Measurement of Peak-to-Average Power Ratio for HRIT

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Abstract: QPSK (Quaternary Phase Shift Keying) will be adopted as the modulation of HRIT (High Rate Information Transmission) which is transmitted to COMS (Communication, Ocean and Meteorological Satellite) through HPA (High Power Amplifier) in ground segment. Due to the nonlinearity of HPA, IMD (Inter-Modulation Distortion) of multi-carrier signals and PAPR (Peak-to-Average Power Ratio) of modulated HRIT must be considered to estimate the output power of HPA. In this paper, we measured the PAPR to various the roll-off factor of RRC (Root Raised Cosine filter) which is filtering the modulated HRIT signal for reducing ISI (Inter-Symbol Interference) and bandwidth. It was found that the minimum PAPR is 2.78dB at 0.5 of roll-off factor for scrambled data. It's 2.78dB of PAPR will be in output power selecting in COMS earth station.
Keywords: COMS, QPSK, Peak-to-Average Power Ratio.

1. Introduction

COMS launch is expected in 2008. It will be the first Korean geostationary satellite which has three main missions, i.e. satellite communication mission, ocean monitoring mission and meteorological mission. The raw image data generated by the Meteorological Imager and Geostationary Ocean Color Imager are downlinked in L Band in real-time to the ground segment, Meteorological/Ocean Data Application Center (MODAC), which is the primary Data Processing Center (DPC). This center generates calibrated image data as well as derived products and uplinks them in S-Band back to the spacecraft. Data are then disseminated in L-Band to regional users. This dissemination complies with the international HRIT/LRIT standard (High Rate and Low Rate Information Transmission) of the Coordinated Group of Meteorological Satellites (CGMS). [1]

Table 1. The specification of HRIT and LRIT

	HRIT	LRIT
Data Rate [Mbps]	3	≤ 0.256
Modulation	QPSK	BPSK
Forward Error Correction	Viterbi,RS	Viterbi,RS
Bandwidth [MHz]*	5.15	≤ 0.88
Power at MODAC[W]	100	100

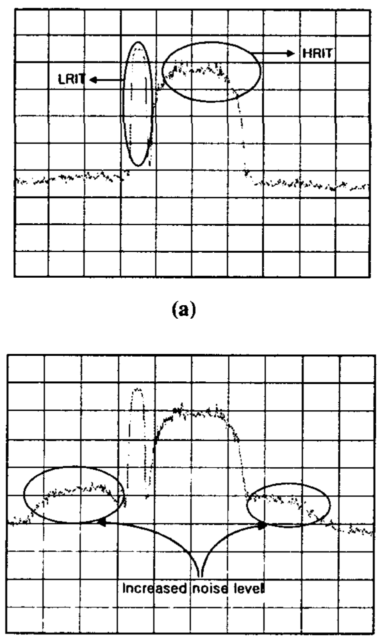
* Roll-off factor is assumed as 0.5

The difference of center frequency between HRIT and LRIT is about 3.2~4.7MHz. Considering bandwidth in Table 1, these signals's edge which faces each other is very close. In case of transmitting adjacent signals, the following factors should be considered very significantly. [2]

- Inter-Symbol Interference (ISI)
- Inter-Modulation Distortion (IMD)

Although the band-limiting filter is used to keep the wanted signal from its neighbors, the filtered symbol becomes spreading and it comes to be overlapped with the next ones. Therefore the filtered signal has a high probability of being interpreted incorrectly, which is called Inter-Symbol Interference. The main tool used to reduce ISI is to use Root-Raised Cosine (RRC) filter. When the timing pulse of RRC slices the symbol to determine the value of the symbol at that instant, it does not care what the symbol looked like before or after it. So the symbols can be kept from interfering in such a way that they do not affect the amplitude at the slicing instant.

In generally, Inter-Modulation Distortion depends on the characteristic of High Power Amplitude (HPA). If the power of the desired signal and its adjacent one is exceed HPA's linear input power range, the third order harmonic element, which results from the mixing between two signals, makes the in-band noise level increase as shown in fig.1.



(a)

(b)

Fig. 1 HRIT and LRIT spectrum at (a) HPA's linear range; (b) HPA's nonlinear range

To decrease this phenomenon, the input power level has to be at the boundary of linear operation of HPA. Therefore the higher input power requires the more back-off power from HPA's saturation power to maintain the linear characteristic. This means that the HPA's available output power has to be increased and its price becomes very high. In this paper, we probed the output power of QPSK modulated data in time-domain to design the HPA's output power correctly. The test data was simulated according to table 1.

