Vsat Bandwidth Efficiency on Satpath System

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Abstract:- Satellite communication, especially VSAT, is still become the main option in establishing long distance communication. VSAT utilizes satellite transponder as the media in transmitting and receiving information. It is necessary to have a transponder management system to efficient the use of bandwidth capacity which is very limited. Bad transponder management could be minimized by the advent of Satpath System. Satpath is a DAMA-based telecommunication service. This research aim is to analyze the bandwidth efficiency of Satellite Palapa D Transponder 5 Vertical on every poll of Satpath System. In this work, these items are calculated: Remote Total Efficiency, Remote Inbound Channel Total Efficiency, and Empty Bandwidth Efficiency by using Threshold method.

Keywords:- *Bandwidth, DAMA, Efficiency, Satpath, VSAT.*

I. INTRODUCTION

The rapid development in the use of satellites as a communication medium requires a good transponder management to maximize the use of the available bandwidth on the satellite. Poor transponder management results in wasted bandwidth usage.

Therefore, we need to analyzed the efficiency that occurs in the transponder channel in a VSAT communication using the Satpath System. In addition to the Satpath System, examples of systems used in VSAT communication are SCPC/SCPC+, MCPC, and Broadband.

The Satpath system exists to correct transponder management errors caused by calculation errors in utilizing limited transponder bandwidth. The Satpath system is a VSAT communication system utilizing SCPC+ technology.

The method used is a DAMA technology-based method that utilizes unused bandwidth to maximize a communication line in order to increase the number of remotes in a very limited bandwidth of the transponder bandwidth.

II. SATELLITE COMMUNICATION BASIC PRINCIPLES

A. Satellite Communication System

The basic principle of satellite telecommunications systems is a radio communication system using satellites as repeaters.

The main part of a satellite communication system consists of ground segment and space segment. Ground segment is all devices contained in the earth station while space segment is a satellite that is in its orbit. In general earth stations can function as transmitters or receivers.

Space Segment is the part when a signal is transmitted in the form of radio waves to the satellite. These radio waves are called uplink. Earth Segment is the part where there are receiver/transmitter stations on earth. Radio waves emitted from satellites to the Earth Segment are called downlinks. When an earth station sent a signal to a satellite, the signal will be received by the transponder that is on the satellite. This transponder will allocate the frequency sent by the sending station. The signal sent by the sending station is still in high frequency. On the transponder, this signal will be lowered and will be sent again to the earth receiving station. [5].

B. Satellite Orbit

Geostationary orbit is an orbit where the satellite looks relatively fixed when viewed from a point above the surface of the earth. Satellites that are in orbit are often referred to as geostationary satellites. In geostationary satellites, satellites will have an orbit of 0º. In addition, satellites must orbit the earth in the same direction as the earth's rotation and the same speed. To achieve this constant speed, Kappler II's law must be made which fills the circular orbit. The height of the satellite from the surface of the earth is 35,768 Km. While the radius of the earth is 6.378,14 Km. The travel time of a satellite that is in a geostationary orbit is 23 hours 56 minutes in one rotation of the earth. [6]

C. Satellite Transponder

Carrier signals are received by satellites at very low power levels because of the distance traveled by radio waves. Satellites require an additional signal power level before transmitting back to earth to ensure that the signal can be detected by an earth station receiver. Communication satellites can be considered as remote repeaters whose function is to receive the uplink carrier, process it, and retransmit that information to the downlink.

Modern satellite communication consists of multichannel repeaters (transponders) composed of several components, including filters, amplifiers, frequency switches, switches, multiplexers, and hybrids.

D. Satellite Transponder Frequency Allocation

Table 1 shows the frequency allocation that is generally used for satellite communication. Generally, the higher the frequency, the more susceptible to rain attenuation, and the more expensive the equipment needed. However, congestion generally occurs at low frequencies and then rises to higher frequency operations.

Band Frequency	Uplink	Downlink
L-Band / S-Band	2.483 to 2.50 GHz	1.610 to 1.625 GHz
C-Band	5.925 to 6.425 GHz	3.7 to 4.2 GHz
Ka-Band	14.0 to 14.5 GHz	11.7 to 12.2 GHz
Ku-Band	27.5 to 30.5 GHz	17.7 to 21.7 GHz

Table 1:- Satellite Transponder Frequency Allocation [9]

The most popular satellite frequency band is the C-Band (4.2 to 6.425 GHz) because the signal at this frequency is not affected by rain and it is free of interference from terrestrial microwave signals. The total number of transponders is 24, while the bandwidth of each transponder channel is 36 MHz and guard-band 4 MHz. If calculated linearly, will get 24 transponders × (36 + 4) MHz = 960 MHz. That is, for 24 transponders with 36 MHz on each transponder with a guard-band size of 4 MHz, the total channel bandwidth is 960 MHz. But in fact with 500 MHz the need for channel bandwidth is fulfilled. That means it can save channel bandwidth by almost half. This happens because there is a wave polarization (electromagnetic) that can be utilized, namely that two waves whose polarization is perpendicular to each other will be isolated from each other. The amount of this isolation factor is around 30 dB or one thousandth. In other words, two signals can use the same frequency as long as the polarization is different 90°. With this phenomenon, it can save channel bandwidth by half. [2][3]

E. Transponder Management

Transponder comes from the words Transmitter and Responder. The basic function of the transponder is receiving RF signals from the earth, filtering, frequency conversion, canalization, amplifying and sending RF signals back to earth. Transponders management is done to adjust the bandwidth of the limited bandwidth with the power used. The ideal conditions, good transponder management is shown in Figure 1.

