Direct sequence spread spectrum

In direct sequence (DS) spread spectrum systems, the amplitude of an already modulated signal is amplitude modulated by a very high rate NRZ binary stream of digits. Thus with the original signal

$$s(t) = Ad(t)\cos\omega_0 t$$

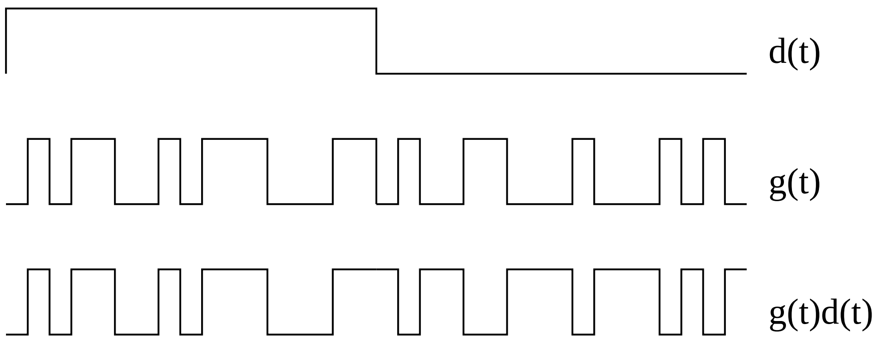
the DS spread spectrum signal is

$$v(t) = g(t)s(t) = Ag(t)d(t)\cos\omega_0 t,$$

where $g(t)$ is a pseudo-random noise (PN) binary sequence taking on values ± 1.

Assume therefore that both $g(t)$ and $d(t)$ are binary sequences. The sequence $g(t)$ is generated in a deterministic manner and is repetitive, but without serious error we can assume that it is truly random. Also, the bit rate f_c of $g(t)$ is usually much greater than the bit rate f_b of $d(t)$. $g(t)$ therefore chops the data into "chips", and f_c is called the **chip rate**.

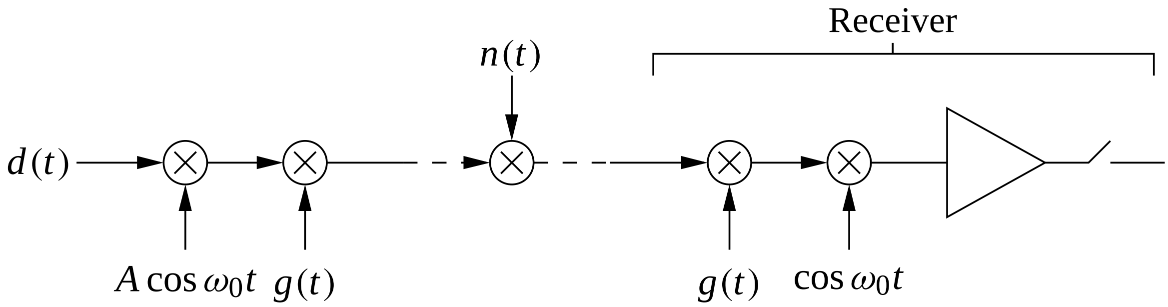
It is standard practice to make the edges of $g(t)$ and $d(t)$ coincide, so that each transition in $d(t)$ coincides with a transition in $g(t)$. An example of a waveform, a chipping waveform, and the product waveform is shown below:



The product sequence is seen to be similar to $g(t)$ — if $g(t)$ were truly random, then the product sequence would be another random sequence $g'(t)$ having the same chip rate f_c as $g(t)$. Since the bandwidth of the BPSK signal

$s(t)$ is nominally $2f_b$ and the bandwidth of the BPSK spread spectrum signal $v(t)$ is $2f_c$, the spectrum has been spread by the ratio f_c/f_b. The power transmitted by $s(t)$ and $v(t)$ is the same, so the power spectral density $G_s(f)$ is reduced by the factor f_b/f_c.

A receiver for the DS spread spectrum signal is shown below:



The incoming signal is first multiplied by the waveform $g(t)$, and then by the carrier $\cos\omega_0 t$. The resulting waveform is then integrated for the duration of the bit, and sampled to yield the data $d(kT_b)$. Thus at the receiver it is necessary to regenerate both the sinusoidal carrier of frequency ω_0 *and* the PN waveform $g(t)$.

One of the primary advantages of spread spectrum signals are their immunity to interfering signals. This is particularly useful in military communications. Suppose a jamming signal of amplitude A_J is present at the carrier frequency ω_0. The input to the receiver then becomes

$$v_I(t) = A_0 d(t) g(t) \cos(\omega_0 t) + A_J \cos(\omega_0 t).$$

At the receiver, after multiplying by the PN signal one obtains

$$A_0 d(t) \cos(\omega_0 t) + A_J g(t) \cos(\omega_0 t).$$

The first term here is a conventional BPSK signal, but the interference in the second term has been spread out in frequency by the action of multiplying by $g(t)$. By lowpass filtering the resulting signal the effective power of the interference can be reduced: if f_c is the chip frequency and f_b the bit frequency, then the jammer power at the receiver output is

$$P = \frac{A_J^2}{f_c/f_b}.$$

The spread spectrum receiver has therefore reduced the effect of narrowband jamming by a factor f_c/f_b. This ratio is called the **processing gain** of the SS receiver.