

How to Estimate the Unmodulated Carrier Power Level of a Modulated Telemetry Signal

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ABSTRACT

This paper will present methods to both measure the unmodulated carrier power of a modulated signal and to estimate the unmodulated carrier power level from the measured power spectrum. The unmodulated carrier power level is needed to convert measured spectra into units of dBc.

KEY WORDS

Carrier power Power spectrum dBc

INTRODUCTION

A common requirement is the need to measure a telemetry signal with respect to the unmodulated carrier level (units of dBc) but only the modulated signal may be available and a power meter measurement is not practical. Some examples include the telemetry spectral mask in chapter 2 of the Telemetry Standards (IRIG 106) and some items on page 2 of a DD form 1494 (Application for Equipment Frequency Allocation). To measure power with respect to the unmodulated carrier power, the unmodulated carrier power must be known. This power level is the 0-dBc reference (commonly set to the top of the display). Since angle modulation (FM or PM) by its nature spreads the spectrum of a constant amount of power, a method to estimate the unmodulated carrier power is required if the modulation can not be turned off. For most practical angle modulated systems, the total carrier power at the spectrum analyzer input can be found by setting the spectrum analyzer's resolution and video bandwidths to their widest settings, setting the analyzer output to max hold, and allowing the analyzer to make several sweeps. The maximum value of this trace will be a good approximation of the unmodulated carrier level.

DISCUSSION

One should then set the spectrum analyzer to the IRIG 106 Chapter 2 conditions for measuring telemetry spectra (which in 2005¹ were resolution bandwidth = 30 kHz and video bandwidth = 300 Hz with max hold off). After measuring the signal spectrum one can verify the 0 dBc level by finding the nominal peak level of the measured spectrum which should be about $(X - 10\log R)$ dBc.

where $X = -16$ for PCM/FM (Advanced Range Telemetry (ARTM) tier 0) with correct peak deviation, -12 for FQPSK and SOQPSK (ARTM tier 1), -11 for ARTM CPM (ARTM tier 2) and R is bit rate (Mb/s).

A more general approximation² for the spectral energy near center frequency for randomized NRZ PCM/FM is $10\log\left(\frac{B_{SA}f_b}{\pi^2(\Delta f)^2}\right)$ dBc

where:

B_{SA} is spectrum analyzer resolution bandwidth in kHz

f_b is the bit rate in kb/s

Δf is the peak deviation in kHz

Δf can be estimated² using $\Delta f = f_b - \frac{\text{null spacing}}{2}$

where *null spacing* is the frequency spacing between the closest spectral nulls on each side of the center frequency.

Examples: if one measures the spectrum of a 10 Mb/s randomized NRZ PCM/FM signal with a peak deviation of 3.5 MHz one should get a maximum level of about $-16 - 10\log(10) = -26$ dBc which matches quite well with the spectral plot shown in figure 1. Using the equation one would get $10\log(30 \cdot 10000 / (9.87 \cdot 3500 \cdot 3500)) = -26.05$ dBc or essentially the same value. If one measures the spectrum of a 10 Mb/s SOQPSK-TG, FQPSK-B or FQPSK-JR signal the maximum level of the spectrum should be about $-12 - 10\log(10) = -22$ dBc (the tolerance should be about ± 1 dB). Figures 1, 2, and 3 show the measured spectra for 10 Mb/s signals with both wide spectrum analyzer settings (red traces, to find approximate 0 dBc level) and IRIG 106 settings (blue traces). The actual 0 dBc values were found by removing the modulation. The approach presented here appears to work reasonably well for these modulation methods and bit rates up to at least 20 Mb/s. Figure 4 shows the expected maximum spectral values in dBc for bit rates between 1 and 10 Mb/s for randomized NRZ PCM/FM and ARTM tier 1 modulation methods.

¹ RCC 106-05 Chapter 2; <http://www.jcte.jcs.mil/RCC/manuals/106-05/chapter2.pdf>; RCC Secretariat, WSMR, NM.

² Law, E. L., "RF Spectral Characteristics of Random NRZ PCM/FM and PSK Signals", Proceedings of the 1991 International Telemetry Conference, pages 109-119, Las Vegas, NV.