In Figure 1, shows that the role of transponder management largely determines whether the bandwidth channel that will be used is efficient. The condition is said to be ideal if the bandwidth consumption and power consumption are the same as a percentage in each frequency. While transponder management errors can cause inefficient channel bandwidth usage and power consumption that is too wasteful. [10]

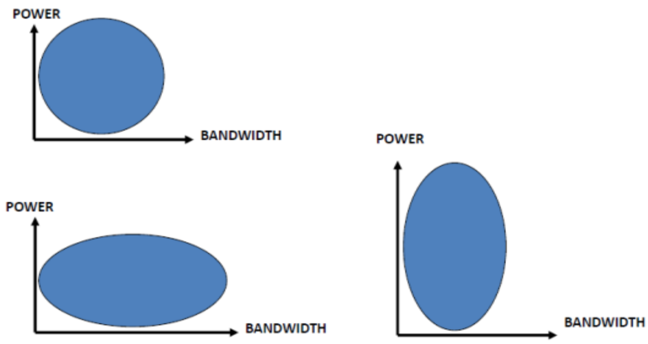

Fig 1:- Illustration of Transponder Management [10]

F. Very Small Aperture Terminal (VSAT)

VSAT stands for Very Small Aperture Terminal, a terminal used in satellite data communication, voice and video signals, not including broadcast television. VSAT consists of two parts, a transceiver that is placed outside (outdoor) that can be directly reached by satellites and a device placed indoors (indoor) that connects the transceiver with the communication devices of users, for example, the transceiver receives and sends signals to the satellite transponder in the sky.

VSAT communication network devices that are easily and quickly installed can not only provide high-quality data transmission but also flexible in network development. Using geostationary satellites causes the VSAT communication network to have a wide coverage area and does not need to track the direction of the satellite's movements so operational and maintenance costs are low. With a variety of advantages VSAT communication networks can provide solutions to increase data communication needs today.

Based on the service, VSAT is divided into 2 categories, namely VSAT Link and VSAT IP. Respectively, both VSAT Link and VSAT IP have advantages in operation. The difference between the two is as follows. [6]

- VSAT Link is a data communication service that uses satellite access media with SCPC (Single Channel per Carrier) technology. Types of VSAT Link relationships can be either Point to Point relationships or Point to Multipoint relationships. The VSAT Link service is suitable for: (1). Data communication includes LAN to LAN connections based on IP protocol, sending large files and images such as CAD/CAM and video files. (2). Voice Communication includes direct voice communication by telephone between the two locations (Direct Line). Besides voice communication through a private local central network (PABX). (3). Video communication. (4). Interactive communication through video and voice (video and voice conference)
- VSAT IP is a data communication service that uses satellite access media with Time Division Multiplex (TDM)/Time Division Multiple Access (TDMA)

technology based on the Internet Protocol (IP) standard. The VSAT IP service is suitable for: (1). Transactional and interactive applications include inter-branch online, hotel/airplane ticket reservations, ATMs (Automated Teller Machines), small data traffic. (2). Remote terminal/telnet/terminal emulation application with centralization in the database, including data input, inventory control, Payment Point. 3). Web Surfing, including e-mail, Instant Messaging, File Transfer Protocol (FTP).

G. Multiple Accessions on VSAT Communication Systems

The advantage of satellite communication systems that are not owned by other communication systems is the ability to connect all earth stations together either multidestionally or point to point. Because one satellite transponder can be used by many earth stations together, a technique is needed to access the transponder to each earth station. This technique is called Satellite Multiple Access or satellite access method. There are 3 types of access methods used for satellite communication at this time, namely FDMA, TDMA and CDMA. This method is the simplest method and is used since the existence of communication satellites. Each earth station that uses the FDMA method known as SCPC (Single Channel per Carrier) uses one or more specific carrier frequencies throughout the service time.

The FDMA method is not used for low speed data transmission but for data transmission with speeds above 56 kbps. In the TDMA method, a number of earth stations use a satellite transponder by dividing in time fields. This division is done in a certain time interval, called a TDMA frame (TDMA frame). Each TDMA frame is further divided into a number of time slots. Information is entered in different time slots and transmitted periodically at the same time interval. [2][3]

H. Link Budget Parameters in Satellite Communication Systems

Link budget calculation in a satellite communication system is used to assess the quality of the link. The end result shows the percentage of power and bandwidth used by the system. Referring to the link budget, the parameter used is Effective Isotropic Radiated Power (EIRP). [2][3]

EIRP (Effective Isotropic Radiated Power) is used to express the transmission power from an earth station or satellite. EIRP earth station is symbolized by $EIRP_{SB}$ which has the equation:

$$EIRP_{SB} = P_T G_T \quad (1)$$

Or logarithmically:

$$EIRP(dBW) = 10\log P_T + 10\log G_T - 10\log L_S \quad (2)$$

where:
P_T = transmit signal carrier power in the transmitter antenna feeder (dBW)
G_T = transmitter gain antenna (dB)
L_S = loss attenuator

