Spectral subtraction is a method for restoration of the power or the magnitude spectrum of a signal observed in additive noise, through subtraction of an estimate of the average noise spectrum from the noisy signal spectrum. The noise spectrum is estimated, and updated, from the periods when the signal is absent and only the noise is present. The assumption is that the noise is a stationary or a slowly varying process, and that the noise spectrum does not change significantly in-between the update periods. For restoration of time-domain signals, an estimate of the instantaneous magnitude spectrum is combined with the phase of the noisy signal, and then transformed via an inverse discrete Fourier transform to the time domain. In terms of computational complexity spectral subtraction is relatively inexpensive. However, due to random variations of noise, spectral subtraction can result in negative estimates of the short-time magnitude or power spectrum. The magnitude and power spectrum are non-negative variables, and any negative estimate of these variables should be mapped into a non-negative value. This nonlinear rectification process distorts the distribution of the restored signal. The processing distortion becomes more noticeable as the signal to noise ratio decreases. In this chapter we study spectral subtraction, and the different methods of reducing and removing the processing distortions.
9.1 Spectral Subtraction

In applications where, in addition to the noisy signal, the noise is accessible on a separate channel, it may be possible to retrieve the signal by subtracting an estimate of the noise from the noisy signal. For example, the adaptive noise canceller of Section 1.3.1 takes as the inputs the noise and the noisy signal, and outputs an estimate of the signal. However, in many applications, such as at the receiver of a noisy communication channel, the only signal that is available is the noisy signal. In these situations it is not possible to cancel out the random noise, but it may be possible to reduce the average effects of the noise on the signal spectrum. The effect of additive noise on the magnitude spectrum of a signal is to increase the mean and the variance of the spectrum as illustrated in Figure 9.1. The increase in the variance of the signal spectrum results from the random fluctuations of the noise, and can not be cancelled out. The increase in the mean of the signal spectrum can be removed by subtraction of an estimate of the mean of the noise spectrum from the noisy signal spectrum. The noisy signal model in the time domain is given by

\[ y(m) = x(m) + n(m) \]  \hspace{1cm} (9.1)

where \( y(m) \), \( x(m) \), and \( n(m) \) are the signal, the additive noise, and the noisy signal respectively, and \( m \) is the discrete time index.

Figure 9.1 Illustrations of the effect of noise on a signal in the time and the frequency domains.