JURNAL ILMIAH METADATA, E-ISSN :2723-7737, Vol.7 No.2
Edition May 2025, Published : 30-05-2025, Page: 349-356
DOI: 10.47652/metadata.v7i2.646

BIT ERROR RATE ANALYSIS ON POWER LIMITED PAIRED CARRIER MULTIPLE ACCES TURBO PRODUCT CODE VERY SMALL APERTURE TERMINAL (VSAT)

by
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ABSTRACT

Bit Error Rate (BER) is one of the main parameters in assessing the performance of digital communication systems. In this research, BER analysis was carried out on the Paired Carrier Multiple Access (PCMA) Very Small Aperture Terminal Single Channel Per Carrier (VSAT SCPC) scheme which was applied to the Turbo Product Code (TPC). PCMA is a transmission technique that allows the use of limited power to increase frequency spectrum efficiency, while TPC is used as an error correction technique to increase the reliability of data transmission. Conventional VSAT SCPC requires two carrier frequencies to communicate while PCMA SCPC only requires one carrier frequency so it is more efficient in bandwidth usage. There are two possibilities for SCPC PCMA, namely Power Limited or Bandwidth Limited. This research discusses how SCPC Power Limited is converted into bandwidth limited and its effect on transponder efficiency and the resulting Bit Error Rate (BER). The research results show that changing power limited to bandwidth limited SCPC PCMA Turbo Product Code increases bandwidth efficiency but reduces the quality of the bit error rate.

Keyword: SCPC PCMA, Power Limited, Bit Error rate

ANALISIS TINGKAT KESALAHAN BIT PADA SISTEM AKSES MULTI-CARRIER BERPASANGAN DENGAN BATASAN DAYA DAN KODE PRODUK TURBO UNTUK TERMINAL APERTUR SANGAT KECIL (VSAT)

ABSTRAK

Bit Error Rate (BER) merupakan salah satu parameter utama dalam menilai kinerja sistem komunikasi digital. Dalam penelitian ini, analisis BER dilakukan pada skema Paired Carrier Multiple Access (PCMA) Very Small Aperture Terminal Single Channel Per Carrier (VSAT SCPC) yang diterapkan pada Turbo Product Code (TPC). PCMA adalah teknik transmisi yang memungkinkan penggunaan daya terbatas untuk meningkatkan efisiensi spektrum frekuensi, sementara TPC digunakan sebagai teknik koreksi kesalahan untuk meningkatkan keandalan transmisi data. VSAT SCPC konvensional memerlukan dua frekuensi pembawa untuk berkomunikasi, sedangkan PCMA SCPC hanya memerlukan satu frekuensi pembawa, sehingga lebih efisien dalam penggunaan bandwidth. Ada dua kemungkinan untuk SCPC PCMA, yaitu Power Limited atau Bandwidth Limited. Penelitian ini membahas bagaimana SCPC Power Limited diubah menjadi bandwidth limited dan dampaknya terhadap efisiensi transponder serta Bit Error Rate (BER) yang dihasilkan. Hasil penelitian menunjukkan bahwa mengubah SCPC PCMA Turbo Product Code dari power limited menjadi bandwidth limited meningkatkan efisiensi bandwidth tetapi mengurangi kualitas bit error rate.

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Kata Kunci: SCPC PCMA, Power Limited, Bit Error

INTRODUCTION

In satellite communication systems, transponder capacity usage must take into account the availability of bandwidth and power. Its use must be efficient so that it does not occur that the bandwidth capacity is still available while the power capacity has been exhausted so that the remaining bandwidth that has not been used cannot be used. Efficiency can be done with a PCMA system that can operate under two circumstances, namely limited bandwidth and limited power. Bandwidth limited occurs when the bandwidth usage is greater than the power consumption (PEB). Meanwhile, Power limited is when the power consumption of the transponder (PEB) is greater than the bandwidth consumption.

In a conventional Single Channel Per Carrier (SCPC) system, two frequency spectrums are needed to communicate with each other. PCMA (Paired Carrier Multiple Access) technology is the most advanced invention in radio transmission technology today, where the same frequency spectrum can be shared by two ground stations in the same time slot so that the bandwidth occupied (bandwidth used) required by a pair of ground stations becomes half of the total bandwidth of conventional SCPC, or there is a doubling of the number of carriers. [1]

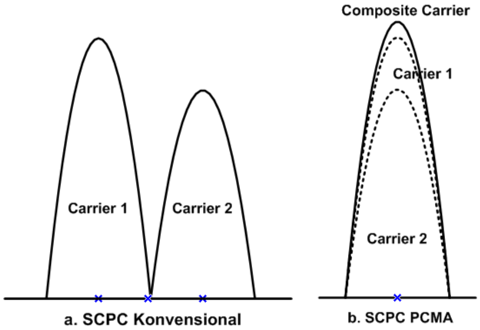

Figure 1 Conventional SCPC and PCMA Carrier signal frequency spectrum

The bandwidth of the transponder that can be occupied by a signal carrier is expressed by:

Bwocc = (1)$\left[\left(\frac{\text{Rinfo}}{\text{m.FEC}}\right)(1+\alpha)\right]$

Bwocc : Occupied Bandwidth (MHz)
Rinfo : data rate (Kbps)
m : number of bits per symbol (modulation index)
α : Roll of factor ($0 < \alpha < 1$)

Power Flux Density Calculation : [2]

PFD (dBW /m^2) = EIRPSB - FSL + Gi (2)

EIRPSB : Effective Isotropic Radiated Power Earth Station
FSL : Free Space Loss
Gi : Antenna gain per m^2

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BER is an important factor in determining and evaluating the performance and usefulness of the modulation scheme. In digital transmission, the performance measure can be measured in the Bit Error Ratio (BER), which is the ratio of the bits of error received to the total number of bits transmitted in a given time. [3] Simply formulated with:
BER = Errors / Total number of bits (3)
When BER transmission is greatly affected by noise, interference, wireless multipath fading, attenuation, and synchronization issues. BER can also be defined as Probability of Error (POE):

POE = (1- $\frac{1}{2}$yard) (4)$\sqrt{\text{Eb/No}}$

Where erf is an Error function, Eb energy is used to transmit a single bit and No Noise power spectral density. The error function is different for each modulation. POE is comparable to Eb/No which is another form of Signal to Noise Ratio.

Bishoy Rifaat Misdary Francis (Practical Evaluation of Carrier in Carrier Technique for Spectrum Utilization, Sudan University of Science and Technology, 2015) in his thesis compares the utilization of the frequency spectrum between conventional SCPC and PCMA. Using PCMA can save bandwidth by 50%. [4]

Akram Marseet and Ferat Sahin (Self Interference Cancellation for BandwidthcOptimization on Satellite Communications, 2017) compared the performance of a station that uses two different frequencies to transmit with a station that uses the same frequency. As a result, the performance of the two scenarios showed an SNR difference of less than 0.1 dB. The use of Self Interference Cancellation can save bandwidth by 50%. [5]

This research paper not only discusses bandwidth savings but also examines the limitations of transmission power required, what if the transmission power is lowered and its effect on the bit error rate and bandwidth efficiency produced.

RESEARCH METHODS

The research method was carried out through simulation by building a point-to-point SCPC VSAT installation using a 3.8 meter antenna on one side and a 2.4 meter antenna on the other. Data rate (data rate) 2048 kbps, Turbo Product Code (TPC) i.e. Encoder/decoder is based on the Vector Soft In Soft Out (VSISO) Algorithm. [6].

The first stage After the VSAT communication link is formed by marking a successful ping test in the remote direction between two routers and a test can be carried out. The second stage was to collect data by measuring occupied bandwidth and utilizing the use of Solid State Power amplifier power and calculating the use of satellite power transponders, both conventional SCPC VSAT and VSAT SCPC PCMA with several types of modulation and Forward Error Correction (FEC). The third stage of the measurement data is entered in a table to see if the operation is in bandwidth limited or power limited and calculate the resulting efficiency by comparing the conventional SCPC VSAT and SCPC PCMA. The fourth stage of VSAT, which operates in

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limited power, is lowered its power transmit little by little so that it can operate in limited bandwidth until the VSAT link is momentarily disconnected marked with a ping rto. This decrease in power results in an increase in the value of the bit error rate (BER) and then record the BER produced. The final stage is to calculate the efficiency produced and the results of the bit error rate to draw conclusions whether with the reduction of VSAT power transmit efficiency is still obtained by looking at the bit error rate and how much efficiency is produced and whether the SCPC PCMA VSAT link is still feasible to use

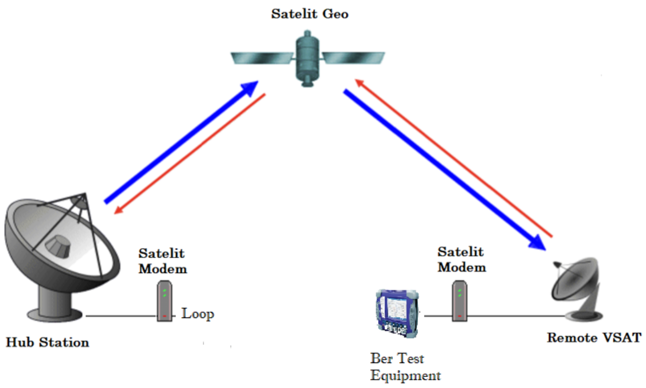

Fig. 2 Single Link VSAT Single Channel Per Carrier (SCPC)

