Mu-Law Encoding in MATLAB

Mu-law encoding (µ-law) is a non-linear companding method that can be used to reduce the bit depth of a digital audio signal in a way that preserves the dynamic range of samples at low amplitudes. The word “companding” is used because this method works by compressing the bit depth of an audio signal and then expanding it again after the signal has been transmitted. Mu-law encoding is non-linear because it uses more bits to quantize low amplitude samples as opposed to high amplitude ones. This method works well for telephone communication because it reduces the signal-to-noise ratio in the area where it matters most – in low amplitude values, which are common in human speech and are particularly subject to noise distortion. The equation for non-linear compression by mu-law encoding is

\[ m(x) = \text{sign}(x) \left( \frac{\ln(1 + \mu|x|)}{\ln(1 + \mu)} \right) \]

where \(-1 \leq x \leq 1\), and \(\text{sign}(x)\) is \(-1\) if \(x\) is negative and 1 otherwise. \(\mu\) is 255 when samples are being quantized to 8 bits. (In some sources, you will see this equation using \(\log_2\) rather than the natural log. The definitions are equivalent.)

Decompression operates by the inverse equation:

\[ d(x) = \text{sign}(x) \left( \frac{(\mu + 1)|x| - 1}{\mu} \right) \]

Here is a scenario in which mu-law encoding could be used. A 16-bit digital audio signal – for example, a telephone signal – is to be transmitted across a network. It is reduced to 8-bits by mu-law encoding and then transmitted. At the receiving end, it is decoded back to a 16-bit signal. Because the amount of error for low amplitude samples is less than it would have been in a linear encoding, the effect is that a dynamic range of 72 dB is achieved with mu-law encoding (as opposed to 48 dB that you would expect from an 8-bit audio signal).

Your assignment is to write a MATLAB function or sequence of commands that implements mu-law encoding and decoding with the equations above. Compare the error you get with mu-law encoding versus the error you get with a linear companding method.