Evaluating biomedical data acquisition systems

Dipl.-Ing. Dr. techn. Alois Schlögl
<a.schloegl@ieee.org>

Abstract:

Currently, the technical specification of any recording equipment is provided solely by the producing company. No objective and independent criterion for the quality of biosignal acquisition systems is available. In this work is summarized how the quality of biosignal acquisition systems can be quantified.

Introduction:

The main parts of a biosignal recording system are the amplifier, the Analog-to-digital converter (ADC) and the software for storing the data.

Limiting factors for the signal quality are:

1. noise from electrode impedance
2. amplifier noise
3. quantisation noise
4. aliasing
5. interference from power line
6. saturation effects in amplifier or ADC
7. recording artifacts (due to electrode movement)
8. artifacts due to other electrical activity

Figure 1 displays the various noise sources in the spectral domain. In the low frequency range is the amplifier noise the largest source for noise, the impedance noise can not be neglected for higher frequencies. The quality of the digitized data was discussed by Schlögl et al. (1999). This covers the quantization noise, the dynamic range and saturation effects. Now, a testsuite for the analog pathway will be presented. It quantifies the amplifier noise, the noise from the electrode impedance, and line interference.

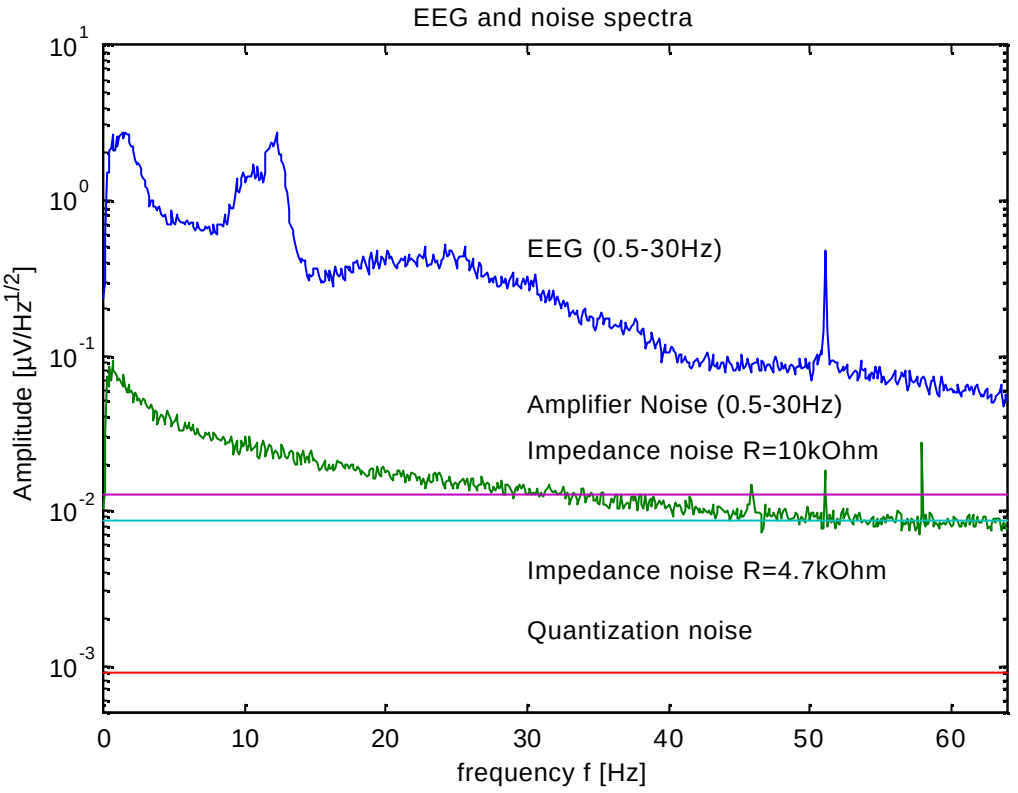

Figure 1: Spectra of EEG, amplifier noise, impedance noise and quantization noise.

Method:

A test suite has been developed; it consists of the following steps:

1. Download questionnaire [2]
2. Follow the instructions on the questionnaire and fill in the open fields. Use the same settings as for your recordings.
3. Perform your own protocol
4. Send all files and the questionnaire to <a.schloegl@ieee.org>

The resulting files will be used to perform a detailed analysis of the acquisition system. Next, the results of some analysis are presented.

Results:

The test suite has been applied to an available EEG amplifier. The results are shown Table 1, Fig. 1 and Fig. 2.