$EIRP_{Satellite}$ is included in the characteristics of the satellite in question. For $EIRP_{linier}$ ($EIRP_{SB}$ dan $EIRP_{SAT}$), can be written:

$$EIRP_{SBLinier}(dBW) = SFD + 10\log(4\pi d^2) + PAD - IBO_{Total} \quad (3)$$

$$EIRP_{SatLinier}(dBW) = EIRP_{SatSaturated} - OBO_{Total} \quad (4)$$

I. Introduction to the Satpath System

The Satpath system is one of the many system choices used in VSAT-based FDMA (Frequency Division Multiple Access) based communication. Configuration and operational settings, carried out in NMCS (Network Management and Control Server), are used to monitor the remotes inside. Figure 2 shows the position of the NMCS in the Satpath System network configuration, where the NMCS Satpath is within the scope of the HUB. HUB is a small earth station that functions as a remote control center in the scope of the HUB. [4][12][13]

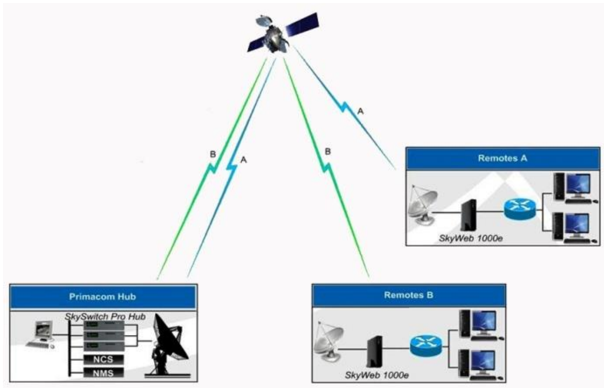

Fig 2:- Illustration of NMCS in Satpath System Network Configuration

J. Basic Threshold Concept

Threshold is a tolerance limit given to a value. The threshold, includes the upper threshold (maximum) and lower threshold (minimum). Threshold is a calculation of the maximum limit given. While the minimum threshold is the calculation of the minimum threshold. The existence of this threshold, provides a tolerance value for a range or range of values under study.

III. RESEARCH METHODOLOGY

The method used in this research is to conduct a literature study to obtain data, information, and existing references such as textbooks, handbooks, books, textbooks, and the internet as supporting material. In addition, data testing is done by calculating data, monitoring results data, and data capture, which is associated with DAMA technology in multiple FDMA access with a Network Management and Control Server (NMCS) platform that shows data in real-time.

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IV. RESULT OF RESEARCH

A. Bandwidth Channel Planning

In bandwidth channel planning, calculations are needed in allocating poll channels. The channel width of a poll depends on the need for the number of remotes to be generated in it. Bandwidth channel planning, is closely related to the configuration that will be done. The configurations include transponder configuration, HUB configuration, and remote configuration.

B. Configuring the Transponder Channel

Satellite defines poll as a range of frequency channels to be used by HUB terminals to generate remote. Poll is a collection of frequency bands provided by satellite operators. Frequency bands do not have to be adjacent bandwidth channels, but each band must be on the same transponder.

In Figure 3, it is known that the width of the Palapa D - 5 Vertical transponder bandwidth channel is 36 MHz, where the channel widths of each poll differ. For poll-1 channels is 6.91 MHz. For poll-2 channels, the bandwidth allocated is 4.925 MHz. Whereas the poll-3 channel is 5.025 MHz.

In Figure 4, seen in the Spectrum Analyzer, the width of the Palapa D - 5 Vertical transponder channel is 36 MHz along the frequency from 52.00 MHz to 88.00 MHz.

The division of the poll channel into 3 parts is part of a transponder management. This is due to the allocation of available bandwidth channels, making it possible to divide the poll channel into 3 parts. In ideal conditions, one poll channel in one transponder is far more efficient than 3 poll channels. However, the division of poll channels into 3 blocks has no effect on the quality of the given communication link.

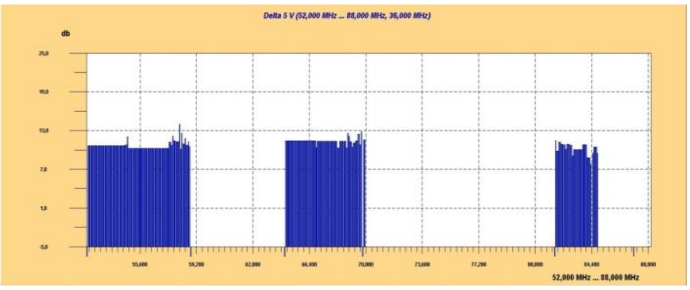

Fig 3:- Distribution of Poll Width in a Satpath System

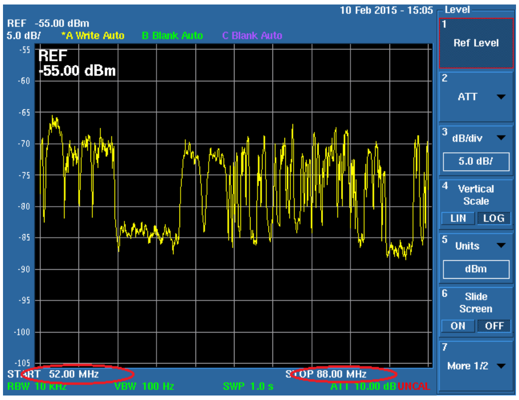

Fig 4:- Palapa D5 Transponder Width - Vertical Freq. 52.00 MHz to 88.00 MHz

C. HUB Configuration

HUB configuration, or commonly called a terminal configuration, is related to the Outbound capacity that will be generated in each poll. Outbound is a transmit carrier that will be passed by the data from the HUB to the remote. This Outbound Carrier will be seen by remote carriers which is transmitting to carry out communication without interruption.

