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Analysis of Utilization Bandwidth and Power Transponder Extended C-Band on The Satellite Telkom 3S VSAT SCPC

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Abstract - On satellite communication systems, bandwidth and power are limited and expensive resources. Optimization of bandwidth and power utilization in Telkom 3S Satellite could be achieved if the ratio value of the percentage of bandwidth and power is 1:1. The optimization conditions are influenced by the calculation of the link budget, the use of appropriate modulation and FEC settings. QPSK and 8-PSK modulation techniques with FEC used are 3/4, 7/8, and 9/10 with a 9 m Hub antenna and VSAT SCPC with a diameter of 2.4 m with roll-off factor 0.5 and data rate of 1024 kbps. Based on the results of this research, the lower the modulation technique used, the lower the ratio of bandwidth and power. The most optimal FEC value to be used was 8-PSK modulation at FEC 93/100 with the resulting percentage was 97.25%, where the total carrier bandwidth generated was 93.415, and the amount of carrier power was 96.05, whereas was QPSK with FEC 3/4 by which producing a percentage of 35% which is in the limited power category. Thus, the most appropriate modulation used on the Telkom 3S Satellite is the 8-PSK modulation with an FEC of 93/100.

Keywords – QPSK, 8-PSK, FEC, VSAT SCPC, Roll-off factor 0.5, data rate 1024 kbps.

I. INTRODUCTION

A satellite communication system has a large capacity and has a high speed, and could reach into remote areas. In the operation of the satellite, bandwidth and power are the main parameters. There are two conditions for a transponder capacity, which could be bandwidth limited or power-limited. The best condition is when it is in optimum condition, where the percentage of bandwidth usage is equivalent to the percentage of power-limited usage [1].

Conditions for the availability of bandwidth and power are always different in percentage even though to achieve the optimum value, the value of bandwidth-limited must be the same as power-limited. To achieve the optimum value in a satellite transponder, parameters should be considered, such as choosing the right modulation technique, end-to-end link budget calculation. Bandwidth and power availability are very limited [2]. Then it is necessary to choose the right modulation technique, such as QPSK modulation technique, or 8-PSK modulation technique that will be used for the most appropriate comparison between the modulation techniques. Based on the economic value of PT. Aplikanusa Lintasarta the price of bandwidth and power is relatively expensive, it is necessary to calculate the end-to-end budget link calculation, and perform Error-Correcting Scheme (Forward Error Correction or FEC) measurements to optimize the use of bandwidth and power on the transponder, analyzing the effect of QPSK modulation techniques and 8-PSK in terms of bandwidth and satellite power, analyzing the influence of SCPC (Single Channel Per Carrier) for optimizing bandwidth and satellite power. The company's costs could be reduced to a minimum so that bandwidth and power usage could be used optimally.

This research examines the effect of modulation changes on bandwidth and link quality in satellite communication systems. The choice of modulation parameters *causes* changes in bandwidth requirements adjusted to the modulation technique used in this research using three modulation techniques including QPSK, 8-PSK, and 16-APSK which produce FEC values of 3/4 and produce data rate values of 8 Mbps. 16-APSK produces the most bandwidth values small, and more efficient with a bandwidth difference of up to 3886.18 KHz. In contrast, the use of 8-PSK modulation has a difference of 2590.83 KHz [3].

In the other examination, the performance of the modem used by PT. Metrasat on the Chinasat-11 satellite is measured. To find out the quality of PT. Metrasat, it is necessary to calculate the link budget first. The lower the modulation level used, the wider the bandwidth value [2].

Another research examines the feasibility analysis of modulation on Telkom-1 satellites in terms of bandwidth and power. The result is that the most appropriate modulation used on the Telkom-1 satellite for IDR services is the QPSK modulation technique that uses 3-meter antenna diameters, and the worst modulation used on the Telkom-1 satellite is the 16QAM modulation technique. The transponder capacity will be even greater when using a high-order modulation, this is viewed in terms of bandwidth, whereas if viewed in terms of power, the higher the modulation order, the smaller the transponder capacity [4].

Based on this background, the author conducts the analysis of bandwidth and power by comparison between QPSK and 8-PSK modulation techniques, with the calculation of an end-to-end budget link to get the optimum value of satellite transponders with the lowest possible cost on VSAT-SCPC conducted at Indosat Jatiluhur Earth Station, Purwakarta.

