SIGNAL TRANSMISSION THROUGH SATELLITE CHANNELS

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RÉSUMÉ

Une expression est derivé pour le calcul de taux d'erreur pour la modulation dite "16 - ary off set- QAM".
Le canal de transmission simulant une sate llite est non-lineaire, avec un bruit Gaussian additive.
Une Comparison avec la modulation Conventionelle "dite" 16 - ary QAM" montre la superiorité de la modulation proposé.

ABSTRACT

This paper is concerned with the performance assess-ment of 16-ary offset quadrature amplitude modulation with sinusoidal - shaping (16-ary offset-QAM). An expression for the symbol error probability (SEP) is derived taking into consideration the effect of on-board satellite TWT power amplifier back-off from saturation, the up-link and down-link addetive gaussian noise, and ISI cased by filtering.
The computation results reveal that the performance of 16-ary offset QAM signals with sinusiodal pulseshaping is superior than NLA - 16 - QAM system at all values back-off.

I- INTRODUCTION

The error increasing demand for satellite Communications capacity and the crowded conditions prevailing in many regions of the radio spectrum combined with the new emphasis on digital satellite transmission has created a need for improved spectrum utilization techniques.

From the spectral efficiency point of view 16-ary QAM, and 16-ary offset with a theoretical maximum efficiency of 4 bits/S/HZ are a very attractive modulations techniques[1], In satellite transmission, nonlinearities are encountered in both transmitting earth station and the satellite repeater power amplifiers. The travelling wave tube (TWT) power amplifiers exhibits AM-to-AM and AM-to-PM effects and cause distortion of signals having large envelope fluctuations; such as 16-QAM.

The performance analysis of 16-QAM signaliing through two-link nonlinear satellite channels in the presence of additive gausesian noise is discussed in [2] . Referance [3] evaluate the performance of 16-QAM scheme in the same enviroments considered in [2] , in addition to the effect of intersymbol interferance (ISI) introduced by filters in the up-link channel. In this paper the performance of 16-ary-offset QAM with sinusoidal shaping scheme in the satellite nonlinear channel is evaluated analytically for nonlinear satellite channel in a narrowband case considering the up-link and down-link noise on-board TWT power amplifier nonlinearity, and ISI effect by filters in the up-link channel.

II-MATHEMATICAL ANALYSIS OF SEP

The digitally modulated signals (Fig.1) which incorporate in-phase and quadrature channels offset by one half symbol duration ($T_1=T/2$) as in MSK signal may be expressed as :

$$S'(t)=\sum_{even}^{k} a_k p(t-KT_1)\cos w_0 t - \sum_{odd}^{k} a_k p(t-KT_1)\sin w_0 t \quad \ldots (1)$$

$$S''(t)=\sum_{even}^{k} b_k p(t-KT_1)\cos w_0 t - \sum_{odd}^{k} b_k p(-KT_1)\sin w_0 t \ldots (2)$$

The pulse $p(t)$ is defined for MSK signal as :

$$p(t)=\begin{cases} A\cos \pi t/2T_1 & T_1 \leq t \leq T_2 \\ 0 & \text{elsewhere} \end{cases} \quad \ldots (3)$$

The transmitted signal s(t) which is the sum of the two signals s'(t) and s"(t) that are 6-dB difference in power takes the form (NLA-16-O QAM/MSK) that can be expressed as

$$S(t)=\sum_{even}^{k} d_k p(t-KT_1)\cos w_o t - \sum_{odd}^{k} d_k p(t-KT_1) \sin w_o t \ldots (4)$$

where d_k is a random variable related to $\{a_k\}$ and $\{b_k\}$ by the relation $d_k=a_k+2b_k$.

