths of the system and

the interfering signal, and  $I_2$  is the maximum tolerable interference level.

The MCL is achieved by adequate geographical separation of the two systems considered. The transmission loss (TL) needs to be greater than the MCL in order to ensure sufficient attenuation of signals from the interferer to the victim system. The TL in dB is given by

$$TL = 20\log f + 10n\log d + K + G_t - G_r + A, \quad (2)$$

where  $f$  is frequency in Hz and  $n$  is the decay index.  $n$  is 2 for free space and 4 for aloes-to - ground propagation.  $d$  is distance in  $m$ ,  $G_t$  and  $G_r$  are the transmit and receive antenna gains, respectively and  $A$  is any additional loss such as building penetration losses.  $K$  is a grouping of fundamental constants given by

$$K = 20\log\left(\frac{C}{4\pi}\right), \quad (3)$$

where  $C$  is the speed of light,  $C = 3 \times 10^8$  m/sec. The TL is used in the calculations to calculate a minimum separation distance of the system and its interferer.

#### IV. SIMULATION RESULTS

In the simulations, interference scenario is that both 802.22 WRAN and DTV systems operate at 473MHz. As Fig. 1, the MCL and consequently the minimum separation distance are evaluated for the systems co-existing in the same bands.

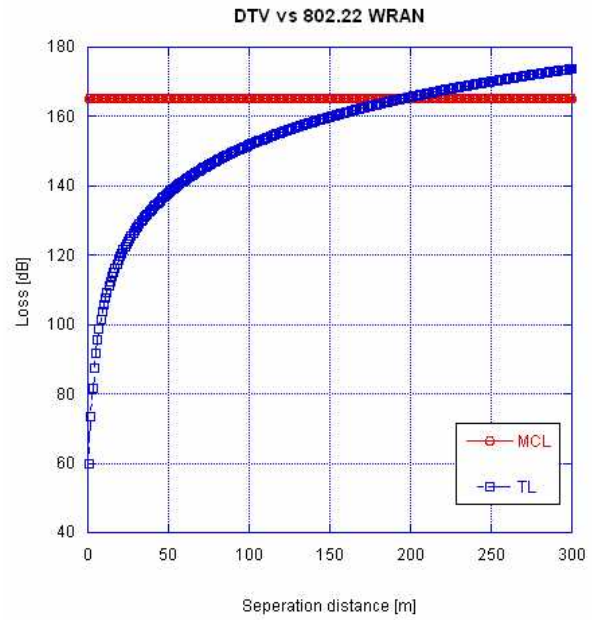


Fig.1 Transmission loss in accordance with separation distance of 6 MHz bandwidth.  
그림 1. 6MHz 대역 거리와 일치하는 전송 손실

#### V. CONCLUSIONS

In this paper, we analyzed the compatibility between 802.22 WRAN and DTV systems. We set DTV as an interfering system and 802.22 WRAN as a victim system. In order to determine the compatibility, we calculated the MCL. Then, the TL was compared with the calculated MCL at separation distances 195m, we interpreted that there was potential interference when the TL was not greater than the calculated MCL. When the spectrum is managed, the results of this paper can be applied for determining the minimum separation distance not only between DTV device and 802.22 WRAN but also among several radio systems.

#### ACKNOWLEDGEMENT

"This research was supported by the MKE(The Ministry of Knowledge Economy), Korea, under the ITRC(Information Technology Research Center) support program supervised by the NIPA(National IT

Industry Promotion Agency)" (NIPA-2010-(C1090-1011-0005))

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