II. RESEARCH METHOD

This research analyzes the use of C-band bandwidth and power transponder on a particular satellite in order to obtain the value of satellite optimization using QPSK, 8-PSK modulation techniques, and simulations to show the signal results of the comparison between the two modulations. The simulation model implemented in this research uses the SatMaster program.

A. Bandwidth and Power

Bandwidth or width of a frequency band is a roll-off factor of the number of bits in a single symbol that is calculated into the speed of information (FEC). In calculating the bandwidth, there is a digital encoding that serves to detect and correct errors and correct BER, which will show errors in digital transmissions. The coding uses FEC coding. FEC will increase the number of bits sent so that the bit rate increases but does not extend the transmission time [4]

$$BWocc=\frac{\left(\frac{DR}{FEC}\right)}{Mod}\times(1+Rollofffactor) \quad (1)$$

$$SymbolRate=\frac{\left(\frac{DR}{FEC}\right)}{Mod} \quad (2)$$

Information :
DR : Data Rate (kbps)
FEC : Forward Error Correction [3]
Mod : Modulation
α : Roll-off factor ($0 \le \alpha \le 1$) [4]

In terms of bandwidth, it could be seen the number of carriers in one transponder that could be formulated as follows [4]

$$numberofcarrier=\frac{BW_{xpdr}}{BW_{ALL}} \quad (3)$$

Meanwhile, the power transponder operation can be calculated as follows (4),

$$Power_{Sat.Operation}=EIRP_{Sat.Saturation}-OBO \quad (4)$$

In terms of power, the number of carriers in one transponder can be formulated by (5),

$$numberofcarrier=EIRP_{Sat.Saturation}-OBO+Powerocc \quad (5)$$

$$comparisonofBW/PWR=\frac{numberofcarrierbandwidth}{numberofcarrierpower}\times 100\% \quad (6)$$

Information :
BW_{OCC} : Bandwidth Occupied
OBO : Output Backoff
BW_{XPNDR} : Bandwidth Transponder
$EIRP_{Sat.Saturation}$: Effective Isotropic Radiated Power Satellite saturation [4]

B. QPSK Modulation Technique

In QPSK modulation or Quadrature Phase Shift Keying, the carrier signal presents four phase states to express four symbols, with one symbol consisting of two bits namely "00", "01", "10", and "11". In QPSK modulation the value of m = 2, which means $2^m = 4$ [5]

C. 8-PSK Modulation Technique

The 8-PSK or Eight-state Phase Shift, Keying modulation technique, undergoes a phase change of 45° derived from the value of m = 3, $2^m = 2^3 = 8$ and then $\frac{360^\circ}{8} = 45^\circ$ so that the phase size produced by modulation 8 -PSK is 45°. The information bitrate is 3 times the speed of the symbol, in 8-PSK modulation it presents eight phases for eight symbols, with one symbol consisting of 3 bits, namely "000", "001", "011", "010", "110", "111", "101" and "100"[4]

D. Link Budget Calculation

a) Effective Isotropic Radiated Power (EIRP)

The EIRP will show the effective power emitted from an antenna that has its gain. If there is attenuation on the transmission line or there is a loss of feeder, then the EIRP value will be reduced [3].

$$EIRP = Pout\ HPA\ (dBw) + G\ antenna\ (dB) - IFL\ loss\ (dB) \quad (7)$$

EIRP prices could be reduced and enlarged by:

- Shortening or extending IFL value
- Reduce or enlarge the HPA output
- Shortening or extending IFL [6]

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b) System Noise Temperature (T)

The noise system T is a function of the noise temperature antenna. It has influenced by meteorological conditions and rain attenuation due to rising temperatures in the atmosphere. Meanwhile, the noise temperature in the antenna depends on the elevation angle. G / T is defined as the minimum value of the elevation angle and is in clean atmospheric conditions. At the earth station, the cleaner the G / T value will be better [7].

c) Gain to Noise Temperature (G/T)

The G/T value is usually used to indicate the performance relation between the earth station antenna and the LNA or Low Noise Amplifier to determine the quality of the downlink signal coming from the satellite. Gain to Noise Temperature or G/T, has two parameters, namely the G parameter and the T parameter. The G parameter itself is the receiver antenna gain based on the LNA (Low Noise Amplifier) input value, while the T parameter is the system noise temperature at the earth station based on the LNA (Low Noise Amplifier) [8].

