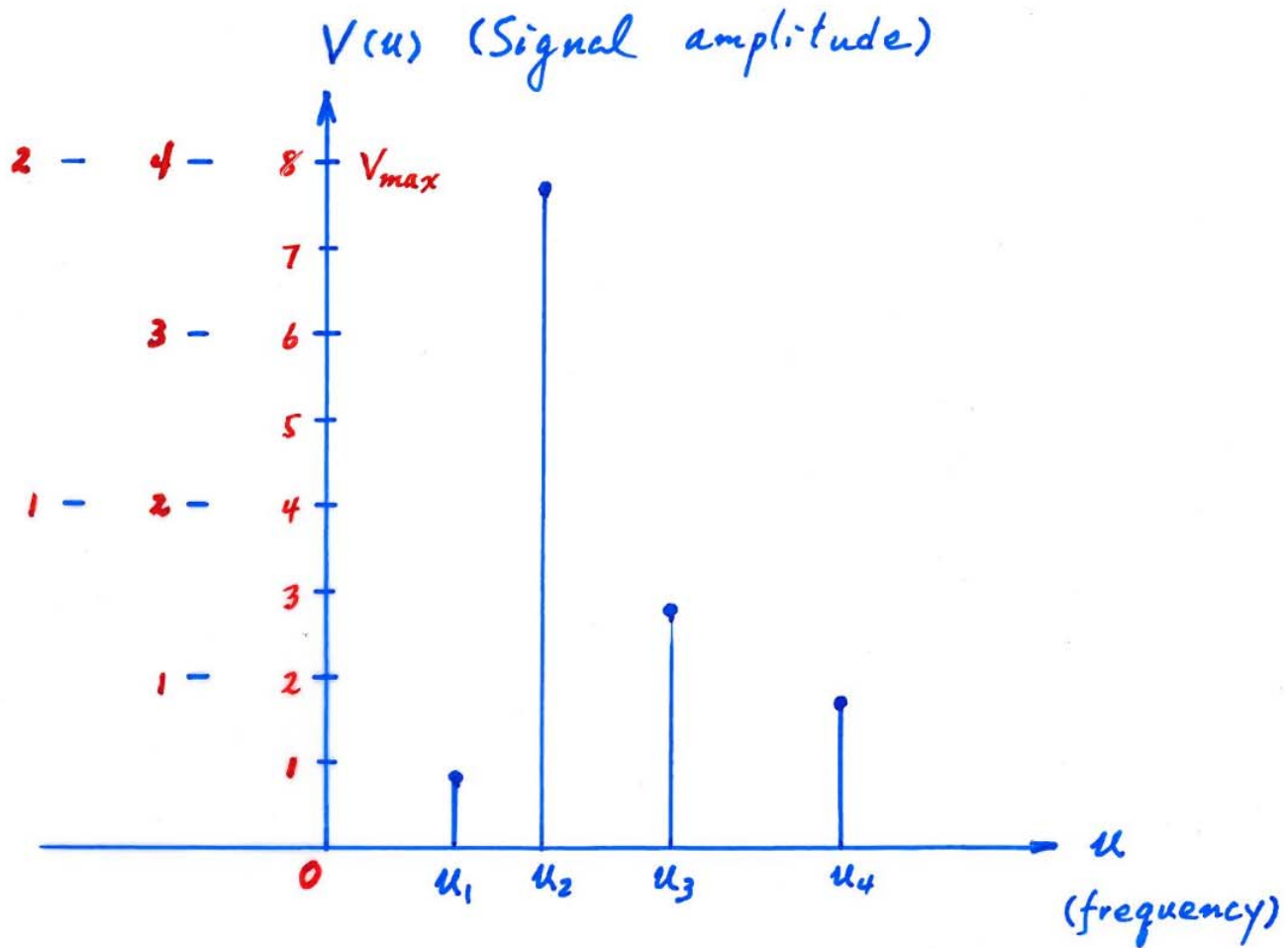