Planning and analyzing DVB-T technology in Pulo Aceh using high altitude platform station

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Abstact. The development of telecommunication technologies has shown remarkable improvement rapidly in this decade, one of which is in information computer and telecommunication technology. On the other hand, the services can be provided with the advance of information technology has not reached all levels of society. In Indonesia, geographic and demographic factors are among the obstacles that limit the dissemination of information. This generally occurs in remote areas such as Pulo Aceh region. To solve the problem, this study proposes a solution to overcome the isolation of information. The technology chosen for the dissemination of information is the Digital Video Broadcasting-Terrestrial (DVB-T) using High Altitude Platform Station (HAPS) technology to provide the services. The implementation of HAPS technology is expected to be able to be used as an alternative for minimizing the high cost of terrestrial infrastructure investment. This discussion is devoted to the planning of implementing HAPS in Pulo Aceh to serve the needs of communication to that community. Based on ITU recommendation, the results show that the analysis of link budget calculation with elevation angle, 34.06^0 has met the standard requirement. It can be concluded that Pulo Aceh can be served by a single HAPS both in terms of capacity and coverage area.

Keywords: HAPS, DVB-T, link budget, capacity, coverage area

Introduction

Nowadays digital technology has been deployed throughout all aspect of human life, including television broadcasting. A number of countries including U.S, Japan and other European nations started to implement digital broadcasting. Analog receivers and equipment will be eventually phased out and no longer be used as digital broadcasting technology become standard throughout the world. The TV broadcasting digitalization has more advantage compared to analog broadcasting, such as better picture and sound quality, high resistance of disturbance and channel effisiency. Digital broadcasting system that has been developed in Europe is Digital Video Broadcasting-Terrestrial (DVB-T). In the implemetation, the wireless telecommunication infrastructure technology which is called HAPS (High Altitude Platform Station) is offered as a wireless communication media to cope with an area that applied DVB-T system.

HAPS is one of telecommunication facilities that provides broadband telecommunication service such as broadcasting service (Aragon, 2008). HAPS is designed to operate on the area at altitude up to 22 km which is on the stratosphere (Tozer & Grace, 2001). The advantage of HAPS is that it is recoverable (Fourie 2009), means it can be returned to the earth make it easy to be maintained, fixed, modified, and up-graded. In the advance development, HAPS is accepted by International Telecommunication Union (ITU) as an alternative method to serve IMT-200/UMTS (International Mobile Telecommunication System 2000/Universal Mobile Telecommunication System). Using HAPS, DVB-T can benefit the use of bandwidth efficiently. A satellite transponder used to be applied to one TV programme only, using DVB-T it can serve eight digital TV channels.

DVB-T and HAPS Technology

DVB-T as Digital Broadcasting System

DVB-T is a transmitter system used to transmit TV broadcast/Digital video to the end user. One popular standard in Europe and other countries is DVB (Digital Video Broadcasting) standard. The DVB-T standard has become successful for broadcasting of television services to terrestrial devices. Its flexible parameters allow optimal reception for fixed or mobile devices (Bürklin, et al.. 2007). Digital data used in DVB standard is a compressed data in MPEG-2 format (Sugaris & Reljin, 2011). This format is chosen based on the consideration of the good quality of the compression, and from the commercial point, it gives more profit. Besides that, MPEG-2 format has become a standard in digital video system as in DVD format.

As shown in Figure 1, DVB-T technology is known well as the digital TV broadcasting, has been a standard that is widely implemented. There are some of the advantages, especially the reability of DVB-T that can transmit a large amount of data on a high rate by point-to-multipoint. The digital modulation used in DVB-T is Orthogonal Frequency Division Multiplexing (OFDM) technique with Quadrature Phase Shift Keying (QPSK), 16-QAM or 64-QAM (Biro & Borbely, 2010). Using this system, the bandwidth utilization (around 6 – 8 MHz) can be efficient as it allows one channel for several contents.

