Software-Defined Radio: A Hands-On Course

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 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:

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

where A and f_c are arbitrary positive constants,

$$m(t)$$

is the information signal, and K is such that 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 $carrier$.

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 $A|\cos(2\pi f_c t)|$ is a periodic signal of period $\frac{1}{2f_c}$. Hence its Fourier transform consists of delta Diracs located at multiples of $2f_c$ (see the Appendix if you need to review this). Recall also that the Fourier transform of a product of signals is the convolution of the Fourier transformed signals. Convolving a signal with delta Diracs is easy.

Hence, if

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

then

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

for some sequence $\{A_k\}_{k=-\infty}^{\infty}$ of Fourier series coefficients. (I recommend deriving the above for yourself and making a qualitative plot of $|s_{abs\mathcal{F}}(f)|$.)

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

$Km(t)$ (assumed to be zero-mean) can then easily be obtained from $e(t)$.

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*

Appendix: The Fourier Transform of a Periodic Signal

Let p(t) be a periodic signal, with period T_p. Then we can use the Fourier series to write

$$p(t) = \sum A_k e^{j2\pi \frac{t}{T_p} k}$$

for some sequence $\{A_k\}$. Its Fourier transform is

$$p_{\mathcal{F}}(f) = \sum A_k \delta(f - \frac{k}{T_p}).$$