Figure 5 shows that in the HUB configuration there are BOD and DAMA, the parameters that must be input are Low Rate (LIR) and High Rate (HIR), Threshold, Measure Time, Rate Increment, and Committed Rate (CIR). Low Rate (LIR) and High Rate (HIR) are the upper and lower limits of bandwidth usage for Outbound. Threshold is the threshold for bandwidth usage of the total allocated Outbound bandwidth. Measure Time is the maximum time used by a remote to perform carrier transformation on bandwidth. Rate Increment is the average data rate of data usage. [4][12][13]

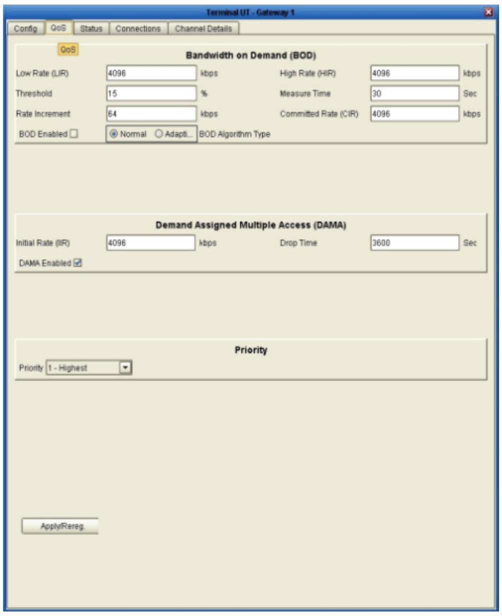

Fig 5:- HUB Configuration

The Committed Rate (CIR) is the maximum limit of data usage permitted on the remote. In addition, there is an Initial Rate where the capacity of data flow that will pass is always the same as the Low Rate (LIR). While the Drop Time in the HUB configuration is the amount of time that is tolerated by the remote if there is a down on the carrier Outbound side. If within the specified time the Outbound carrier is still in the down position, then the remote carrier will automatically die.

D. Remote Configuration

The transponder or HUB configured, and also the remote will be configured. Figure 6 shows that in the remote configuration there are several parameters that must be inputted. The parameters intended are Site Name, Site ID, Latitude, Longitude, G/T Antenna and Site EIRP.

Site Name and Site ID, inputted based on the remote location to be configured. Longitude and Latitude are HUB coordinates based on data from the Palapa D. Satellite. Remote network configuration is shown as in Figure 6. [4][12][13]

Table 2 shows the location coordinates of the cities of Jakarta and Balikpapan based on Palapa D Satellite data.

Country	City / Location	Long.	Lat.	EIRP	G/T	SFD
Indonesia	Daan Mogot	106.75	-6.15	43.07	1.35	-90.95
Indonesia	Jatiluhur	107.41	-6.52	43.06	1.27	-90.87
Indonesia	Balikpapan	116.83	-1.28	44.36	1.81	-91.41
Indonesia	Jakarta	106.8	-6.17	43.08	1.35	-90.95

Table 2:- Location Coordinates of Palapa D Satellite City Location

For Antenna G/T, the HUB antenna size is 4.5 meters, while for the antenna size at the location is 2.4 meters. Based on the antenna data used, an Antenna G/T for Jakarta can be set at 25.0 dB/K, referring to Table 3. The value is a fixed value. Table 3, shows the G/T Antenna values based on the size of the antenna used.

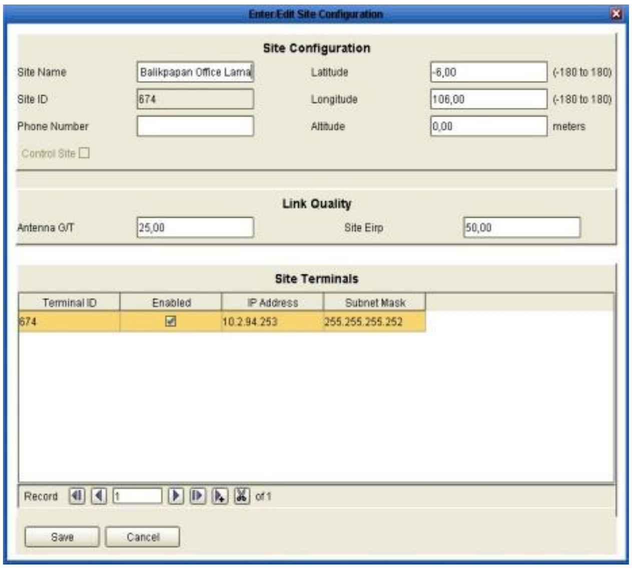

Fig 6:- Remote configuration

Diameter (m)	Tx Gain (dBi)	Rx Gain (dBi)	G/T (dB/K)
1.8	39.0	36.0	17.0
2.4	41.5	38.0	19.5
3.0	43.5	40.0	21.5
3.4	44.5	41.5	22.5
3.7	45.0	42.0	23.0
3.8	45.5	42.5	23.5
4.5	47.0	43.5	25.0
5.0	48.0	44.5	26.0
6.0	49.5	46.0	27.5
7.6	51.5	48.0	29.5
9.0	53.0	49.5	31.0
10.0	54.0	50.5	32.0

Table 3:- Tx Gain, Rx Gain and G/T Value Based on Antenna Size

EIRP (Effective Isotropic Radiated Power) is used to express the transmission power from an earth station or satellite. For the EIRP value on the remote configuration shown in Figure 6 above, it can be described based on equation (2.5).