d) Elevation Angle

Elevation angle is the angle formed from the local horizon plane with LOS (Line of Sight) of the Earth Station towards the satellite direction with the zero point located in the local horizon plane with the direction of rotation upward [9].

$$E = tan^{-1} \quad (8)$$

Information:
cos l : cos station latitude value
cos L : earth station's longitude reduction value with the longitude of the satellite[6]

e) Azimuth Angle

The angle between the north direction line and the line towards the satellite projection point in the local horizon plane of the earth station is the azimuth agle. To calculate the satellite elevation angle, use the following (9)[9],

$$A_z = tan^{-1} \frac{b}{c} \quad (9)$$

b : | longitude SB-longitude satellite |
c : latitude Earth Station[7]

E. Telkom 3S Satellite

Satellite communication has an extensive reach that could reach remote areas. Telkom 3S Satellite is a satellite owned by Telkom Indonesia in GEO (Geostationary Earth Orbit) orbit. Telkom 3S satellite has a circular path with the same axis of rotation as the earth and placed in a position above the equator. Telkom 3S Satellite Coverage is the territory of Indonesia, Southeast Asia, and parts of East Asia. Telkom satellite launch on February 15, 2017, at 04.39 WIB at Guiana Space Center, Kourou, French Guiana, by using the Ariane 5 ECA VA235 rocket owned by the satellite launch company, Arianespace Europe. Telkom 3S satellite is in an orbital position 118° with a satellite age of 17 years and with a mass of 3550 kg [10].

F. VSAT SCPC (Single Channel Per Carrier)

SCPC or Single Channel Per Carrier is a form of transmission of satellite communication where the transmission process is carried out on a single carrier that has been predetermined. In SCPC, you can uplink the same transponder from many locations[11].

In SCPC, satellite communication can be operated analog or digital, if analog, then using FM (Frequency Modulation). Meanwhile, it can also be digitally using PSK modulation or Phase Shift Keying [12].

SCPC has the principle of using access based on frequency division [13]. To carry out the processing of signal channel modulation a separate RF carrier, which is then trasmitted to FDMA Transponder. SCPC has a carrier that is divided into two operating modes as follows:

1. Pre- Assigned FDMA, the frequency slots are pre-assigned to the Earth stations. The slot allocations are pre-determined and do not offer flexibility. Hence, some slots may be facing the problem of over-traffic, while other slots are sitting idle
2. Demand Assigned FDMA the transponder frequency is subdivided into a number of channels and the Earth station is assigned a channel depending upon its request to the control station. [14].

G. Power-Limited and Bandwidth-Limited

Fig.1 is a graph of the optimization of bandwidth and power values to specify whether the transmission values in the modulation and the FEC used are included in the bandwidth- or power-limited. Bandwidth and power usage will be specified for achieving optimization if the ratio between the two is 1:1. Power-limited is a condition in which satellite transmission uses too much power, so it does not reach the optimization value.

Fig.2 represents a power-limited condition where the condition exceeds the 1:1 ratio limit. This could be seen in the pink graph above the ratio of power-limited and bandwidth-limited, while the bandwidth-limited condition could be seen in Fig. 3.

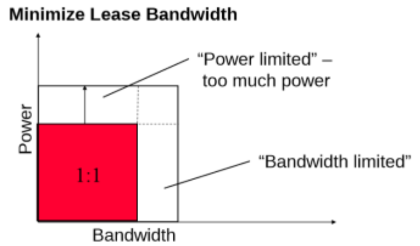

Fig.1. Power-Limited and Bandwidth-Limited Grap [15]

The following is a power-limited condition graph:

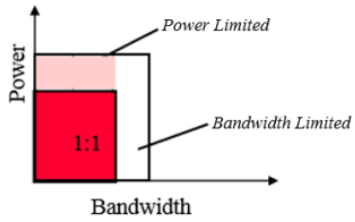

Fig.2. Power-Limited Graph [15]

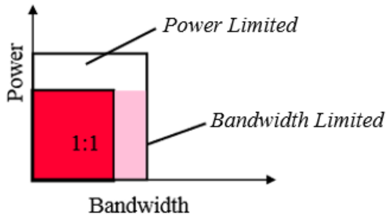

Fig. 3. Bandwidth-Limited Graph [15]

It is categorized bandwidth-limited if the value of the ratio between power and bandwidth is not 1: 1; this means the bandwidth used exceeding what it should be. Bandwidth limited values could be seen on the pink raph to the side.

