World Applied Sciences Journal 13 (4): 670-677, 2011
ISSN 1818-4952
© IDOSI Publications, 2011

Digital Dividend Spectrum Utilization Optimization in Ultra High Frequency (UHF) Band for Digital Terrestrial Tv Broadcasting and Mobile Broadband Services in Indonesia

Djamhari Sirat, Muhammad Feriandi Mirza and Filbert H. Juwono

Department of Electrical Engineering, Universitas Indonesia, Depok 16424, Indonesia

Abstract: Analog TV broadcasting system to digital broadcasting system transition is a necessity that can not be avoided. With this transition, there will be an increase in the quality of TV broadcasting and efficiency of the radio frequency spectrum usage. This spectrum efficiency will generate the empty spectrum that is used to be vacated by analog TV. This phenomenon is referred as digital dividend, which will become a very valuable development for the application of information and communication technology that utilizes radio frequency spectrum. Digital dividend spectrum in UHF band is extremely valuable because it lies in the range of frequency bands that provide an optimum trade-offs between coverage and bandwidth requirement. Therefore, the use of the digital dividend spectrum should be taken carefully. This research analyses dividend spectrum for mobile broadband services. To determine the spectrum allocation for DTTB and other terrestrial application services, it is analyzed from the technical and non-technical aspects. The technical aspects namely channel bandwidth, the selection of compression standard for DTTB, etc. Non-technical aspects will be more focused on the potential revenues from each application, including the calculation of investment and operational costs. Analysis was done by calculating the optimization using the linear programming method.

Key words: Spectrum efficiency · Digital dividend · UHF · Digital terrestrial TV broadcasting (DTTB) · Mobile broadband · Optimization · Linear programming

INTRODUCTION

Transition from analog terrestrial TV broadcasting to digital terrestrial TV broadcasting (DTTB) is a necessity that cannot be avoided. As with any effort to change, there are always doubts and concerns from the industries and societies over the shape and direction of these changes. In Indonesia, the frequency master plan for TV broadcasting in accordance with the Minister of Transportation Decree No. KM. 76 of 2003 only provides 2 (two) frequency channels for the DTTB [2] and this is clearly not sufficient. So, it is important to plan and map the frequency channels as a supplement or revision of the current frequency master plan to obtain optimal channel allocation for DTTB.

Digital TV broadcasting uses less bandwidth than analog TV. So, there will be empty spectrum when the transition is fully conducted, that is called digital dividend. In relation to the digital dividend, there are other potential applications besides DTTB that may very possible to open up the competition. Therefore, it is important to determine the proportion of the bandwidth allocation to be used by any application including DTTB that is reviewed from technical, economic and social or public interests.

In this paper, the discussion will be limited to the implementation of DVB-T as the DTTB system since the Government of Indonesia has stipulated DVB-T as a DTTB standard for free-to-air with fixed reception mode in year 2007 and utilization of the digital dividend spectrum for mobile broadband services.

Objectives and Methodology: This paper is intended as a reference in order to determine the optimum allocation of bandwidth requirement for the needs of DTTB and mobile broadband services in the Ultra High Frequency (UHF) Band results from the transition from analog to digital system. The methodology used is first by modeling the system by using linear programming. Next step is to determine the parameters and their values. The last step is optimizing the system to get the optimum bandwidth. The values of the parameters is determined by using the real data from TV stations such as operational cost, investment cost, etc.

Corresponding Author: Djamhari Sirat, Department of Electrical Engineering, Universitas Indonesia, Depok 16424, Indonesia. E-mail: djsirat@ee.ui.ac.id.