Where is known the uplink = 6.125 GHz, aperture (antenna size) = 2.44 meter, desired antenna efficiency = 90%, expected EbNo = 11.0 dB, then:

Gain Transmit Antenna (G/T) $= \eta\left(\frac{\pi f d}{c}\right)^2$ × efficiency

$$= 10\log 10\left(\frac{\pi \times 6{,}125GHz \times 2{,}4m}{0{,}3}\right)^2 \times 90\%$$

= 43.43 dBi

Uplink Flange Power (PT) = 7.5 – 0.87

= 6.63 dBW

Then, based on equation (2.1) and equation (2.2), the EIRP value for the remote is:

EIRP (dBW) $= 10 \log PT + 10 \log GT - 10 \log LS$
$= 10 \log (6.63\ dBW) + 10 \log (43.43\ dBi) - 10 \log LS$
$= 50.06\ dBW \approx 50\ dBW$

Threshold is the threshold for bandwidth usage of the total bandwidth allocated and used by the remote to carry out carrier transformation. In its application, the Threshold value depends on the needs of the remote. In the calculation of the Threshold value used by the remote, a Threshold value of 15% is given and can be described as follows:

BW Tolerance $= Threshold(\%) \times BW_{Remote}(KHz)$
$= 15\% \times 64KHz$
$= 9.6\ KHz \approx 0.0096\ MHz$

So the maximum threshold and minimum bandwidth that can be used by the remote are:

BW Maximum $= BW_{Remote}(KHz) + BW_{Tolerance}(KHz)$
$= 64KHz + 9{,}6KHz$
$= 73.6\ KHz \approx 0.0736\ MHz$

BW Minimun $= BW_{Remote}(KHz) - BW_{Tolerance}(KHz)$
$= 64KHz - 9{,}6KHz$
$= 54.4\ KHz \approx 0.0544\ MHz$

E. Satpath System Configuration Connectivity

Grouping the remote into a group based on the similarity of parameters on each remote. Group network settings with thousands of remotes in terminals, simplified into a structured network so that each group will have the same connection. Therefore, the group that regulates it is called the Connection Group (CG). [4][12][13]

F. Demand Assigned Multiple Access (DAMA) and Bandwidth on Demand (BOD) / Adaptive Bandwidth on Demand (ABOD) on Satpath Systems

VSAT communication technology using the Satpath System presents its own uniqueness. Unlike technology that is carried by SCPC (Single Carrier per Channel) which uses PAMA (Permanent Assigned Multiple Access) technology where there are a pair of carriers, namely carrier Tx (transmit) and carrier Rx (receive), which stand permanently at work frequencies that have been determined, the uniqueness is precisely presented by the Satpath System that carries DAMA technology.

DAMA technology enables existing frequencies to automatically carry out carrier transformations on frequencies that are considered empty without having to sever existing communication links quickly in order to maximize bandwidth capacity within the scope of Inbound frequencies. [4][12][13]

G. Outbound and Inbound Frequency Measurement

In Figure 7 can be seen that the remote using poll-3 is transmitting. This is indicated by the green indicator lights, the EbNo obtained, and the existence of data traffic connectivity in the form of PING results from the HUB to the remote.

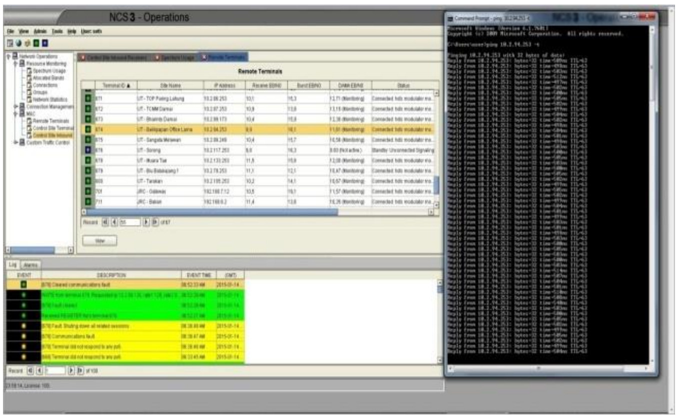

Fig 7:- Remote in Transmit Position

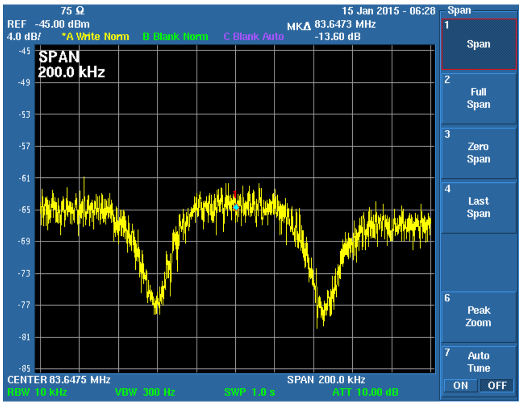

Fig 8:- Frequency of Remote Carrier in Spectrum Analyzer

In Figure 9, it can be seen that the Outbound HUB transmit frequency carrier is at the center frequency of 66.20 MHz in the Spectrum Analyzer, where the Outbound bandwidth is 2.048 MHz While in Figure 8, it appears that the carrier is a remote Inbound, at a center frequency of 83.6475 MHz