The signal s(t) is bandlimited by a filter whose impulse response is:

$$H(t)=2h(t) \cos w_o t \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

signal s(t) is given by :

$$S_1(t)= \sum_{even}^{k} d_k q(t-KT_1)\cos w_o t - \sum_{odd}^{k} d_k q(t-KT_1) \sin w_o t \ldots\ldots\ldots (6)$$

where,

$$q(t) = p(t) * h(t) \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

After corruption with up-link narrowband gaussion noise, the signal $S_2(t)$ is :

$$S_2(t)=R(t) \cos\ w_o t + \Phi(t) \ldots\ldots (8)$$

where;

$R^2(t)=X^2(t)+Y^2(t)$, $\Phi(t)=\tan^{-1}[Y(t)/x(t)]$,

$x(t)=d_o q(t)+ \sum_{even}^{k} d_k q(t-KT)+n_{uc}(t)$ and

$Y(t)= \sum_{odd}^{k} d_k q(t-KT_1)+n_{us}(t)$

$n_{uc}(t)$ and $n_{us}(t)$ are independent gaussian processes each with zero mean and variance σ_u^2. The signal $S_2(t)$ is amplified by the TWT amplifier on board of the satellite, thus:

$$S_3(t)=F(R)\cos[w_o t+\emptyset(t)+ \psi(R)- \varepsilon] \ldots (9)$$

where F(R) and ψ(R) denote the AM-AM and AM-PM conversion. The signal $S_3(t)$ is now corrupted with the down-link AGN, thus:

$$S_4(t)=F(R)\cos[w_o t+\emptyset(t)+ \psi(R)-\varepsilon] +n_{dc}(t) \cos w_o t - n_{ds}(t) \sin w_o t \ldots (10)$$

where $n_{dc}(t)$ and $n_{ds}(t)$ are the in-phase and quadrature components of narrowband down-link noise. The receiver coherently demodulates the input signal $S_4(t)$ with the reference carrier, to get the inphase and quadrature baseband components:

$$x_4(t)=F(R)\cos[\emptyset(t)+ \psi(R)- \varepsilon]+n_{dc}(t)$$

$$Y_4(t)=F(R)\sin[\emptyset(t)+ \psi(R)-\varepsilon]+n_{ds}(t).$$

The ISI due to up-link filtering is taken into consideration. Omitting the time variable, the random variables x and Y may be written as

$$x = d_o q_o+ \alpha + n_{uc} \ldots\ldots (11)$$

$$y = \beta + n_{us}$$

where,

$$\alpha = \sum_{even}^{k} d_k q_k, \quad \beta = \sum_{odd}^{k} d_k q_k$$

and $q_k=q(t-KT)$, at K=0 and $q_o=q(t)$ where, α and B are the ISI in the in-phase and quadrature channels, respoectively.

The symbol error probability SEP can be expressed as:

$$Pe=\tfrac{1}{2}[Pe,\Lambda_1 + pe,\Lambda_2] \ldots\ldots\ldots (12)$$

where Pe,Λ_1 and Pe,Λ_2 are:

$$Pe,\Lambda_1 =1-1/2\pi \sum_{1,m}(-1)^{(1+m)/2}(1/\sqrt{2\sigma_u^2})^{1+m} b_{1,m}$$

$$-\tfrac{1}{2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}[\operatorname{erf}(F(R)\cos\theta)/\sqrt{2\pi\sigma_\alpha^2} +\operatorname{erf}\ d'-F(R)\cos\theta/\sqrt{2\pi\sigma_\alpha^2} \cdot P_{\Lambda_1}(x,y)\,dx\,dy \ldots\ldots (13)$$

$$Pe,\Lambda_2=1-1/2\pi \sum_{1,m}(-1)^{(1+m)/2}(1/\sqrt{2\sigma_u^2})^{1+m} b_{1,m}$$

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}[1-\operatorname{erf}\ d'-F(R)\cos\theta)/\sqrt{2\sigma^2}]\exp\cdot[-\frac{x-3q_o}{\sqrt{2\sigma_q^2}}]\exp\cdot[-(\frac{y}{\sqrt{2\sigma_\alpha^2}})^2]\,dx\,dy \ldots (14)$$

The computation of expressions of Pe,Λ_1 and Pe,Λ_2 require the knowledge of F(.,), ψ(.), σ_u^2, qo, b_1, m, ε and d'. Each double integral defining the conditional error probabilities Pe,Λ_1 and Pe,Λ_2 is numerically evaluated Using the Cartesian products of gauss-Hermite quadrature formulas [4] .