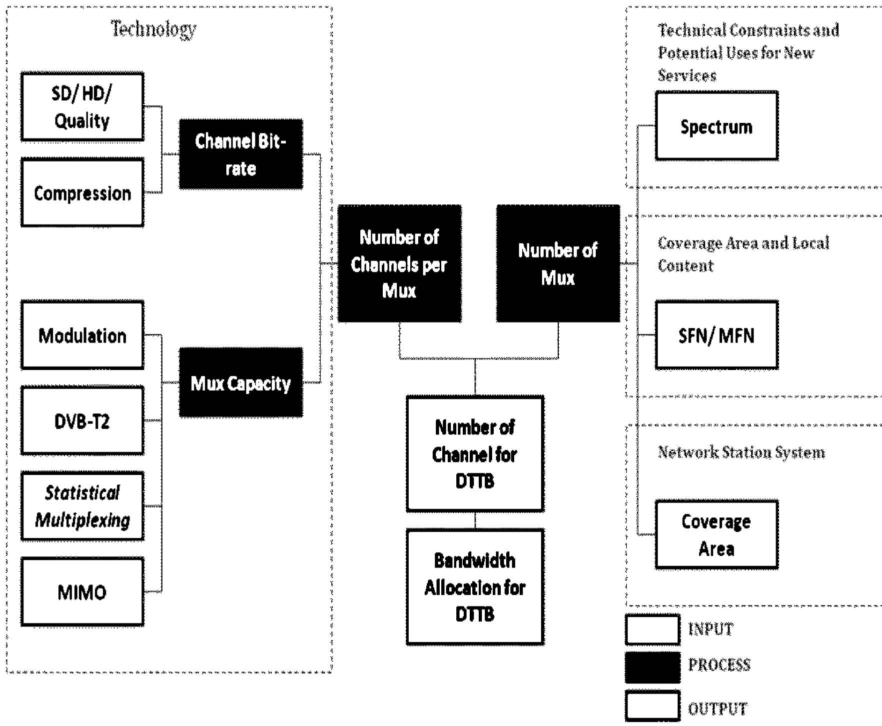

Fig. 1: Basic Framework for the Determination of Bandwidth Allocation for DTTB

System Modeling and Its Parameters

Basic Framework: When full migration of analog terrestrial TV broadcasting towards DTTB has been fully undertaken, there will be spectrum available vacated by the analog terrestrial TV broadcasting that is very valuable. What makes the spectrum very valuable is that the fact that the spectrum is located between 200 MHz up to 1 GHz. This part of spectrum is very optimum in terms of the needs of coverage and bandwidth [3].

In other countries, the use of the digital dividend spectrum itself until now, is still much debated between broadcasters that are eager to broadcast more channels of digital programs or offer contents in high-definition (HD) format, with the telecommunication operators intending to offer faster and wider geographical range of broadband communication services.

Bandwidth allocation, coverage area and policies on the use of Single Frequency Network (SFN) or Multi Frequency Network (MFN) will affect the number of multiplex that will be used in the implementation of DTTB. On the other hand, the number of channels that can be distributed in each multiplex is influenced by applicable technological factors.. So in order to determine the DTTB bandwidth allocation, the number of channels that can be distributed into each multiplex and the number of multiplex in a coverage area are utilized. The basic framework of this research is modification based on the research method conducted by Spectrum Value Partners in assessing the utilization of the digital dividend spectrum [4]. The basic framework of the research that is used to determine the bandwidth allocation is shown in Figure 1.

System Model: The optimization is done by using the linear programming method with the following models:

Objective Function:
Maximize:

$$c_1 x_1 + c_2 x_2 \quad (5)$$

With constraint functions:

$$a_1 x_1 + a_2 x_2 \le b \quad (6)$$

$$d_1 x_1 + d_2 x_2 \le e \quad (7)$$

$$f_1 x_1 + f_2 x_2 \le g \quad (8)$$

Where,
x1 = The number of service TV content providers
x2 = The number of mobile broadband operators
c1 = Revenue for DTTB services
c2 = Revenue for mobile broadband services

a1 = Investment costs for DTTB services
a2 = Investment costs for mobile broadband services
b = Upper limit for investment costs
d1 = Operational costs for DTTB services
d2 = Operational costs for mobile broadband services
e = Upper limit for operational costs
f1 = Channel bandwidth for DTTB services
f2 = Channel bandwidth for mobile broadband services
g = Total bandwidth on analyzed UHF band

Channel Bit-Rate Evaluation: The data needed to determine the useable channel bit-rate on each channel depend on: type of content, format of content (Standard Definition/SD or High Definition/HD) and picture quality. Figure 2 below describes the factors that affect the channel bit-rate.