H. SatMaster Setting of Telkom 3S Satellite

In this research, link budget calculation is used with formulas and SatMaster software in Table 1. The purposes of using the SatMaster software are to get the accuracy of the results of using link budget calculation with formulas, and then compare the result of the formulas with SatMaster software. If it's the same, it is precise.

Table 1. SatMaster Setting of Telkom 3S Satellite

No.	Parameter	Calculation Result	SatMaster Result	Deviation (%)
1	G/T	2 dB/K	2 dB/K	0
2	Elevation	74.986°	75.36°	0.496
3	Azimuth	59.485°	59.83°	0.576
4	Gain antenna uplink	54.428 dBi	53.82 dBi	1.117
5	Gain antenna dowlink	37.403 dBi	36.80 dBi	1.612
6	Transmit EIRP	68.0388 dBW	68.73 dBW	1.005
7	Free Space Loss Uplink	199.714 dB	199.76 dB	0.046
8	System Margin	2 dB	2 dB	0
9	Symbol Rate	367.025 kSps	0.3670 Mbaud	0.0068
10	Bandwidth Occupied	385.376 kHz/carrier	0.3854 MHz	0.0062
11	Percentage transponder bandwidth used	1 %	1.39 %	28.057
12	Percentage transponder power used	2.17 %	2.17 %	0 %
	Limited by : power equivalent bandwidth usage			

III. RESULT

Utilization of bandwidth and power analysis is performed using two modulation techniques, namely QPSK, and 8-PSK with FEC values of 3/4, 7/8, and 93/100 at a data rate of 1,024 Mbps. Satellite transmission is performed using a 9 m diameter hub antenna and a 2.4 m diameter VSPC SCPC loopback using a Teledyne Paradise Datacom Satellite Modem. Based on the results of the Telkom 3S satellite transmission, the carrier signal is obtained using QPSK modulation on the FEC 3/4 as shown in Fig. 4.

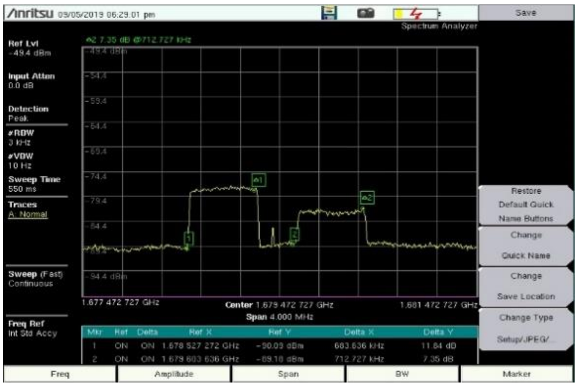

Fig. 4. Carrier Signal on the QPSK Modulation FEC 3/4

The transmission of the satellite is also using the 8-PSK modulation with FEC of 93/100. The carrier signal is shown in Fig. 5.

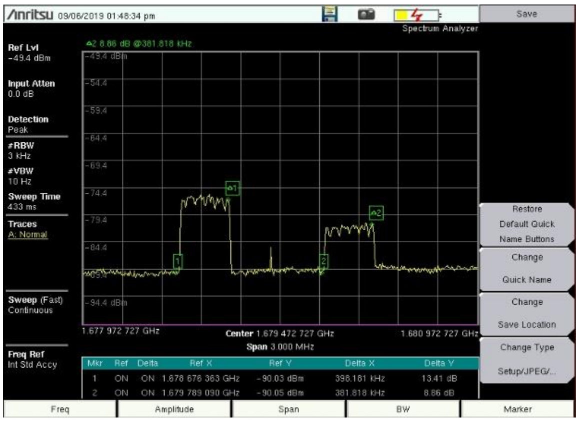

Fig. 5. Carrier Signal on the 8-PSK Modulation FEC 93/100

The following of Table 2 is the result of link budget calculation in terms of bandwidth occupied and some carrier bandwidth percentage.

Meanwhile, the number of carrier power could be seen on Table 3.