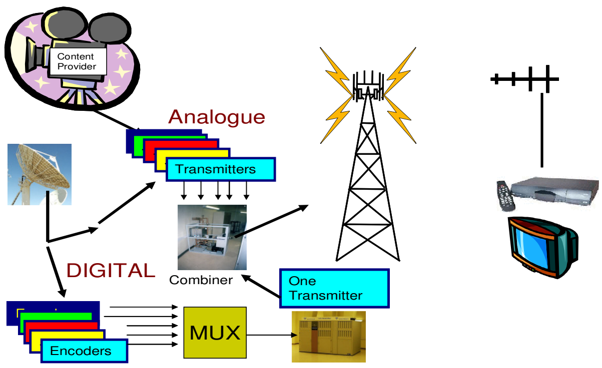

Figure 1 The scheme of DVB-T system (Roddy, 2006)

On the receiver unit, it needs a digital receiver system like Set-Top-Box (STB) functioning to accept DVB-T modulated signal and process it so that the broadcast signal can be seen in the regular tv. STB equipment has the same construction and function as the satellite receiver/decoder like the one belong to Indovision or Astro, only that this equipment is quickly installed to the ordinary antenna.

HAPS communication System

HAPS is a telecommunication infrastructure technology that provide a broadband telecommunication service or other wireless services like broadcasting. One HAPS can cover a wide service area, depend on the altitude of HAPS and the receiving elevation of the end user.

A communication system based on HAPS can be composed basically of two main elements: a stratospheric segment and a ground segment. The stratosphere is part of the Earth's atmosphere. The HAPS ground segment supports operations between the HAPS and users on the ground, as well as controlling some functions related to the operation of the HAPS itself (Aragon, 2008).

Simply, the concept of HAPS communication is a user on the earth is connected to a telecommunication network by means of repeater or base station that installed to a platform placed on the air. On the network, HAPS is connected to a gateway forwarded to a terrestrial network. The function of HAPS is just like an earth station base, only that it is placed on the earth, or like the function of satellite but with altitude only 20-50 km.

HAPS Configuration

A HAPS network has star configuration where HAPS as the main conjunction. The system is designed to provide variable rate, full duplex, digital channels to houses and offices.

Payload on HAPS transmitted multiple spot beam to the earth and provide service for certain coverage area. User terminal is a portable equipment to communicate with the payload directly. A user terminal consists of an antenna unit and a digital interface unit.

Gateway station is placed there so that the user can access public network like PSTN. The system is designed to allow gateway station to be placed in the location under the coverage area. The amount of the gateway station on the earth also can be added as demanded. The system on the earth consists of gateway station and HAPS control centre. An interface multitude is required to link the gateway station to the public network.

HAPS Frequency

Based on Recommendation of World Radio Conference (WRC-97, Geneva), frequency band allocated for HAPS in the Fixed Service is 47.2-47.5 GHz and 47.9-48.2 GHz. According to the following recommendation (WRC-2000-Istanbul), it is also being allocated frequency band of 27.5-28.35 GHz and 31-31.3 GHz for the countries that have high rainfall. ITU is considering the possibility of the utilization of frequency 3-18 GHz for HAPS operational to achieve better HAPS performance. The allocation of the frequency is 3-7 GHz for mobile service and 7-18 GHz for fixed service. The frequency chosen for uplink communication is 7 GHz and for downlink communication is 8 GHz.

Design and Parameters

This research has been carried out using analytical approach and formula. The planning process is done by collecting data from relevan source such as survey and literatures: maps, regulations, text book, and scientific paper.

Parameter of Radio Wave Communication

The propagation of radio signals between HAPS and ground equipment is affected by the aeronautical channel in several ways, but the most important effect is related to the multipath phenomena and therefore with the availability of the radio link. The scenario to consider for this HAPS communication system uses radio wave as the transmition media. Following are the theory of several parameter used in radio wave communication.