Format of Content: DTTB with HD content requires a larger data in the distribution that would require a higher bit-rate. Likewise, the SD content requires a smaller data in the distribution compared to HD format.

Picture Quality: Whatever the format is, whether SD or HD, broadcasters have the option to modify the level of picture quality which is distributed to the viewers by reducing the channel bit-rate that is used.

Type of Content: The type of content distributed will affect the channel bit-rate. For instance, talk show program requires less channel bit rate compared to sport program.

Compression: The compression standards generally used are MPEG2 and MPEG4 Part 10 AVC (ITU-T Standard H.264). In general, MPEG4 AVC has the advantages of the technical aspects when compared to MPEG2. MPEG4 AVC has capabilities in providing video quality as good as MPEG2 standard, but with a lower bit-rate, i.e. between 30 – 50% lower than the bit-rate used in MPEG2. This means that for the same multiplex and the same application, MPEG4 AVC is able to provide a channel capacity 30 to 50% larger than when using MPEG2.

Multiplex Capacity Evaluation: Multiplex capability in distributing TV channels depends on the throughput of the multiplex (in Mbps) and the percentage of throughput that is used to non-broadcasting services, such as for operating the multiplex or data services.

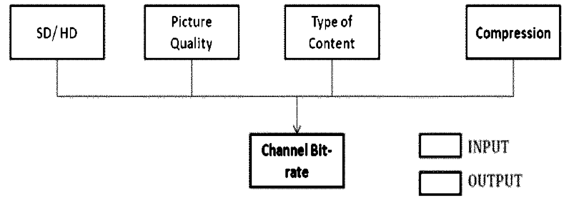

Fig. 2: Factors Affecting the Channel Bit-Rate

Multiplex Throughput: The ability or capacity of the multiplex in distributing the TV broadcasting channels is limited by the total multiplex throughput influenced by technical factors as follows:

- Modulation; the modulation standards widely used are 16QAM and 64QAM. With the same transmitter, 16QAM has a lower throughput, but with more extensive coverage area and better signal reliability.
- Forward Error Correction (FEC) and guard band; multiplex operators can increase the reliability of the signal by increasing the FEC and guard band.

Utilization of the Multiplex Throughput for Non-broadcasting Services: Non-broadcasting services can use multiplex capacity. Managing the multiplex channels is considered by looking at the number of channels compared to the quality of services.

In addition to FEC and guard band manipulation, enhancing multiplex capacity is conducted by using advanced DTTB technology. For example, by implementing DVB-T2 standard, MIMO multiplexing and statistical multiplexing.

Number of Channels per Multiplex Evaluation: Number of channels per multiplex can be determined by analyzing the results of channel bit-rate and evaluating the capacity of the multiplex. The number of channels per multiplex will affect the bandwidth allocation for DTTB.

Number of Multiplex Evaluation: Each multiplex distributes broadcast contents using 1 (one) radio frequency channel with 8 MHz bandwidth. GE-06 Conference allocates 392 MHz of spectrum for broadcasting in the UHF band (band IV and V) ranging from 470 to 862 MHz. This means there are 49 channels available for DTTB ideally. But practically, it will not be fulfilled because of the following reasons:

Radio Frequency Network Pattern: Consideration on the use of SFN or MFN, including technical considerations to avoid interference in a coverage area or inter-regional coverage area.

Table 1: Multiplex Throughput Capacity of OFDM Modulation [4]

		Guard band						Guard band			
16QAM		1/4	1/6	1/16	1/32	64QAM		1/4	1/6	1/16	1/32
FEC	1/2	9.95	11.05	11.71	12.06	FEC	1/2	14.93	16.59	17.56	18.10
	2/3	13.27	14.75	15.61	16.09		2/3	19.91	22.12	23.42	24.13
	3/4	14.93	16.59	17.58	18.10		3/4	22.39	24.88	26.35	27.14
	5/5	16.59	18.43	19.62	20.11		5/5	24.88	27.65	29.27	30.16
	7/6	17.42	19.35	20.49	21.11		7/6	26.13	29.03	30.74	31.67

Table 2: Summary of Multipleks Evaluation

Technical Standard	Value
System	DVB-T
Modulation	64QAM
Guard Interval	1/8
FEC	¾
Total Capacity (Mbps)	22,12
% reserved for non-TV	5%
Remaining Capacity (Mbps)	21,014
Channel Bit-rate (Mbps)	3,5
Number of Channels per Mux	6

Coverage Area: Coverage area of a multiplex affect the number of radio frequency required for each multiplex. Wider coverage area needs greater overlap for each service.

