6.3.1 Required Backoff with a Non-Ideal Power Amplifier

The previous section demonstrated that peak windowing is very effective in reducing the PAP ratio. This does not immediately tell us, however, what backoff is required for a practical power amplifier to attain an acceptable level of out-of-band radiation. The backoff is defined here as the ratio of the output power and the maximum output power (saturation power) with a sinusoidal input signal. Another definition that is frequently used in the literature uses the power at the 1-dB compression point instead of the saturation power. Because the 1-dB compression point is typically 1 to 3 dB lower than the maximum power level, depending on the amplifier transfer function, the backoff values according to the latter definition are 1 to 3 dB smaller than the values mentioned in this section.

To simulate a power amplifier, the following model is used for the AM/AM conversion [2]:

$$g(A) = \frac{A}{\left(1 + A^{2p}\right)^{\frac{1}{2p}}} \tag{6.5}$$

The AM/PM conversion of a solid-state power amplifier is small enough to be neglected. Figure 6.10 gives some examples of the transfer function for various values of p. A good approximation of existing amplifiers is obtained by choosing p in the range of 2 to 3 [2]. For large values of p, the model converges to a clipping amplifier that is perfectly linear until it reaches its maximum output level.

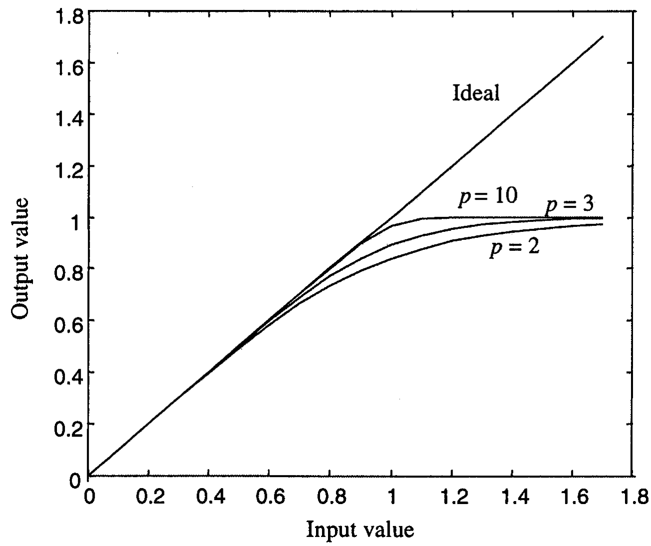

Figure 6.10 Rapp's model of AM/AM conversion.

Figure 6.11 shows the output spectra of an undistorted OFDM signal and the spectra of two distorted signals, assuming a highly linear amplifier model (p = 10 in (6.5). The backoff relative to the maximum output power was determined such that any significant distortion of the spectrum is at least 50 dB below the in-band spectral density. In this case, peak windowing gives a gain of almost 3 dB in the required backoff relative to clipping. This difference in backoff is much less than the difference in PAP ratio at the input of the power amplifier; without peak windowing, the PAP ratio is about 18 dB for the OFDM signal with 64 subcarriers. With peak windowing, this PAP ratio is reduced to approximately 5 dB. Hence, for the latter case, it is clear that the backoff of a highly linear amplifier must be slightly above this 5 dB to achieve a minimal spectral distortion. It is not true, however, that without peak windowing, the backoff must be in the order of 18 dB for the same amount of distortion as with peak windowing. The reason is that there is little energy in the signal parts that have a relatively large PAP ratio, so it does not affect the spectrum that much if those parts are distorted. After peak windowing or any other PAP reduction technique, however, a significant part of the signal samples are close to the maximum PAP ratio (e.g., 5 dB); in this case, any distortion of samples that is a dB or so below this maximum produces more spectral distortion than clipping the original OFDM signal at 10 dB below its maximum PAP level, simply because for the latter, a much smaller fraction of the signal is affected. Thus, the lower the PAP ratio is made by PAP-reduction techniques, the less tolerant the signal becomes against nonlinearities in the area of its maximum PAP ratio.

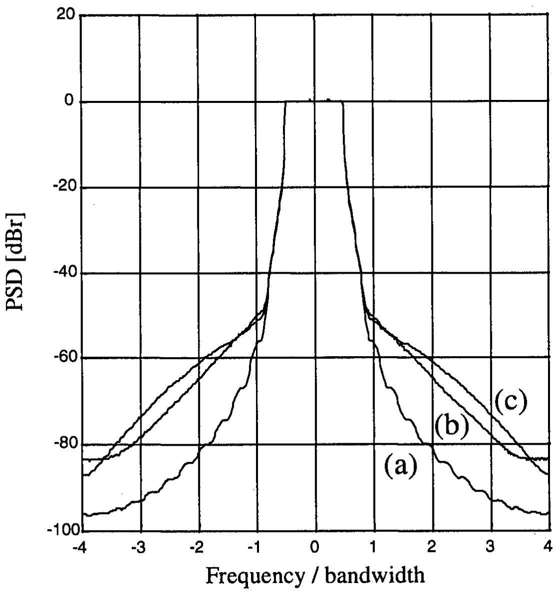

Figure 6.11 (a) Ideal OFDM spectrum for 64 subcarriers, (b) spectrum after highly linear amplifier (Rapp's parameter p = 10) with 8.7-dB backoff, (c) spectrum using peak windowing with 5.9-dB backoff.

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