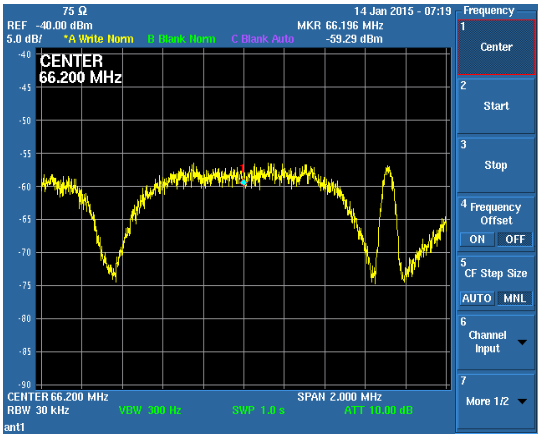

Fig 9:- Frequency of Carrier Outbound in a Spectrum Analyzer

In Figure 10, it can be seen that the operational frequency of Outbound, has experienced a center frequency shift caused by DAMA that works well. In Figure 9, it can be seen that the Outbound center frequency, which is 66.20 MHz, has experienced a shift to the center frequency of 67.5375 MHz as shown in Figure 10, where the width of Outbound bandwidth is 2.048 MHz

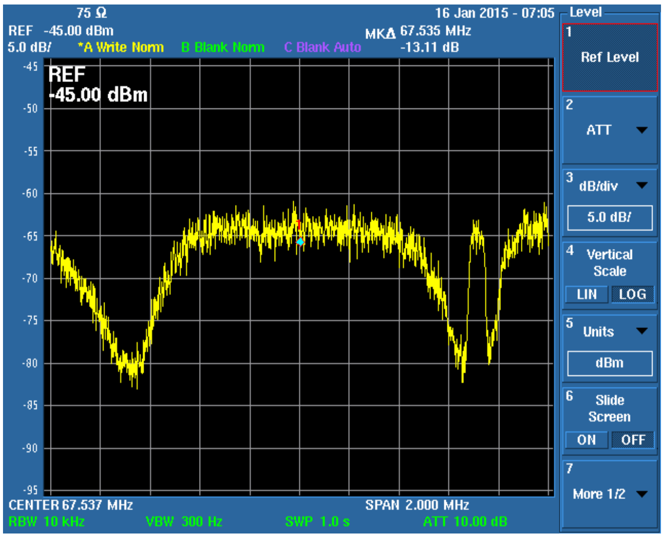

Fig 10:- Outbound Carrier Frequency in Spectrum Analyzers Experiencing Center Frequency Shift

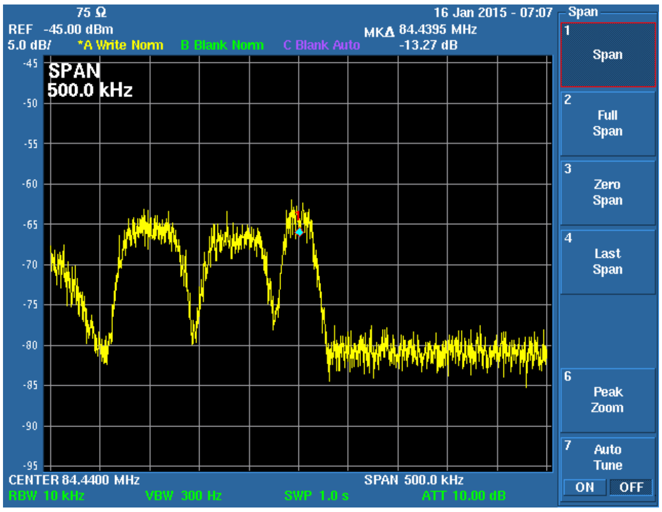

Fig 11:- Remote Carrier Frequency in a Spectrum Analyzer Experiencing a Frequency Center Shift

Whereas in Figure 11, it appears that the carrier is the Inbound remote, at a center frequency of 84.440 MHz which has experienced a center frequency shift of 83.6475 MHz as shown in Figure 8.

H. Efficiency of Remote Bandwidth Channels with the Threshold Method

To get the percentage (%) of bandwidth efficiency from the Satpath System, it is necessary to calculate the Threshold. Threshold is the threshold of the use of remote bandwidth used. By using 3 parameters, namely total remote efficiency, total efficiency of Inbound channels, and efficiency of empty channels (idle) on Inbound, it can calculate the amount of efficiency that occurs in each poll.