Table 2 shows the evaluation summary for channel bit-rate, capacity of the multiplex, number of channels per multiplex and the number of multiplex.

DTTB Services: Calculation of parameters for DTTB services using the following data:

TV Advertising Revenue: TV advertising revenue obtained will be used for forecasting the revenue of DTTB services industry until the year of 2018, when all analog TV broadcasts will be stopped entirely. This is based on Article 24 paragraph (8) of the Ministerial Decree No. 39 Year 2009 on Basic Framework of the Implementation of Digital Terrestrial TV Broadcasting Fixed Reception Free-to-Air, which states that a simulcast activities held at least at the latest until the end of 2017. TV advertising revenue forecasting calculations carried out using polynomial regression model. The 2nd order polynomial regression model was used because the coefficient of determination (R^2) for this regression model is most closely approximates the value of 1. The coefficient of determination indicates the ability of independent variables in explaining variance of the dependent variable. The coefficient of determination has a range of values between 0 and 1.

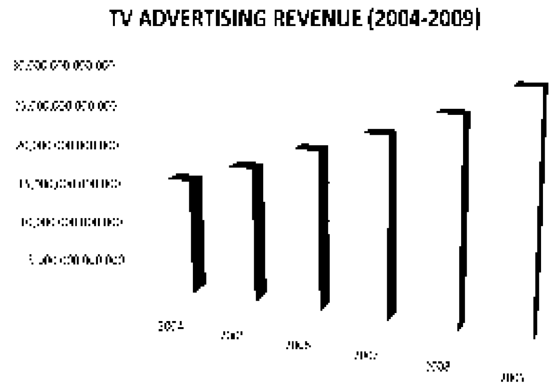

Fig. 3: TV Advertising Revenue

The higher the coefficient of determination, the higher the ability of independent variables in explaining the variance of the dependent variable.

The 2nd order polynomial regression model is

$$y = a_0 + a_1x + a_2x^2 + \varepsilon \quad (1)$$

The solution for equation (1) is given by

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} 1 & x_1 & x_1^2 \\ 1 & x_2 & x_2^2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \quad (2)$$

The TV advertising revenues from year 2004 – 2009 is shown in figure 3 below:

By using data in Fig 3 and equation (1), the regression equation for TV advertising revenue can be modeled as

$$y = 117.767.857.143x^2 + 2.110.425.000x + 12.878.700.000.000 \quad (3)$$

Therefore, approximate value of TV advertising expenditures in 2018 was IDR 71,032,843,428,992,-. Research conducted by AGB Nielsen in TV advertising revenue was counted without considering rebates or

Table 3: DTTB Investment Cost

No	Description	QTY	IDR
1	DVB-T Transmitter	1	5,775,000,000
2	Antenna System	1	588,500,000
3	Feeder System	1	467,500,000
4	Head End System		
	-Mutltiplexer	1	682,000,000
	-Encoder	6	1,320,000,000
5	TVRO System		
	-Antenna Dish	1	176,000,000
	-Integrated Receiver Decoder	6	660,000,000
6	AVR + UPS	1	522,500,000
7	Shelter	1	385,000,000
8	Installation Material	1	93,500,000
9	Tower 300m	1	15,000,000,000
Total			25,670,000,000