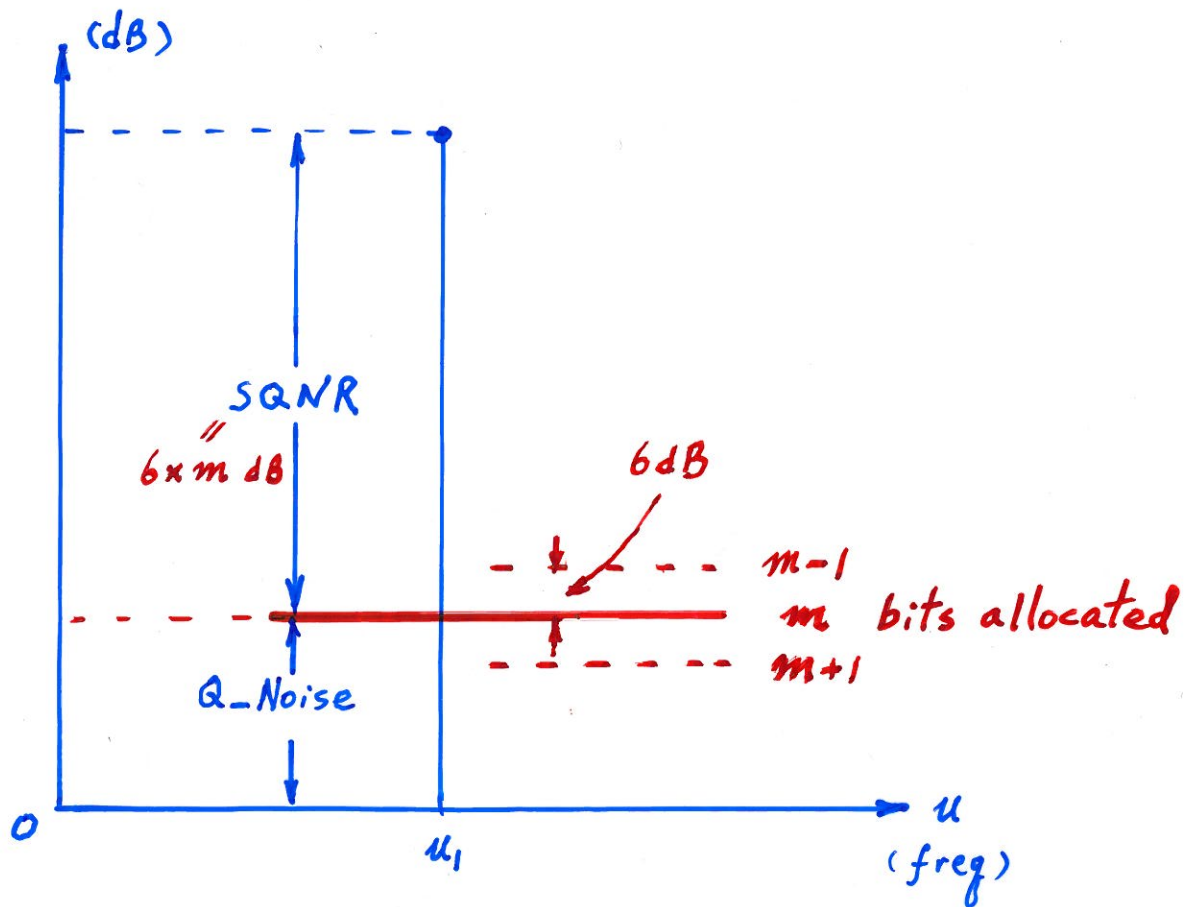# A closer look at SQNR