Table 2. Number of Carrier Per Modulation in Terms of Bandwidth

	Modulasi QPSK			**Modulasi 8-PSK**		
Data Rate 1024 kbps	**3/4**	**7/8**	**93/100**	**3/4**	**7/8**	**93/100**
	50.223 carrier	58.593 carrier	62.276 carrier	75.335 carrier	87.890 carrier	93.415 carrier

Table 3. Number of Carrier Per Modulation in Terms of Power

	DATA RATE: 1024 kbps					
	QPSK			**8-PSK**		
FEC	**3/4**	**7/8**	**93/100**	**3/4**	**7/8**	**93/100**
HUB	96 crr	95.9 crr	95.72 crr	96.16 crr	96.28 crr	96 crr
REM	95 crr	95 crr	94.67 crr	95.49 crr	95.58 crr	96 crr

IV. DISCUSSION

In Fig. 4, it could be seen that the shape of the more significant carrier signal represents the carrier signal generated by the 9 m hub antenna. In comparison, the one next to it was representation of the 2.4 m diameter antenna. The bandwidth value obtained in the QPSK modulation with FEC of 3/4 is 683.636 kHz on the 9 m antennae, while the 2.4 m antenna is 712.727 kHz. Meanwhile, occupied bandwidth, which has been calculated using QPSK FEC 3/4, produces a value of 716.8 kHz. The bandwidth value is obtained from the calculation of the formula and satellite transmission is almost the same. The C/N value obtained by 9 m diameter antenna using QPSK modulation FEC of 3/4 is 11.84 dB, which is included in the good link category. Whereas, for 2.4 m antennas get a C/N value of 7.35 dB while the results of the calculation produced the value of $(C/N_0)^{-1}_{Up.HUB}$ is 15.34 dB and $(C/N_0)^{-1}_{Dn.REM}$ is 13.35 dB.

The bandwidth value obtained in Fig. 5 for the 8-PSK modulation with FEC of 93/100 is 398.181 kHz on the 9 m antennae, while in the 2.4 m antennae, the value is 381.818 kHz. The value generated from the results of satellite transmission is 381.818 kHz. In comparison, the results of the calculation of the formula are 385.376 kHz, so the bandwidth values obtained from the calculation results of the formula and satellite transmission are almost the same then the exact value for the formula calculation. The power obtained at 9 m antenna is -90.03 dBm, and at 2.4 m antenna is -90.05 dBm. The C/N value obtained at the 9 m antenna is 13.41 dB, which is included in the good link category. Meanwhile, for 2.4 m antennas gain a C/N value of 8.86 dB. The value of C/N is useful to calculate the $(C/N)^{-1,}$ and it produces the result of $(C/N_0)^{-1}_{Up.HUB}$ is 16.91 dB and $(C/N_0)^{-1}_{Dn.REM}$ is 14.86 dB.

The following is the comparison between bandwidth and power on 8-PSK modulation with FEC of 0.93.

- Power receive on antenna diameter of 9 m is 90.03 dBm = 90.03 -30 = 60.03 dBW
- Power recive on antenna diameter of 2.4 m adalah 90.05 dBm = 90.05-30 = 60.05 dBW

- *Number of carrier pwr*$_{(Hub)}$
  $= (EIRP_{Sat.Saturation}\text{-}OBO)+PowerOccupied$
  $= (42\text{-}6)+60.03$
  $= 96.03$ carrier
- *Summary carrier power*$_{(Remote)}$
  $= (EIRP_{Sat.Saturation}\text{-}OBO)+PowerOccupied$
  $= (42\text{-}6)+60.05$
  $= 96.05$ carrier

So,

- *comparison between bandwidth* $\wedge$ *power*$_{(hub)}$
- $= \dfrac{summary\ carrier\ bandwidth}{summary\ carrier\ power} \times 100\%$
  $= \dfrac{93.415}{96.03} \times 100\%$
  $= 0.9723 \times 100\%$
  $= 97.23\%$
- *comparison between bandwidth* $\wedge$ *power*$_{(hub)}$
  $= \dfrac{Summary\ carrier\ bandwidth}{Summary\ carrier\ power} \times 100\%$
  $= \dfrac{93{,}415}{96{,}05} \times 100\%$
  $= 0.9725 \times 100\%$
  $= 97.25\%$

QPSK modulation with FEC 3/4 on the hub obtained 52.2% results with the number of carrier Bandwidth of 50.223 carriers, and the number of carrier power of 96.09 carriers, and the remote obtained a percentage of 52.7%. Thus, the worst modulation to use is QPSK with FEC of 3/4. Whereas the most optimal modulation to be used is 8-PSK FEC of 93/100 with the results on the hub of 97.23% with a total carrier bandwidth of 93.415 carrier, and a total carrier power of 96.03 carriers, and on the remote, the results are 97.25 % where both achieve optimization conditions and reach a ratio of 1:1 for bandwidth and power. Following is the calculation of the ratio of bandwidth and power in QPSK modulation with FEC of ¾.