Tabel 4: DTTB Operational Cost

No	Description		IDR
1	ELECTRICITY 60 KVA/YEAR		457,947,000
2	SPECTRUM FEE/YEAR		62,785,069
	-Bandwidth	8,000	
	-Ib	0.640	
	-HDLP	11,772	
	-Power	70.751	
	-Ip	8.430	
	-HDDP	109,481	
Total			520,732,069

discounts given by television stations. In real, television stations often provide discounts to advertisers up to 40%. Regional reviews are used for the analysis are Jakarta, Bogor, Depok, Tangerang and Bekasi (Greater Jakarta) because it is assumed that the Greater Jakarta area contributes up to 56.4% for the TV station revenue. Thus, an estimate of potential income is

40% x 56.4% x IDR 71,032,843,428,992,- = IDR 28, 413, 137, 371, 597,-

Investment Cost: The investment cost used in this research is limited to the investment for the transmitter system only (Table 3).

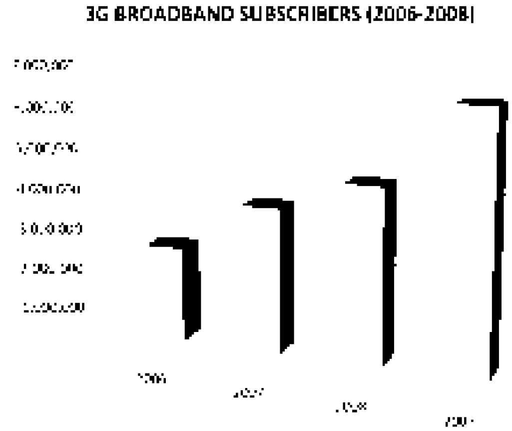

Fig. 4: 3G Broadband Subscribers

Operational Cost: Operational cost used in this research is limited to the operational costs of electricity and the cost of rights of using the radio frequency or spectrum fee (Table 4).

Mobile Broadband Services: Calculation of parameters for mobile broadband services uses the following data:

The number of mobile broadband subscribers is calculated based on the number of 3G subscribers calculations with the assumption that the number of broadband subscribers for 3G is 3.8% of total mobile subscribers [5]. Later, the number of 3G s ubscribers are used as data in the forecasting of mobile broadband customers until year 2018.The prediction mobile broadband subscribers uses 2nd order polynomial regression model. Same as forecasting calculations on the value of advertising revenue of DTTB services, 2nd order polynomial regression model is used because the value of R^2 from this regression has a value that most approximates the value of 1 to the data supplied.

The potential revenue from mobile broadband services will be searched using the 3G broadband data service rates from several operators in Indonesia. 3G broadband data subscribers is as shown in Figure 4 below:

Table 5: Mobile Broadband Services Category and Type of Customer

No	Customer type	Operator	Packet	Tariff (IDR)	Average Tariff (IDR)	% Customer
1	Regular User	Telkomsel	Basic	250,000	236,667	70%
		Indosat	ISAT Medium	300,000		
		Indosat Megamedia	ECO!	160,000		
2	High End User	Telkomsel	Advance	350,000	400,000	20%
		Indosat	ISAT Heavy	500,000		
		Indosat Megamedia	YOU!	350,000		
3	Professional User	Telkomsel	Pro	525,000	1,012,500	10%
		Indosat	ISAT Super	1,500,000		
		Indosat Megamedia	.	.		

Table 6: Mobile Broadband Potential Revenue

No	Customer Type	% Customer	Potential revenue
1	Regular User	70%	6,431,851,281,333
2	High End User	20%	3,105,924,160,000
3	Professional User	10%	3,930,935,265,000
	Total Potential Revenue		13,468,710,706,333

Table 7: Mobile Broadband Investment Costs

No	Deskripsi	QTY	IDR
1	Base Station	1 per BS	460,842,701
2	Installation	1 per BS	112,107,840
3	NMS	1 per BS	9,100,260
4	Supporting Material	1 per BS	181,900,000
	Total		763,950,801

Table 8: Mobile Broadband Operational Costs

No	Deskripsi	QTY	IDR
1	Electricity 6 KVA / Year		47,959,200
2	Uplink and Backhual / Year	8% × Asset	61,116,064
3	Spectrum Fee / Year		29,448,836
	- BandWidth	5,000	
	- Ib	0.640	
	- HDLP	11,772	
	- Power	23.000	
	- Ip	8.430	
	- HDDP	109,481	
	Total		138,524,100