EIRP

Effective Isotropic Radiated Power (EIRP) is the transmitted power by the transmitter with certain antenna gain. It is approached as follow (Pratt & Bostian, 1986):

$$\text{EIRP} = (P_t - L_f) + G_t \quad \text{(dBW)} \qquad (1)$$

where, P_t : transmitted power (dDW)
G_t : transmitter antenna gain (dB)
L_f : feeder loss (dB)

Frees Space Loss

If an antenna transmits equal power to all direction, then the power received by the receiver is not exactly equal to the power transmitted by the transmitter, but along the transmission it sustains free space loss and can be calculated as follow (Pratt & Bostian, 1986):

$$L_{fs} = 20 \log_{10}\left(\frac{4\pi R}{\lambda}\right) \qquad (2)$$

where, L_{fs} : Free Space Loss
R : the distance between the transmitter antenna and the receiver antenna (m)
λ : wavelenght (m)

Rain attenuation

Rain attenuation is expressed as (Pratt & Bostian, 1986):

$$A_r = aR^b \times L \; db \qquad (3)$$

where, A_r : rain attenuation (dB)
aR^b : specific attenuation, which is the attenuation of electromagnetic wave that pass through the rain in every unit of distance (dB/km). *a* and *b* are the

coefficient that depend on the frequency, polarization, temperature, rainfall and other factors.

L : effective length of propagation path affected by the rain.

The value of coefficient *a* and *b* are (Pratt & Bostian, 1986):

$$a = \begin{cases} 4.21x10^{-5} f^{2.42}, & 2.9 \le \mathrm{f} \le 54\ \mathrm{GHz} \\ 4.09x10^{-2} f^{0.699}, & 54 \le \mathrm{f} \le 180\ \mathrm{GHz} \end{cases}$$

$$b = \begin{cases} 1.41 f^{-0.0779}, & 8.5 \le \mathrm{f} < 25\ \mathrm{GHz} \\ 2.63 f^{-0.2772}, & 25 \le \mathrm{f} < 164\ \mathrm{GHz} \end{cases}$$

Atmosphere attenuation

Atmosphere attenuation is an absorbtion of oxygen and steam. This atmosphere attenuation is expressed by (ITU-R P.530-10, 2001):

$$A_a = \gamma_a L \text{ dB} \tag{4}$$

where, A_a : atmosphere attenuation (dB)
γ_a : specific attenuation (dB/km)
L : propagation path length (km)

Received power

The power received is the total power transmitted by the transmitter antenna to the receiver antenna after encounter the attenuation along the propagation.

In an ideal condition, the power received is (Pratt & Bostian, 1986):

$$P_r = EIRP + G_r - L_{fx} \quad \text{dBW} \tag{5}$$

where, P_r : power received (dBW)
EIRP : Effective Isotropic Radiated Power (dBW)
G_r : receiver antenna gain (dBi)
L_{fx} : free space loss (dB)

Elevation angle

Elevation angle is the angle formed by the propagation path from HAPS to the earth station and the horizontal line of the earth surface (perpendicular to the line from the earth station to the earth centre). Elevation angle and the height of the HAPS effects the propagation path length. The relation of the elevation angle and the height of HAPS with the propagation path length is stated as:

$$L^2 = (re + h)^2 + re^2 - 2re(re + \mathrm{h})\cos y$$

$$L^2 = (\mathrm{re}+\mathrm{h})^2 + \mathrm{re}^2 - 2re(re + \mathrm{h}) \times \sin[El + \sin^{-1}\left(\frac{re}{re+h}\cos El\right)] \tag{6}$$

where, L : propagation path length (km)
re : earth radius = 6378 km
h : HAPS altitude (km)
El : elevation angel (degree)
γ : angle between HAPS to center of earth (in degree)

Coverage area

Coverage area is the scope of area that can be served by one HAPS. From the minimum operational elevation angle and height of HAPS, the radius of the coverage area for one