	Poll Width BW (MHz)	**Outbound Width (MHz)**	**Inbound Width (MHz)**	**BW Remote (MHz)**	**BW Min. Remote (MHz)**	**BW Max. Remote (MHz)**
Poll-1	6910	4096	2814	0.064	0.0544	0.0736
Poll-2	4925	4096	829			
Poll-3	5052	2048	2977			

Table 4:- Poll Width and Remote Bandwidth

With reference to Table 4, it can be calculated the Total Remote in each poll by using a normal Bandwidth of 0.064 MHz, a minimum Bandwidth of 0.0544 MHz, and a maximum Bandwidth of 0.0736 MHz. For poll-1 shown in Table 5, poll-2 is shown in Table 6, and poll-3 is shown in Table 7.

Total Remote Efficiency in Poll-1						
Inbound Width (MHz)	**BW Remote (MHz)**	**BW Min Remote (MHz)**	**BW Max Remote (MHz)**	**Total Remote BW = 0.064 MHz**	**Total Remote BW Min = 0.0544 MHz**	**Total Remote BW Max = 0.0736 MHz**
2814	0.064	0.0544	0.0736	43.97	51.73	38.23

Table 5:- Total Remote Efficiency in Poll-1

Total Remote Efficiency in Poll-2						
Inbound Width (MHz)	**BW Remote (MHz)**	**BW Min Remote (MHz)**	**BW Max Remote (MHz)**	**Total Remote BW = 0.064 MHz**	**Total Remote BW Min = 0.0544 MHz**	**Total Remote BW Max = 0.0736 MHz**
829	0.064	0.0544	0.0736	12.95	15.24	11.26

Table 6:- Total Remote Efficiency in Poll-2

Total Remote Efficiency in Poll-3						
Inbound Width (MHz)	**BW Remote (MHz)**	**BW Min Remote (MHz)**	**BW Max Remote (MHz)**	**Total Remote BW = 0.064 MHz**	**Total Remote BW Min = 0.0544 MHz**	**Total Remote BW Max = 0.0736 MHz**
2977	0.064	0.0544	0.0736	46.52	54.72	40.45

Table 7:- Total Remote Efficiency in Poll-3

Based on Table 5, Table 6, and Table 7, it can be seen the Total Empty Bandwidth (idle) shown in Table 8, Table 9, and Table 10.

Efficiency of Empty Bandwidth (idle) in Poll-1					
Total BW Remaining Remote with BW = 0.064 MHz	**Total BW Remaining Remote with BW Min = 0.0544 MHz**	**Total BW Remaining Remote with BW Max = 0.0736 MHz**	**Total BW Empty (idle) with BW = 0.064 MHz**	**Total BW Empty (idle) with BW Min = 0.0544 MHz**	**Total BW Empty (idle) with BW Max = 0.0736 MHz**
0.97	0.73	0.23	0.0621	0.0397	0.0169

Table 8:- Efficiency of Empty Bandwidth (Idle) in Poll-1

Efficiency of Empty Bandwidth (idle) in Poll-2					
Total BW Remaining Remote with BW = 0.064 MHz	**Total BW Remaining Remote with BW Min = 0.0544 MHz**	**Total BW Remaining Remote with BW Max = 0.0736 MHz**	**Total BW Empty (idle) with BW = 0.064 MHz**	**Total BW Empty (idle) with BW Min = 0.0544 MHz**	**Total BW Empty (idle) with BW Max = 0.0736 MHz**
0.95	0.24	0.26	0.0608	0.0131	0.0191

Table 9:- Efficiency of Empty Bandwidth (Idle) In Poll-2

Idle Bandwidth Efficiency in Poll-3					
Total BW Remaining Remote with BW = 0.064 MHz	**Total BW Remaining Remote with BW Min = 0.0544 MHz**	**Total BW Remaining Remote with BW Max = 0.0736 MHz**	**Total BW Empty (idle) with BW = 0.064 MHz**	**Total BW Empty (idle) with BW Min = 0.0544 MHz**	**Total BW Empty (idle) with BW Max = 0.0736 MHz**
0.52	0.72	0.45	0.0333	0.0392	0.0331

Table 10:- Idle Bandwidth Efficiency In Poll-3

As for the Total Efficiency of Inbound Channels, with reference to Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, it can be shown in Table 11, Table 12, and Table 13.

Total Efficiency of Remote Inbound Channels in Poll-1						
Inbound Width (MHz)	**Total BW Empty (idle) with BW = 0.064 MHz**	**Total BW Empty (idle) with BW Min = 0.0544 MHz**	**Total BW Empty (idle) with BW Max = 0.0736 MHz**	**BW Total Efficiency used with BW Remote = 0.064 MHz**	**BW Total Efficiency used with BW Remote = 0.0544 MHz**	**BW Total Efficiency used with BW Remote = 0.0736 MHz**
2814	0.0621	0.0397	0.0169	102.25%	101.43%	100.61%

Table 11:- Total Efficiency of Remote Inbound Channels in Poll-1

Total Efficiency of Remote Inbound Channels in Poll-2						
Inbound Width (MHz)	**Total BW Empty (idle) with BW = 0.064 MHz**	**Total BW Empty (idle) with BW Min = 0.0544 MHz**	**Total BW Empty (idle) with BW Max = 0.0736 MHz**	**BW Total Efficiency used with BW Remote = 0.064 MHz**	**BW Total Efficiency used with BW Remote = 0.0544 MHz**	**BW Total Efficiency used with BW Remote = 0.0736 MHz**
829	0.0608	0.0131	0.0191	107.94%	101.59%	102.40%