RESULTS AND DISCUSSION

A. Result

The results of testing and measuring occupied bandwidth by changing modulation parameters and Forward Error Correction with a data rate of 2048 Kbps obtained the following data:

Table I Occupied Bandwidth

Type Carrier	Modulasi	Coding/ FEC	Occupied BW (KHz)
SCPC Konvensional	QPSK	TPC 3/4	3780
	QPSK	TPC 7/8	3196
	8PSK	TPC 3/4	2477
	8PSK	TPC 7/8	2246
	16QAM	TPC 3/4	1917
	16QAM	TPC 7/8	1662
SCPC PCMA	QPSK	TPC 3/4	1884
	QPSK	TPC 7/8	1583
	8PSK	TPC 3/4	1233
	8PSK	TPC 7/8	1106
	16QAM	TPC 3/4	943
	16QAM	TPC 7/8	822

The higher the bandwidth modulation rate, the smaller this is because the number of bits per symbol (modulation index) is larger. Meanwhile, Forward Error Correction (FEC) also affects bandwidth where the larger the FEC used, the smaller the bandwidth. M-Phase Shift Keying (MPSK) modulation uses a limit on the number of phases to modulate binary bits. Demodulators

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are specifically designed for symbols used by modulators to determine the phase of the received signal and remap the symbols it represents so as to recover the original data. The higher the M-PSK modulation scheme, the higher the error rate is also higher [7].

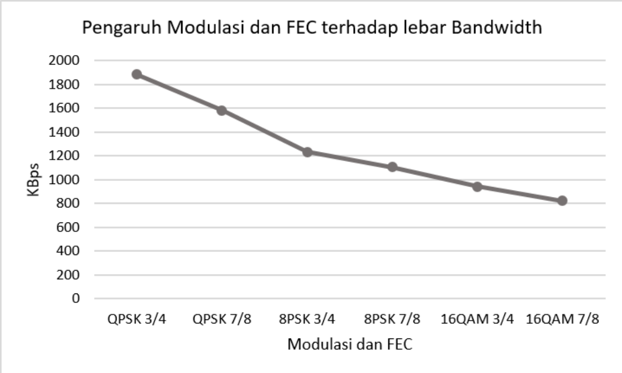

Fig. 3 Effect of Modulation and FEC on Bandwidth

The selection of parameters should not only consider bandwidth but also consider the power requirements to transmit the carrier signal from the ground station to the satellite and forward back to the destination ground station. In order for the carrier signal to reach the satellite, a power is required that depends on the parameters used, the gain produced, the attenuation that occurs and the target signal reception in the direction of the destination ground station. The signal reception target is marked with an acceptable Bit Error Rate (BER) value that is converted into a Bit Energy per Noise (Eb/No) value. Each parameter change requires a different Eb/No value for the same BER target. The code parameters used also greatly affect the required Eb/No value. The results of the measurement of the power output of the Solid State Power Amplifier (SSPA) with a BER level of 10-9 at the two VSAT remote sites are as follows:

Table II Power SSPA

Modulasi	Coding/ FEC	Power Output SSPA Site A (dBm)	Power Output SSPA Site B (dBm)	Eb/No (dB)
QPSK	TPC 3/4	38,62	39,77	5,3
QPSK	TPC 7/8	37,65	38,64	5,1
8PSK	TPC 3/4	41,24	41,74	7,6
8PSK	TPC 7/8	40,75	41,24	7,8
16QAM	TPC 3/4	42,02	42,98	9
16QAM	TPC 7/8	42,22	43,42	9,4

The higher the modulation level requires the larger Eb/No as shown in Figure 4

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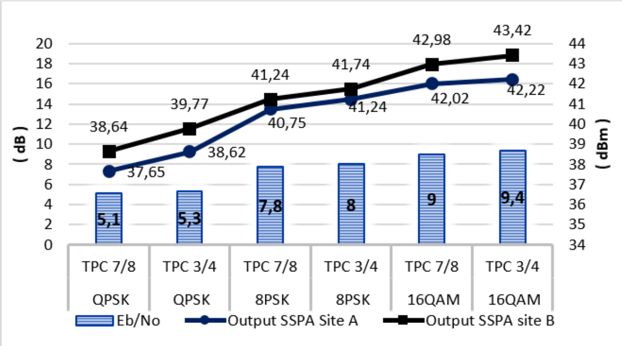

