Modern Digital Communications: A Hands-On Approach

AM Signals

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Goal

The goal of this lecture is to get a quick start in the world of software-defined radio.

We will give you the samples of an AM signal and you use MATLAB/Python to demodulate.

To collect the samples we have attached an antenna to a signal analyzer that amplifies, filters and down-converts the received signal to a center frequency which is suitable for our sampler. The sampled and digitized output will be given to you.

AM Signal

An AM (Amplitude Modulation) signal has the form:

$$s(t) = [1 + Km(t)]A\cos(2\pi f_c t + \phi)$$

where A and f_c are arbitrary positive constants,

$$m(t)$$

is the information signal, and K is such that $|Km(t)| \leq 1$. Then

$$[1 + Km(t)]$$

is never negative and it is indeed the *envelope* of the AM signal $s(t)$. The signal

$$A\cos(2\pi f_c t + \phi)$$

is the *carrier*, where ϕ is an arbitrary phase shift, that from now on we assume to be zero.

Demodulation of AM Signals

At first it seems more reasonable to define an AM signal to be

$$\tilde{s}(t) = Am(t)\cos(2\pi f_c t),$$

but this would require more effort on the receiver side.

To demodulate $s(t)$ (i.e. recover $m(t)$) we first extract its envelope. To do this we first take the absolute value

$$\begin{aligned} s_{abs}(t) &= |s(t)| \\ &= A[1 + Km(t)]|\cos(2\pi f_c t)|. \end{aligned}$$

Notice that $|\cos(2\pi f_c t)|$ is a periodic signal of period $\frac{1}{2f_c}$. Its Fourier Series expansion takes the form

$$|\cos(2\pi f_c t)| = \sum_k A_k e^{j4\pi f_c k t}.$$

for some sequence $\{A_k\}_{k=-\infty}^{\infty}$ of Fourier series coefficients.

Hence, if

$$e(t) = [1 + Km(t)] \Longleftrightarrow e_{\mathcal{F}}(f)$$

then

$$s_{abs}(t) = e(t)A|\cos(2\pi f_c t)| = \sum_k e(t)AA_k e^{j4\pi f_c k t}$$

and

$$s_{abs\mathcal{F}}(f) = \sum_k e_{\mathcal{F}}(f - k2f_c)AA_k$$

A low-pass filter will recover $e(t)$, provided that $2f_c \geq 2B$, where B is the bandwidth of the information signal $m(t)$.

We recommend an easier way to obtain (an approximation of) $e(t)$. The idea is that if you average $s_{abs}(t)$ over a time interval which is large enough to average out $|\cos(2\pi f_c t)|$ but small enough so as not to average out $e(t)$, then you obtain essentially $e(t)$ times a constant. To see this, it suffices to make a qualitative plot of $s_{abs}(t)$.

A scaled version of $Km(t)$ (assumed to be zero-mean) can then easily be obtained from $e(t)$ by removing the DC component.

We have neglected the noise. If we receive a noisy signal $r(t) = s(t) + w(t)$, then the demodulated signal is a noisy version of $Km(t)$.

For more see e.g. Proakis and Salehi, *Communication Systems Engineering.*