2. PAPR measurement

The time-domain output power pattern, which results from simulated QPSK signal by commercial simulation tool, is shown in fig.2.

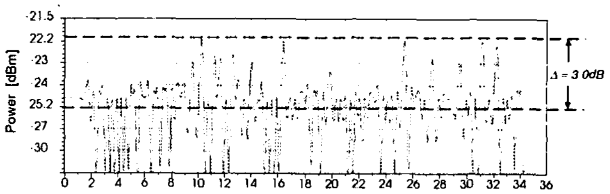


Fig. 2 Simulated QPSK signal's output power

The output power in fig.2 shows fluctuation. The expected output power is consistently -25.2dBm, which is a setting value in simulation, but the output power is not always -25.2dBm, even the instantaneous peak power is -21.2dBm. This implies that the QPSK modulated signal power has two power-levels, i.e. peak power and average power.

From a various simulation, we are able to propose the following dominant factors which cause to generate high PAPR.

- Roll-off factor of root-raised cosine filter
- PN (Pseudo Noise) scrambling

The frequency response of the root raised cosine is given by

$$H(f)=\begin{cases} 1 & \text{for } |f|\le \dfrac{(1-\alpha)}{2T_s} \\ \left\{\cos\dfrac{\pi T_s}{2\alpha}\left(|f|-\dfrac{(1-\alpha)}{2T_s}\right)\right\} & \text{for } \dfrac{(1-\alpha)}{2T_s}\le |f| \le \dfrac{(1+\alpha)}{2T_s} \\ 0 & \text{for } |f| > \dfrac{(1+\alpha)}{2T_s} \end{cases}$$

Here, T_s is symbol time and α is roll-off factor. [3]

From the pulse shape for various roll-off factors, although low-α filters require less bandwidth than high-α filters, they have a longer response and more severe ringing as shown in fig.3. This time-domain ringing results in the addition of more symbols, which causes higher peak-power event.

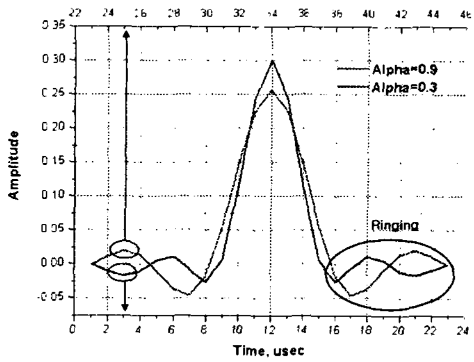


Fig. 3 Time response of RRC (roll-off factor=0.9; 0.3)

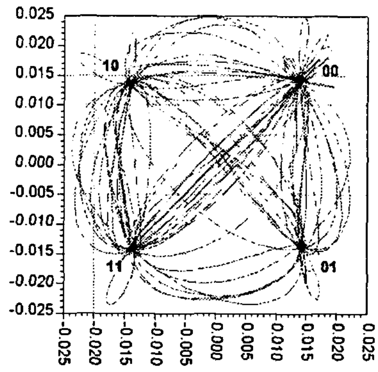
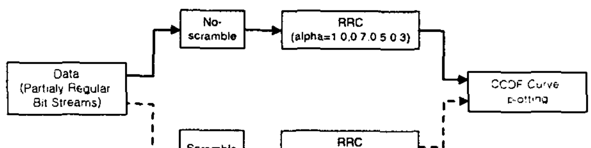
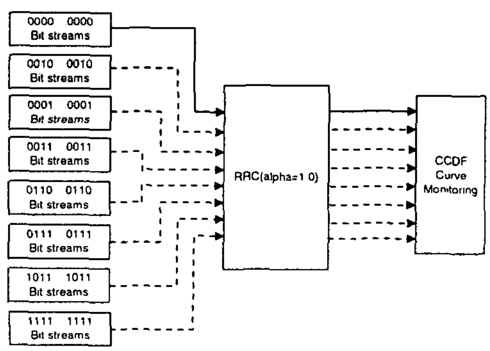


Fig. 4 Constellation of simulated QPSK signal

In fig. 4, there are a lot of signal vector and it is found that their magnitude and phase are not quite same. These unequaled signal vectors's movement may increase peak power. Two PAPR measurement configurations, which have been built to verify the simulated causes described above, are shown in fig 5.