Fig. 4 Ouput Power SSPA

B. Discussion

Effective Isotropic Radiated Power (EIRP) is the amount of signal energy that comes out of the ground station's antenna reflector heading towards the satellite. The EIRP value is affected by the amount of power coming out of the antenna feed and the amount of antenna gain generated minus the damping on the antenna feeder. Meanwhile, Power Equivalent Bandwidth (PEB) is the power of a satellite transponder used by a signal carrier whose size is equal to bandwidth. PEB is related to the bandwidth capacity and power of the transponder used. Based on the results of the calculation of EIRP and PEB resulting from the following measurements:

Table III Power Equivalent Bandwidth

Modulasi	Code/ FEC	EIRP Site A (Watt)	EIRP Site B (Watt)	EIRP Total (Watt)	PEB (KHz)
QPSK	TPC 7/8	114,29	60,39	174,68	780,82
QPSK	TPC 3/4	142,89	78,34	221,23	988,9
8PSK	TPC 7/8	233,35	109,9	343,25	1534,29
8PSK	TPC 3/4	261,22	123,31	384,53	1718,81
16QAM	TPC 7/8	312,61	164,06	476,67	2130,68
16QAM	TPC 3/4	327,34	181,55	508,89	2274,72

In satellite communication systems, transponder capacity usage must take into account the availability of bandwidth and power. Its use must be efficient so that it does not occur that the bandwidth capacity is still available while the power capacity has been exhausted so that the remaining bandwidth that has not been used cannot be used. Efficiency can be done with a PCMA system that can operate under two circumstances, namely limited bandwidth and limited power. Bandwidth limited occurs when the bandwidth usage is greater than the power consumption (PEB). Meanwhile, Power limited is when the power consumption of the transponder (PEB) is greater than the bandwidth consumption. [8]

Results of calculation and measurement and converted into PEB and transponder usage efficiency value:

Table IV Service Status and Transponder Discharging Efficiency

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Modulasi	Coding/ FEC	Occupied BW PCMA (KHz)	PEB (KHz)	Status Layanan Transponder	Efisiensi Transponder
QPSK	TPC 7/8	1582,61	780,82	Bandwidth Limited	50,47%
QPSK	TPC 3/4	1884,61	988,9	Bandwidth Limited	50,14%
8PSK	TPC 7/8	1106	1534,29	Power Limited	31,68%
8PSK	TPC 3/4	1232,61	1718,81	Power Limited	30,61%
16QAM	TPC 7/8	821,74	2130,68	Power Limited	-28,16%
16QAM	TPC 3/4	943,48	2274,72	Power Limited	-18,64%

If the service status of the power limited transponder in table IV is changed to bandwidth limited by lowering the power level of SSPA at each ground station, there will be a decrease in the Eb/No value as a result of which the bit error rate value increases. In this condition, the acceptable bit error rate value is determined by the ping test on the link which means that the link can still be passed by data traffic. If the ping test rto (request time out) of the link cannot be used, then the bit error rate value taken is a value that can still miss the data traffic.

Table V Transponder service status changes

Modulasi	Code/ FEC	PEB (KHz)	Occ BW PCMA	Service Status	Efficiency	BER
8PSK	TPC 7/8	1224,6	1106	Power Limited	45,47%	7.10^{-8}
8PSK	TPC 3/4	1083,7	1232,61	Bandwidth Limited	50,23%	2.10^{-5}
16QAM	TPC 7/8	1687,2	821,74	Power Limited	-1,46%	7.10^{-7}
16QAM	TPC 3/4	1279,2	943,48	Power Limited	33,29%	7.10^{-6}

The change of limited power to bandwidth limited Modcod 8PSK TPC 3/4 efficiency increased from 30.61% to 50.23% with a bit error rate to 2.10-5. As for Modcod 8PSK TPC 7/8 efficiency increased from 31.68% to 45.47% bit error rate to 7.10-8, fixed status power limited, 16QAM TPC 3/4 efficiency increased from -18.64% to 33.29% bit error to 7.10-6 fixed status power limited, if both Modcode service status was changed to bandwidth limited data traffic could not be streamed to the remote destination. The Modcod 16QAM TPC 7/8 still does not provide any efficiency at all. So changing power limited to bandwidth limited will increase the efficiency of using tarnsponder but will also increase BER from the previous target of 10-9 so that to design VSAT communication links it is necessary to pay attention to the Average Bit Error value which will be achieved by paying attention to the use of bandwidth and power transponder.

CONCLUSION

1. The change in service status from power limited to bandwidth limited on Single Channel Per Carrier Pair Carrier Multiple Access (SCPC PCMA) with Turbo Product Code can increase the bandwidth usage efficiency of satellite transponders by 50% but increase the bit error rate or the quality of the VSAT PCMA link to decrease but can still miss traffic so that the VSAT link can still be used.
2. When designing a VSAT communication link, it is necessary to consider the power and bandwidth of the transponder used and the bit error rate that will be achieved so that there is

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a balance between the power and bandwidth of the transponder used.

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