Figs.(2) & (3) show the dependence of SEP on the down link SNR ρ_d^2 for different values of 2BT (normalized bandwidth). The up-link SNR ρ_u^2 =18dB, and the back-off values are B_o=6,9dB.

III-CONCLUSIONS

The NLA-160 QAM/MSK signal is shown to be less sensitive to the nonlinear operation of the on-board satellite travelling wave tube power amplifier (TWTA). This is due to signal shaping and the one half symbol duration overlapping between the in-phase and quadrature components of the generated signal. The comparison of the NLA-16-QAM/QPSK and NLA-16-OQAM/MSK signals from the point of view of spectral shaping is performed on the basis of spectral shaping of QPSK and MSK signals, respectively. The conclusion of that study shows that the rate of spectral decay of NLA-16-OQAM/MSK signal is too much higher than NLA-16-QAM/QPSK, also higher power is included in smaller bandwidth

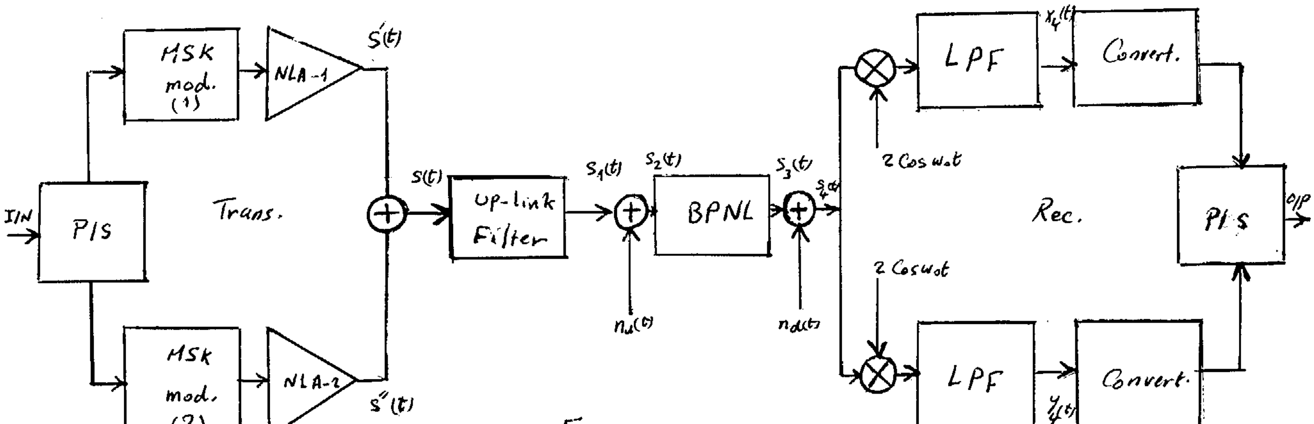

Fig (1)

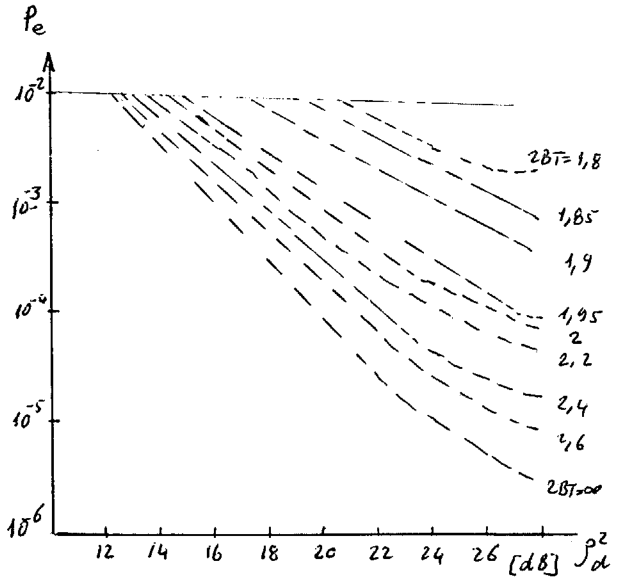

Fig.(2)