By using data in Fig 4 and equation (1), the regression equation for TV advertising revenue can be modeled as.

$$y = 199.173x^2 + 286.612x + 2.027.376 \quad (4)$$

Therefore, the number of mobile broadband subscribers until the year 2018 is 38,824,052 subscribers. To calculate the potential revenue of mobile broadband services, it uses the tariff rates of broadband services from several operators in Indonesia. In addition, it is assumed that this type of broadband service subscribers are divided into 3 (three) categories, namely the regular user, high-end users and premium users. So that the distribution of packet classification based on categories of customer service is assumed as shown in Table 5:

The calculation of potential revenue is shown in Tabel 6:

Investment Cost: Similar to analysis of DTTB services, investment cost for mobile broadband services is limited to investment cost for the base station system devices (Table 7).

Investment cost shown above is valid only for 1 Base Station. So, it needs to count the number of BS needed to serve the Greater Jakarta area by using some of the following considerations:

- Cell Radius Coverage for mobile broadband services at a frequency of 790 to 862 MHz is 2,698 km [6]
- So the coverage area per base station 1 is 45,7134 km^2
- Area of the Greater Jakarta is 5,798 km^2
- The number of base stations required is 127 base stations
- The need of investment cost added with upfront fee for spectrum license of IDR 160,000,000,000,-

Total investment costs = (127 x IDR 763,950,801) + IDR 160 billion = IDR 257,021,751,727,-

Operational Cost: Operational cost used in this research is limited to the operational cost of electricity and the cost of rights of use the radio frequency or spectrum fee (Table 8).

Operational costs for 127 Base Stations = 127 x IDR 138,524,100,- = IDR 17,592,560,652,-

Results and Analysis

Number of Channels per Multiplex: Before performing the optimization process, several assumptions need to be specified. The assumptions are as follows:

- UHF band observed is in the range of 470 to 806 MHz. This band is currently allocated for analog TV.
- Guardband between type of services amounted to 16 Mhz
- Channel bandwidth for DTTB services is 8 MHz
- Channel bandwidth for mobile broadband services is 5 MHz

The linear programming as given in Eq (5) – (8) with the values is given below.

Maximize: $3.004.689.277.046x_1 + 2.693.742.141.267x_2$
With constraints:

$3.208.750.000\,x_1 + 51.404.350.345\,x_2 \le 3.289.878.422.106$
$65.091.509\,x_1 + 3{,}518{,}512{,}130\,x_2 \le 225.184.776.350\ 8\,x_1 + 5\,x_2 \le 320$

The function of the linear programming above yields the following values:

$x_1 = 36.04$
$x_2 = 6.33$

Table 9: UHF Channel Occupancy in Greater Jakarta Area

No	TV Station	Channel
1	B Channel	23
2	Empty	24
3	Cipta Megaswara TV	25
4	Space Toon	27
5	Tranc TV	29
6	Empty	30
7	TVRI	31
8	O Channel	33
9	Elshinta Jakarta Televisi	35
10	Empty	36
11	TPI	37
12	TVRI	39
13	Indosiar	41
14	Empty	42
15	RCTI	43
16	SCTV	45
17	ANTV	47
18	Trans 7	49
19	Global TV	51
20	TV One	53
21	Jak TV	55
22	Metro TV	57
23	DAI TV	59
24	Nusantara TV	61

By evaluating the number of channels per multiplex we obtain the result that the number of channels per multiplex is 6 channels. This means that every multiplex can be used to accommodate 6 services TV content providers. So, the number of multiplex obtained by dividing the number of TV content providers (x_1) with the number of channels per multiplex or equal to 6.006 (rounded to 6).