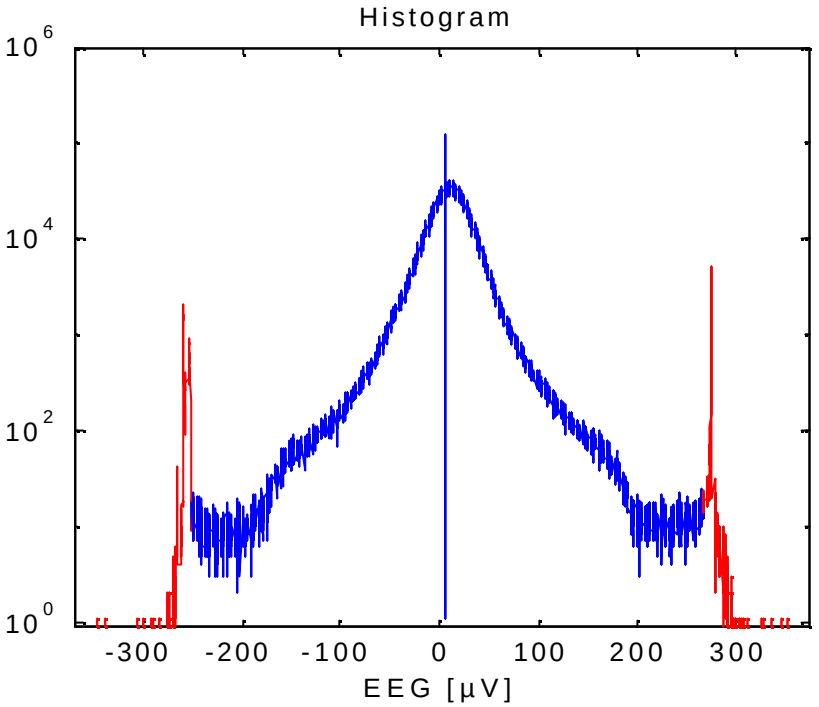

Figure 1: Histogram of a single EEG channel.

The histogram shows two “sidelobes” indicating the saturation effect. In the center, a peak and a zero can be identified. This indicates a quantization step, that is twice as large as everywhere else. This provides a hint that the software might be erroneous. From the histogram can be derived various statistics (mean, rms, etc) including Shannon’s entropy of information (Schlögl et al. 1999). In case of sleep EEG, the typical entropy difference between EEG and quantization is 8 to 11bits per sample (Penzel, 2001).

Table 1: Overview of characteristic values

	#1	#2	#3
Maximum	24 988 nV	24 988 nV	24 988 nV
Minimum	-25 000 nV	-25 000 nV	-25 000 nV
Bit-depth	12 bit	12 bit	12 bit
LSB	12.2 nV	12.2 nV	12.2 nV
Quantization noise (RMS)	3.5 nV	3.5 nV	3.5 nV
Amplifier noise (RMS)	170.1 nV	187.8 nV	407.3 nV
SNR (S=10µV)	58.8	53.2	24.55
Entropy of noise (Notch ON)	4.1	4.0	5.3
Entropy of noise (Notch OFF)	3.9	3.9	5.2

Table 1 shows the results of an EEG recording with 3 channels. The dynamic range and the quantization was the same for all three channels. But the amplifier noise of channel #3 was more than twice as large as for channel #1 and #2. Accordingly, the SNR is also smaller.

The entropy of the noise is in the range of ca. 4 to 5 bits. An EEG recording contains information only if the overall entropy (signal + noise) is larger than the entropy of the noise.

Conclusion:

The quantization noise, the dynamic range, the amplifier offset and the amplifier noise are determined solely by the data acquisition system. Of course, the noise should be as small as possible, and the dynamic range as large as possible.

Summarizing, a test suite for analyzing acquisition systems of biosignals is presented. The test suite can be applied to an acquisition system from any provider. Especially, the cooperation of the producer is not necessary. Therefore, the test suite is a truly independent test.

References:

[1] A. Schlögl, B. Kemp, T. Penzel, D. Kunz, S.-L. Himanen,A. Värri, G. Dorffner, G. Pfurtscheller. Quality Control of polysomnographic Sleep Data by Histogram and Entropy Analysis. Clin. Neurophysiol. 1999, Dec; 110(12): 2165 - 2170.

[2] http://www.dpmi.tu-graz.ac.at/~schloegl/qc/Questionnaire.pdf

[3] Penzel T, Kemp B, Klösch G, Schlögl A, Hasan J, Varri A, Korhonen I. Acquisition of biomedical signals databases. IEEE Engineering in Medicine and Biology Magazine 2001, 20(3): 25-32.