HAPS can be determined. The radius of the coverage area can be calculated using the following equation:

$$R = re\left[ar\cos\left(\frac{re}{re + h}\cos(El) \right) - El \right] \qquad (7)$$

where, R : radius of the coverage area
re : radius of the earth = 6378 km
El : minimum operational elevation angle (degree)
h : the height of HAPS (km)

Link Budget Calculation

Link budget calculation is done to find out the quality of signal of the HAPS communication system. The quality of the signal is presented by the parameter C/N, which is the rasio of received carrier signal power to noise power. C/N is expressed as follow (Pratt & Bostian, 1986):

$$C/N = P_r / P_n \quad (8)$$

where, P_r : received carrier signal power (W)
P_n : noise power (W)

Noise power can be calculated using the following equation:

$$P_n = kT_sB\ (W)$$

(9)

where, k : Boltzman constant = 1,38 x 1^{-23} J/K
T_s : noise temperature (K)
B : bandwidth spectrum (Hz)

Data Analysis and Discussion

Location of Pulo Aceh

Pulo Aceh which is one of the remote island located at the tip of Sumatera has an area of 240.75 km^2. Pulo Aceh subdistrict consists of three *mukim* namely: Pulau Breuh Utara, Pulau Breuh Selatan, and Pulau Nasi; has 17 villages with a population 3739 inhabitants as recorded in 2009. The majority of the population which are fishermen and farmers do not have adequate telecommunications infrastructure. Expected with the availability of telecommunication facilities and services are useful for the development of this area.

As islands, Pulo Aceh district store various places of natural attractions that have not been explored. Tourist attraction with its white sand beaches and marine tourism with a variety of ornamental fish and coral reefs, is a huge potential and opportunity to develop. Pulo Aceh strategic areas, providing an attraction for investors to build oil and gas shelter before being shipped to the destination country.

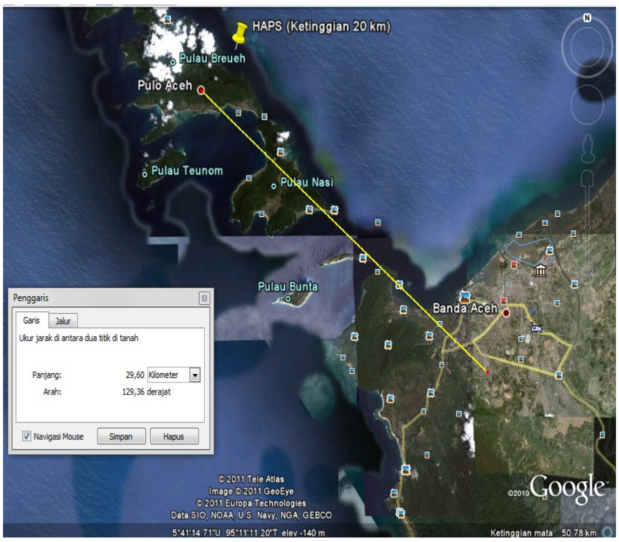

Figure 2. The distance between Banda Aceh and Pulo Aceh

Elevation angle between Banda Aceh and Pulo Aceh, it can be approached using a simple trigonometry formula:

$$\text{Tan } \theta = \frac{20}{29{,}6}$$
$$= 0{,}676$$
$$\theta = \text{Arc tan } (0{,}676)$$
$$\theta = 34{,}06^0$$

And then the distance of Banda Aceh and Pulo Aceh can be calculated as follow:

$$R = 6378 \sin\left[ar\cos\left(\frac{6378}{6378+20} \cos(34{,}06) \right) - 34{,}06 \right]$$
$$= 28{,}21 \text{ km}$$

Parameter and link budget calculation

HAPS specification and earth terminal are assumed with HAPS specification as recommended by ITU-R F.1569 for HAPS with frequency 28/31 GHz with altitude 20 km as shown in Tabel 1. Link budget calculation is needed to find how much power required in the system.