The value of power using the QPSK with FEC of ¾.

- Power receive on antenna diameter of 9 m is 90.09 dBm = 90.09 - 30 = 60.09 dBW.

- Power receive on antenna diameter of 2.4 m is 89.18 dBm = 89.18 - 30 = 59.18 dBW.
- *Number of carrier power*$_{(Hub)}$
  $= (EIRP_{Sat.Saturation} - OBO) + PowerOccuied$
  = (42-6)+60.09
  = 96.09 carrier
- *Summary carrier power*$_{(Remote)}$
  $= (EIRP_{Sat.Saturasi} - OBO) + PowerOccupied$
  = (42-6)+59.18
  = 95.18 carrier

So,

- *comparison between bandwidth* $\wedge$ *power*$_{(hub)}$

$$= \frac{Summary\ carrier\ bandwidth}{Summary\ carrier\ power} \times 100\%$$

$$= \frac{50.223}{96.09} \times 100\%$$

$$= 0.522 \times 100\%$$

$$= 52.2\%$$

- *comparasion bandwidth* $\wedge$ *power*$_{(hub)}$

$$= \frac{summary\ carrier\ bandwidth}{summary\ carrier\ power} \times 100\%$$

$$= \frac{50.223}{95.18} \times 100\%$$

$$= 0.527 \times 100\%$$

$$= 52.7\%$$

In the calculation of the transmission that is done, produce a value that could be categorized into power-limited, namely QPSK modulation with FEC ¾. Meanwhile, the most optimal modulation is 8-PSK modulation with FEC of 93/100.

In VSAT SCPC (Single Channel Per Carrier), each PAMA type is modulated by a single voice or from low to medium bit rate data. In voice transmission, the carrier signal is voice allocation and only uses 40% power or saves 60% power on satellite transponders. However, based on the results of direct satellite calculation and transmission. It is obtained that the excess power usage in the QPSK modulation with FEC is ¾ where the number of carrier power that is obtained, in Table 3, the hub is 96.09 carrier, which is greater than the number of carrier bandwidth produced by 50.223 carriers and on the remote. The number of carrier power is 95.18 carrier in Table 2, while the number of carrier bandwidth is 50.223 carriers. In this research also obtained optimal condition namely using 8-PSK modulation with FEC of 93/100 and obtained a ratio of 1:1 with a total carrier power of 96.03 carriers and a total carrier bandwidth of 93.415 carriers at the hub, and the number of carrier power amounted to 96.05 carriers, and the number of carrier bandwidth is 93.415 carrier.

V. CONCLUSION

Based on the obtained results for which subject to research objective, it can be concluded that calculation of the link budget is done by using the formulas of the calculation, which is then compared using the SatMaster software, the best modulation is used for 8-PSK with FEC of 93/100 the percentage of bandwidth using a formula is 1%, and for SatMaster is 1, 39%. Meanwhile, the percentage of power generated is 2.17% either in formula calculations or with SatMaster software. FEC settings are performed using the Teledyne Paradise Datacom Satellite Modem. Based on the analysis of the link budget by changing the FEC parameters equal to 93/100 on the 8-PSK modulation, the percentage of power and bandwidth is 97.23% for the hub, while for the remote is 97.25%.

The lower the modulation used, the lower the percentage value of the bandwidth and power ratio by using the same FEC value. In this study, the best modulation to be used was 8-PSK at FEC of 93/100, with a percentage of 97.23% at the hub, while at the remote at 97.25%. Meanwhile, the worst to use is QPSK with FEC of ¾ with a percentage of 52.2% on the hub, while on the remote of 52.7%. Based on the calculation of the percentage of bandwidth and power, it is concluded that the transponder has limited power, then the maximum number of carriers that can be occupied in one transponder is 96.03 carriers. Using VSAT SCPC could save power transponder usage by about 60% if the selection of modulation and FEC is correct. If it is not right, it will cause an overload of power so that way the transponder could be saturated.

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