Table 12:- Total Efficiency of Remote Inbound Channels in Poll-2

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Total Efficiency of Remote Inbound Channels in Poll-3						
Inbound Width (MHz)	**Total BW Empty (idle) with BW = 0.064 MHz**	**Total BW Empty (idle) with BW Min = 0.0544 MHz**	**Total BW Empty (idle) with BW Max = 0.0736 MHz**	**BW Total Efficiency used with BW Remote = 0.064 MHz**	**BW Total Efficiency used with BW Remote = 0.0544 MHz**	**BW Total Efficiency used with BW Remote = 0.0736 MHz**
2977	0.0333	0.0392	0.0331	101.12%	101.34%	101.12%

Table 13:- Total Efficiency of Remote Inbound Channels in Poll-3

Based on the calculations performed in Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, Table 11, Table 12, and Table 13, the results are obtained in the form of bar charts, for the three polls that are shown as shown in Figure 12, Figure 13, and Figure 14 using research parameters namely Total Remote Efficiency, Total Inbound Remote Channel Efficiency, and Empty Bandwidth Efficiency, are as follows:

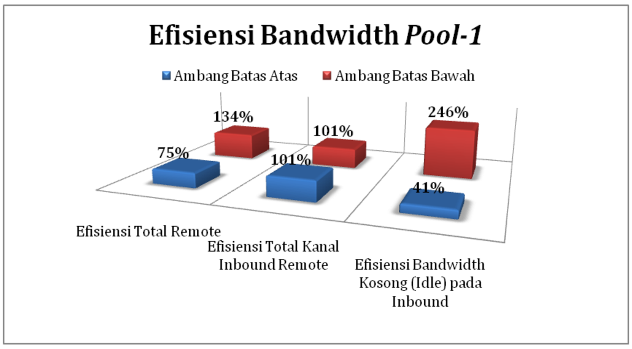

Fig 12:- Poll-1 Bandwidth Efficiency Based on Parameters

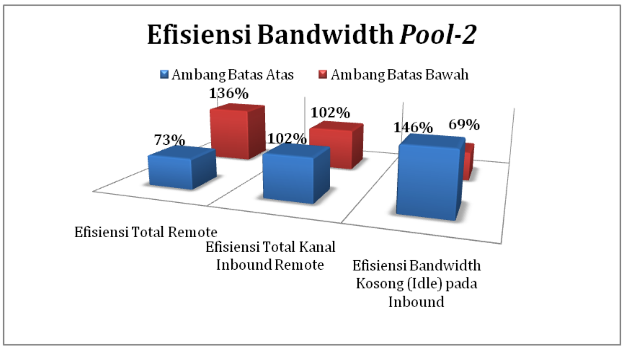

Fig 13:- Poll-2 Bandwidth Efficiency Based on Parameters

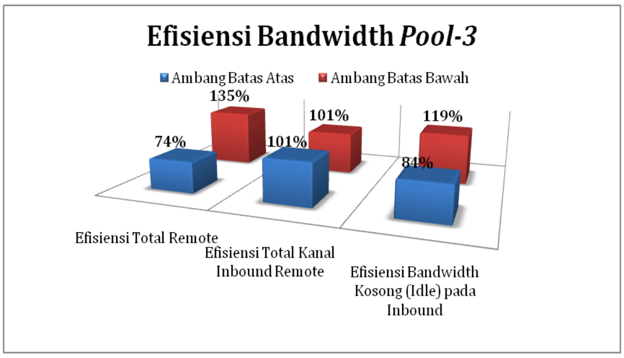

Fig 14:- Poll-3 Bandwidth Efficiency Based on Parameters

V. CONCLUTION

Based on the results of calculations and analysis that have been done, it can be concluded:

- Based on the parameters used in poll-1, poll-2, and poll-3, namely Total Remote Efficiency, it appears that efficiency occurs at the lower threshold of the total bandwidth used by the remote as evidenced by Poll-1's Total Remote Efficiency of 75%, Total Poll-2 Remote Efficiency by 73%, and Total Remote Poll-3 Efficiency by 74%.
- Based on the parameters used in poll-1, poll-2, and poll-3, namely the Total Efficiency of Inbound Remote Channels, it appears that efficiency occurs at the upper and lower threshold of the total bandwidth channel on the Inbound remote proven by Total Efficiency Inbound Remote Poll-1 Channel at 101%, Total Efficiency of Inbound Remote Poll-2 Channel at 102%, and Total Efficiency of Inbound Remote Poll-3 Channel at 101%.
- Based on the parameters used in poll-1 and poll-3, namely Efficiency of Empty Bandwidth (idle) on Inbound, it appears that efficiency occurs at the lower threshold as evidenced by Empty Bandwidth Efficiency (idle) on Inbound Poll-1 of 41%, Idle Bandwidth Efficiency at Inbound Poll-3 of 84%. Whereas in poll-2, efficiency actually occurs at the upper threshold of the total empty Inbound remote empty channel used as evidenced by the Empty Bandwidth Efficiency (idle) of Inbound Poll-2 of 69%.
- From the research parameters used, it can be concluded that the Total Remote Efficiency in each poll is directly proportional to the Total Efficiency of Inbound Remote Channels and inversely proportional to the Efficiency of Empty Bandwidth (idle) on Inbound.

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