$V(u)$ (Signal amplitude)

In general, k bits gives 2^k quantization levels,
2^{k-1} levels each for positive and negative,
the quantization error is $[-\frac{1}{2}, \frac{1}{2}]$

$$SQNR = 20 \log_{10} \frac{V_{max}}{V_{noise}} = 20 \log_{10} \frac{2^{k-1}}{\frac{1}{2}} = 6 \times k \text{ dB}$$

Here, $\quad k = 4 \quad 2^{k-1} = 8 \quad\quad SQNR = 24 \text{ dB}$

$\quad$ or $\quad k = 3 \quad 2^{k-1} = 4 \quad\quad SQNR = 18 \text{ dB}$

$\quad$ or $\quad k = 2 \quad 2^{k-1} = 2 \quad\quad SQNR = 12 \text{ dB}$

An Illustration of SQNR and Quantization_Noise
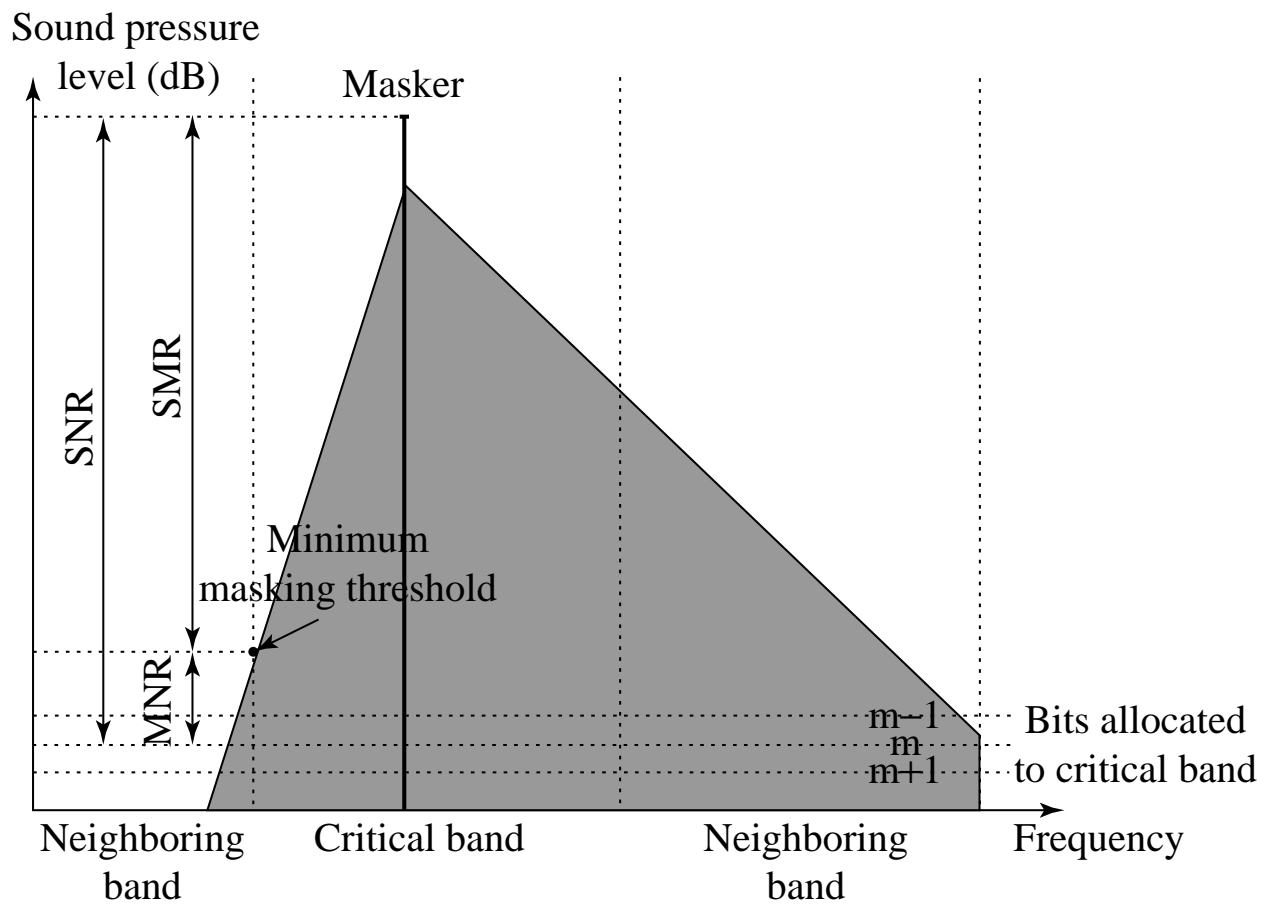in Logarithmic scale (dB)

Figure 1: Mask-to-noise ratio and signal-to-mask ratio. A qualitative view of SNR, SMR and MNR, with one dominant masker and m bits allocated to a particular critical band.

Bit Allocation in MPEG Audio Compression

- The aim is to ensure that all quantization noise values are below the masking thresholds.

1. From the psychoacoustic model, calculate the *Signal-to-Mask Ratio (SMR)* in decibels (dBs) for each sub-band:

$$SMR = 20 \log_{10} \frac{Signal}{Minimum\_masking\_threshold}$$

   - This determines the quantization, i.e. the minimum number of bits that is needed, if available. The amount of a signal above the threshold, i.e. SMR, is the amount that needs to be coded. Signals that are below the threshold do not.

2. Calculate *Signal-to-(quantization)-Noise Ratio (SNR)* for all signals.

   - A lookup table provides an estimate of SNR assuming a given number of quantizer levels.

3. *Mask-to-(quantization)-Noise Ratio (MNR)* is defined as the difference, in dB (See Figure 1).

$$MNR = SNR - SMR$$

4. Iterate until no bits left to allocate:

- Allocate bits to the subband with the lowest MNR
- Look up new estimate of SNR for the subband allocated more bits, and re-calculate MNR

Note:

- The masking effect means we can raise the quantization noise floor around a strong sound because the noise will be masked off anyway. As indicated in Figure 1, adjusting the number of bits m allocated to a subband can move this floor up and down.

- To ensure that all the quantization noise values are inaudible, i.e., below the masking thresholds, so that all MNRs are ≥ 0, a minimum number of bits is needed. Otherwise, SNR could be too small, causing MNR to be < 0, and the quality of the compressed audio could be significantly affected.

- If more bits than the minimum are allowed from the budget, allocate them anyway so as to further increase SNR. For each additional bit, we get 6 dB better SNR.