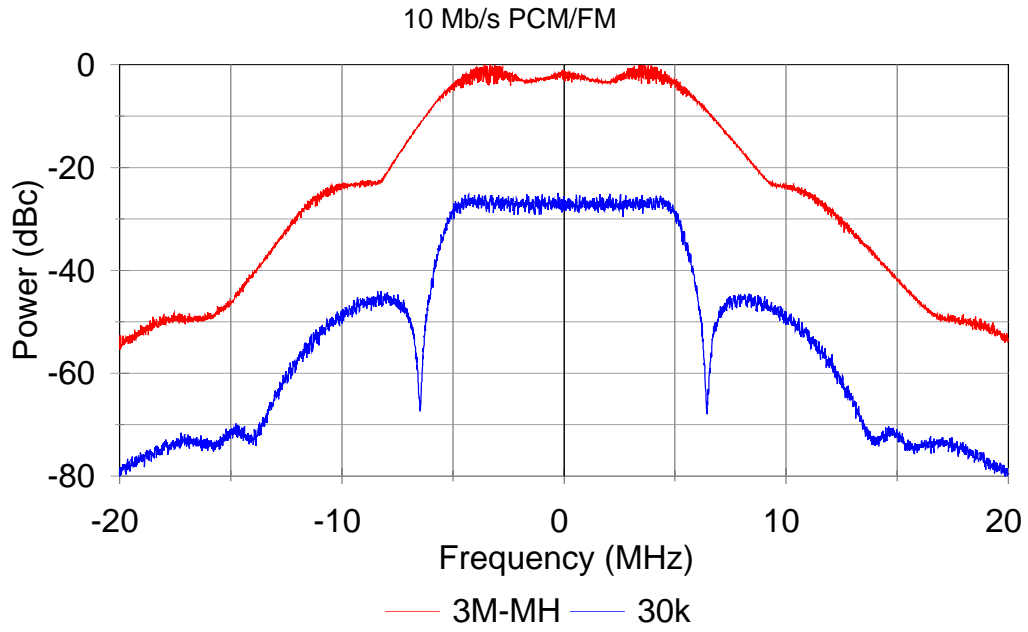


Figure 1. 10 Mb/s NRZ PCM/FM.

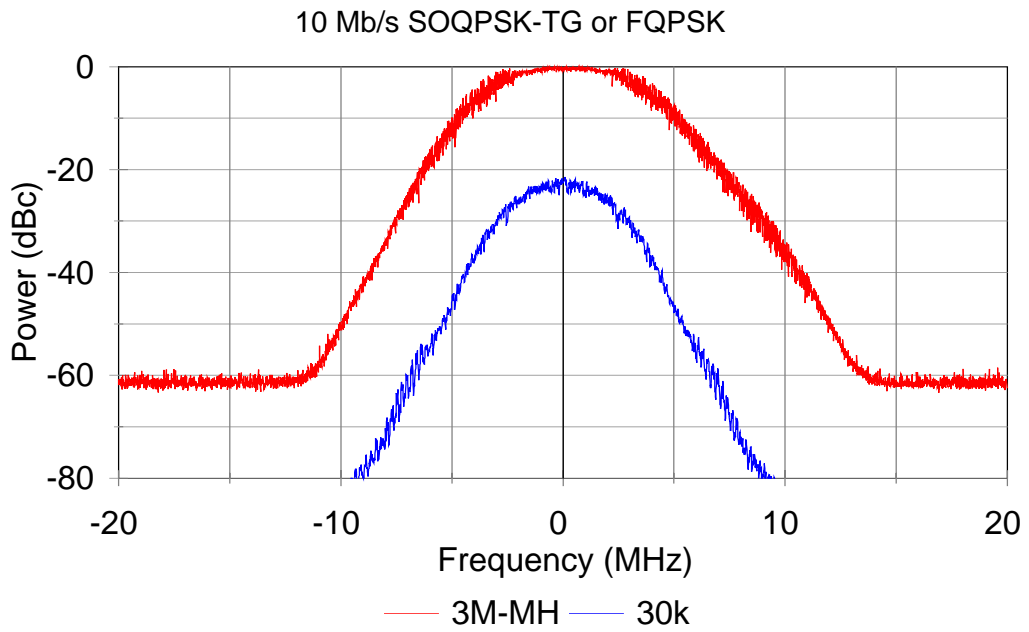


Figure 2. 10 Mb/s SOQPSK-TG or FQPSK.