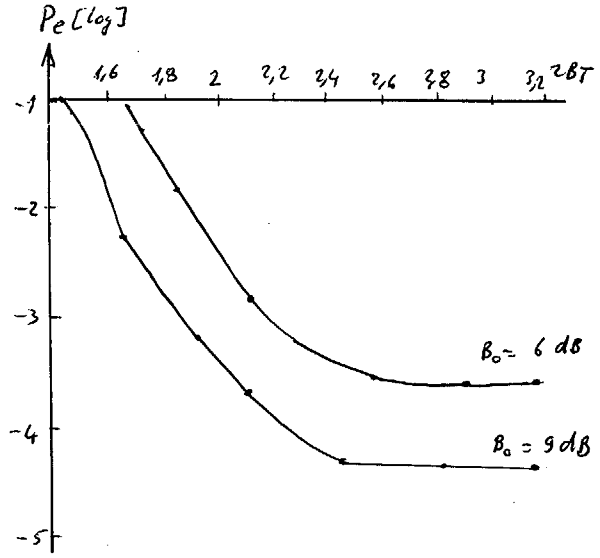

Fig. (3)

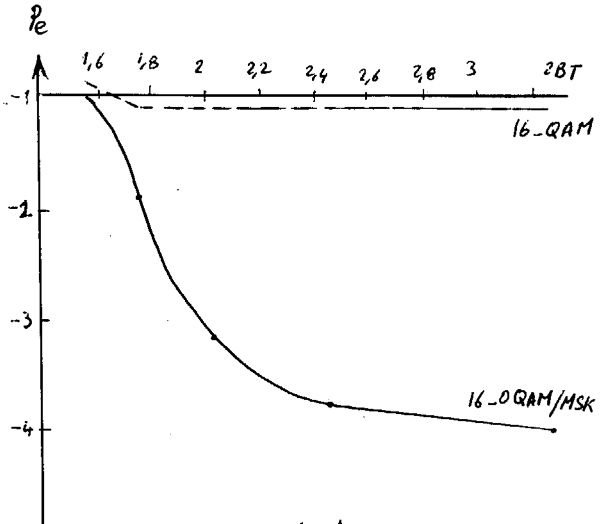

Fig.(4)

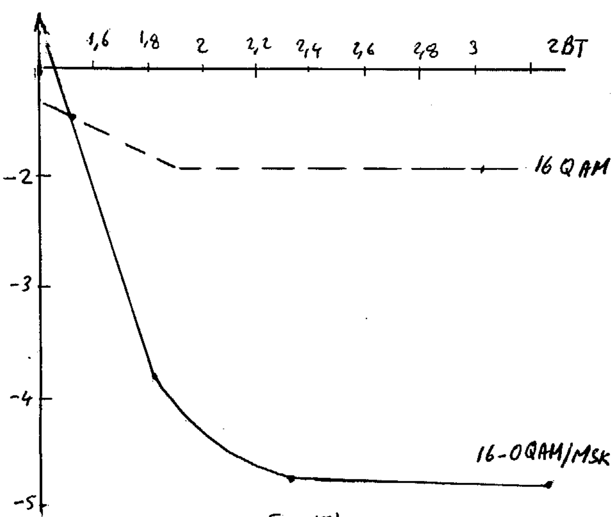

Fig.(5)

exceeds 1.5 the normalized bandwidth. The results of comparison reveal that the performance of NLA-16-OQAM/MSK system is superior than that of NLA-16-QAM/QPSK at all values of back-off i.e at all nonlinear regions of operations of the on-board satellite TWTA.

REFERENCES

[1] C.M THOMAS, WEDNER and S. DURRAN, "amplitude-phase beying with M-ary alphabets", IEEE Trans, Comm. Feb. 1974" Vol. 22.

[2] A.H. AGHVAMI, "Performance analysis of 16-ary QAM Signaling through two-link nonlinear channels in additive gassian noise IEE proc. July 1984 Vol. 131.

[3] D.H. MORAIS and K. FEHER, "the effects of filtering and limiting on the performance of QPSK, offset-QPSK and MSK systems",

IEEE Trans. Comm. 1980. Vol. 28.

[4] A.H. STROUD, "Approximate calculations of multiple integrals", prentice-Hall 1971.