Radio Frequency Channel Plan for DTTB Services: To make a radio frequency channel planning, we need to know the condition of the radio frequency channel occupied by the existing analog TV stations. Table 9 shows the occupation of frequency channels by the existing analog TV stations in Greater Jakarta area of service:

Considerations in Planning a Radio Frequency Channels:

- Required grouping of frequency channels to accommodate the needs of the channel in each service area by taking into account factors such as technical restrictions of co-channel interference and adjacent-channel interference
- Grouping of channels arranged in such way that makes the transition from analog to digital broadcasting system can run smoothly, such as analog TV is still able to conduct simulcast (simultaneously with the analog TV broadcasting to digital TV broadcasts). In other words, the digital channel is set as closely as possible not to collide with the channel that is not currently occupied by existing analog TV.

Figure 5 shows grouping of channels for DTTB services by considering the 2 (two) to the above considerations:

Thus, the allocation of spectrum in the UHF band for terrestrial DTTB and mobile broadband is shown in Fig. 6.

GROUP	Kanal ke-1	Kanal ke-2	Kanal ke-3	Kanal ke-4	Kanal ke-5	Kanal ke-6
GROUP A	22	26	30	34	38	42
GROUP B	23	27	31	35	39	43
GROUP C	24	28	32	36	40	44
GROUP D	25	29	33	37	41	45

Fig. 5: Channel Grouping for DTTB

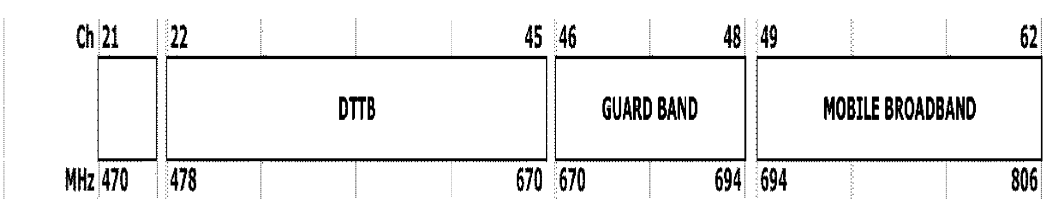

Fig. 6: Spectrum Allocation for DTTB and Mobile Broadband

CONCLUSIONS

Digital dividend spectrum is the spectrum which is available as a result of the migration of analog TV broadcasting to digital TV. If the migration can be fully implemented, then the spectrum can be used for DTTB services or other terrestrial applications. Therefore, the effort required to perform an optimal relocation of the digital dividend spectrum utilization.

Results from this study provide the frequency spectrum allocation for 192 MHz (channel 22 to 45), thus still allowing the use of spectrum that was originally used by analog TV broadcasts at 112 MHz (channel 49 until channel 62) for the mobile broadband services.

REFERENCES

1. Djamhari Sirat, Denny Setiawan, Muhammad Feriandi Mirza, 2009. *A Basic Framework Analysis on the Needs of Radio Frequenct Spectrum Allocation at Ultra High Frequency (UHF) Band for Digital Terrestrial TV Broadcasting in Indonesia,* Jakarta.
2. Direktorat Jenderal Pos dan Telekomunikasi, *Decree of the Minister of Transportation No. KM. 76 of 2003 on the Master Plan of the Radio Frequency for the Special Telecommunication Purposes for Analog Television Broadcasting on UHF Band*, Jakarta.
3. Setiawan Denny, Gunawan Dadang, Sirat Djamhari, *Interference Analysis of Guard Band and Geographical Separation between DVB-T and E-UTRA in Digital Devidend UHF Band*, Jakarta.
4. Spectrum Value Partners, 2008. *Final Report: Broadcast Migration Study, Optimizing DTT Delivery in Europe to Maximize the Gains from Digital Dividend*, London.
5. Direkrorat Jenderal Pos dan Telekomunikasi, 2007, *Draft Roadmap Konvergensi Infrastruktur TIK*, Jakarta.
6. International Telecommunication Union, 2009, List of IMT System Characteristics for Use in Sharing Studies in the Band 790 – 862 MHZ
7. Analysis Consulting Limited, et. al., 2006, *Final Report for OFCOM, Preparatory Study for UHF Spectrum Award*, London.
8. Budiarto Hary and Tjahjono Bambang Heru, 2007. *Sistem TV Digital dan Prospeknya di Indonesia*, Jakarta, PT. Multikom Indo Persada.
9. OFCOM, 2006. *Digital Dividend Review,* London