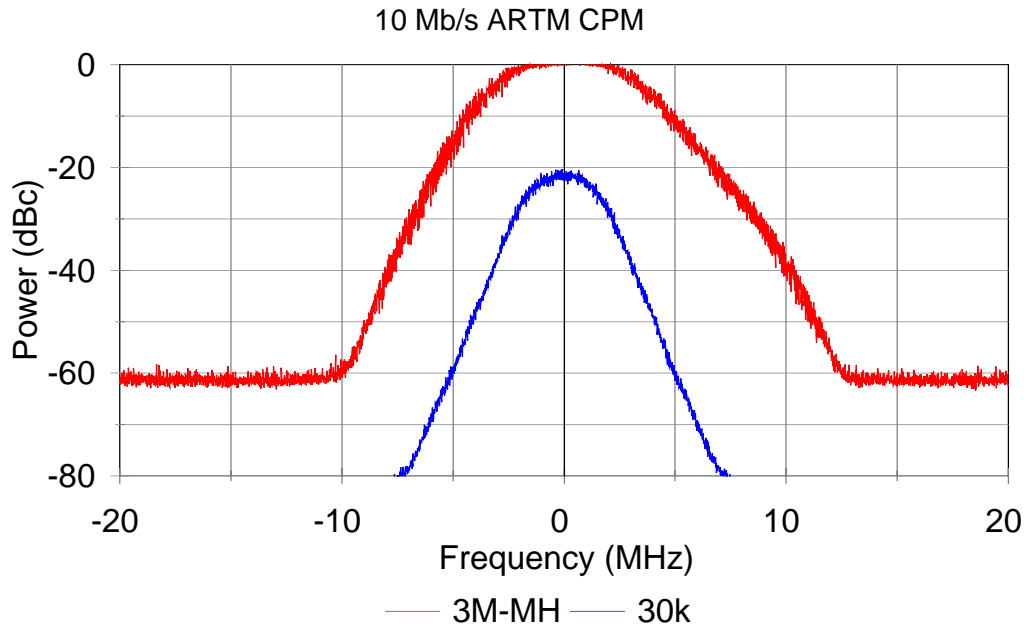


Figure 3. 10 Mb/s ARTM CPM.

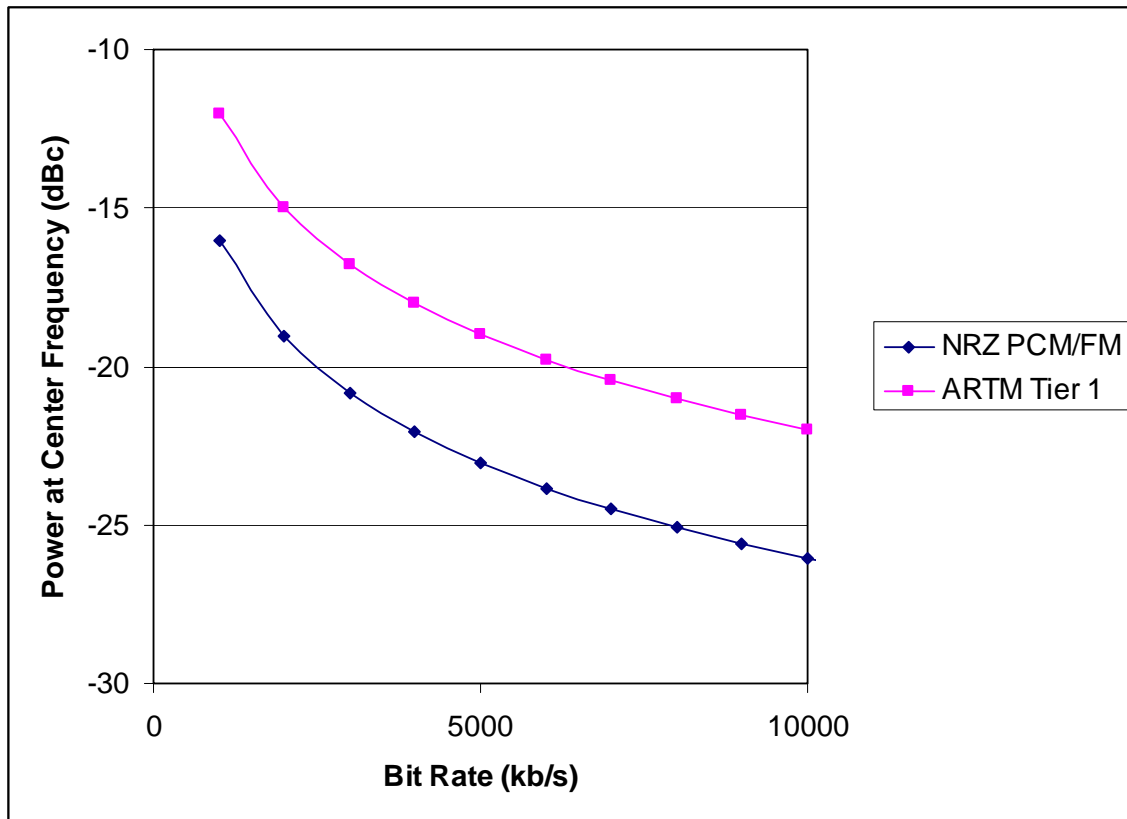


Figure 4. Power at center frequency for various bit rates and NRZ PCM/FM and ARTM tier 1 modulations.

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REFERENCES

¹ RCC 106-05 Chapter 2; <http://www.jcte.jcs.mil/RCC/manuals/106-05/chapter2.pdf> ; RCC Secretariat, WSMR, NM

² Law, E. L., "RF Spectral Characteristics of Random NRZ PCM/FM and PSK Signals", Proceedings of the 1991 International Telemetry Conference, pages 109-119, Las Vegas, NV.