Table 1. Parameter of HAPS and earth terminal (ITU-R F.1569)

HAPS	**Terminal Bumi**
Altitude: 20 km	Elevation Angle: 20°
Frequency: 7 GHz	Antenna height: 0,02 km
Bandwidth: 20 MHz	Receiver Antenna: Technical Receiver Loss: 2,5 dB Feeder Loss: 0,5 dB Gain: 29,5 dB Temperatur Noise: 500°K
Transmitter Antenna: Output power: -14,5 dB Feeder Loss: 0,5 dB Gain: 29,5 dB	

In this paper, the parameter specification of earth terminal and HAPS is according to ITU-R F.1569 for downlink and uplink communication considering rain fade and no rain. While the planning location for earth terminal is at Pulo Aceh, with latitude coordinate 5^0 40′50,22″ south dan 95^0 05′53,90″ west, C/N_o threshold (QPSK, BER=1 x 10^{-6}) is 76,7 dB(Hz). Following is HAPS link budget calculation using frequency 3-18 GHz to overcome the high rainfall in Indonesia specially in Pulo Aceh.

Analysis of signal quality

Based on the result of link budget calculation as shown in Table 2, it can be analyzed that HAPS implementation in Pulo Aceh using specification from ITU at band 7/8 GHz, it is can be deployed either with rain or no rain fade. Both with and without rain attenuation, C//No value can meet the C/No threshold value. For HAPS with altitude 20 km and elevation angle 34.06° as shown in Tabel 2, the result of C/No with rain attenuation is 108.83 dB(Hz) on the downlink (DL) direction and 115,91 dB(Hz) for uplink (UL). While link margin calculation for rain condition shows the value for downlink is 32.13 dB and for uplink is 39.21 dB. With no rain condition, HAPS at altitude 20 km and elevation angle 20°, C/No value for downlink is 108.91 dB(Hz) and for uplink is 115,99 dB(Hz). Whereas the link margin for no rain condition shows the value for downlink is 32.21 dB and 39.29 dB for uplink.

Table 2 Link Budget of HAPS at band 7/8 GHz elevation angle $34{,}06^0$

Propagation loss:				
Free Space Loss	104.68	105.84	140.68	105.84
Rain attenuation	7.60	8.90	0	0
Atmosphere Gas Attenuation	0.10	0.10	0.017	0.017
Receiver Antenna:				
Gain (dBi)	35	29	35	29
Feeder Loss (dB)	0.50	0.50	0.50	0.50
Technical Receiver Loss (dB)	2.50	2.50	2.50	2.50
Received Power(dBW)	-92.78	-84.24	-92.70	-84.16
Noise Temperature (^{o}K)	500	700	500	700
Noise Spectral Density (dBW/Hz)	-201.61	-200.15	-201.61	-200.15
C/No (dB(Hz))	108.83	115.91	108.91	115.99
C/No (required) (QPSK,BER=1 x 10^{-6})	76.7	76,7	76.7	76,7
C/N (dB)	-37.19	-30.11	-37.11	-30.03
Link Margin (dB)	32.13	39.21	32.21	39.29

Conclusions

Based on the results of calculation and analysis has been done, it can take some some conclusions:

1. HAPS is a communication system that uses a vehicle communication system (platform) in air at a height up to 22 km and an alternative communication system in addition to satellite and terrestrial systems.
2. Implementation of DVB-T technology using HAPS provide efficient use of frequency spectrum so that it can better meet the needs of the provision of programs broadcast multiple times more than analog broadcasting.

3. HAPS elevation angle and height of the earth's surface also affects the coverage area of HAPS itself. The greater the angle of elevation and lower HAPS position of the earth's surface, will cause the coverage area becomes smaller.
4. HAPS specifications on the frequency of 7/8 GHz with elevation angles 34.06^0 was feasible planning in Pulo Aceh, because of the link budget calculation results demonstrate the value of C/No is obtained to meet the required value.

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