(a)



(b)

Fig. 5 Test configuration. (a) roll-off factor varying; (b) signal vector's moving

The partially regular data means that it occasionally shows a regular bit stream, for example '111111' or '000000'. PN (Pseudo Noise) scrambling can change the partially regular bit streams into all irregular ones.

After PN-scramble coding, CCDF curve can be obtained with varying the roll-off factor of RRC from 1.0 to 0.3. Plots of CCDF curve for PN-scrambling and various roll-off factors are shown in fig. 6.

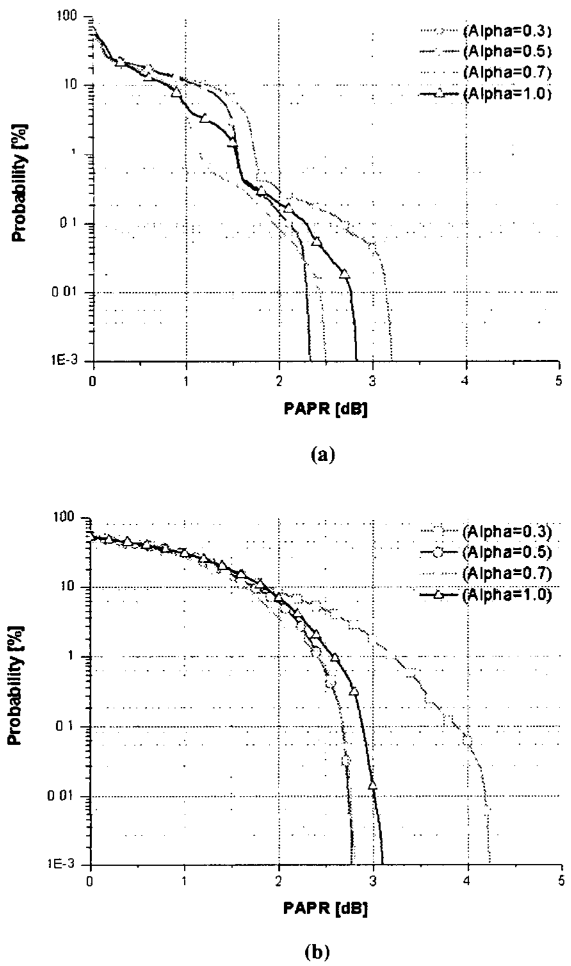


Fig. 6 CCDF plots for (a) non-scrambling; (b) scrambling.

From obtained CCDF plots, the minimum PAPR is 2.34dB and 2.78dB at 0.5 of roll-off factor for non-scrambling and scrambling, respectively. All PAPR shows decreasing feature when roll-off factor goes from 1.0 to 0.5 while increasing feature at 0.3 of roll-off factor.

From the difference between scrambled and non-scrambled data, it is found that the irregular bit streams result in the high PAPR value.

Summary of PAPR for signal's vector in QPSK constellation is shown in the table 2. The minimum PAPR is 0.3 at '00' to '00' or '11' to '11'. But on the other hand the maximum PAPR is 2.95 at '01' to '11'. It is found that the bit streams of '0111' or '1101' are dominant factors to increase PAPR in scrambled data.

Table 2 PAPR for various signal vectors (roll-off factor : 1.0)

Signal vector	PAPR
'00' to '00'	0.3
'00' to '10'	2.84
'00' to '01'	2.84
'00' to '11'	2.72
'01' to '10'	2.7
'01' to '11'	2.95
'10' to '11'	2.94
'11' to '11'	0.3

3. Conclusions

A various PAPR measurements are accomplished for the QPSK modulated signal, likely HRIT, to estimate the HPA's power capability. PN scrambled bit streams cause a higher PAPR about 0.3~1dB than non-scrambled ones. The minimum PAPR is 2.78dB at 0.5 of roll-off factor in scrambled bit streams. In the view of signal vector, the dominant bit stream is '0111' or '1101'. The measured PAPR will be used to decide the output power of HPA for HRIT transmission in ground segment.

References

[1] **URL:** CGMS, 1998. *LRIT/HRIT Global Specifications*, Issue 2.5. Available at: http://www.eumetsat.de/en/area4/msg/news/us_doc/cgms_03_26.pdf

[2] Bernard Sklar, 2000. *Digital Communications*, Prentice Hall.

[3] **URL:** Intuitive Guide to Principles of Communications: Inter Symbol Interference (ISI) and raised cosine filtering Available at: www.complextoreal.com/chapters/isi.pdf