Error-Correcting Amplitude-Shift Keyed Wireless Data Connection

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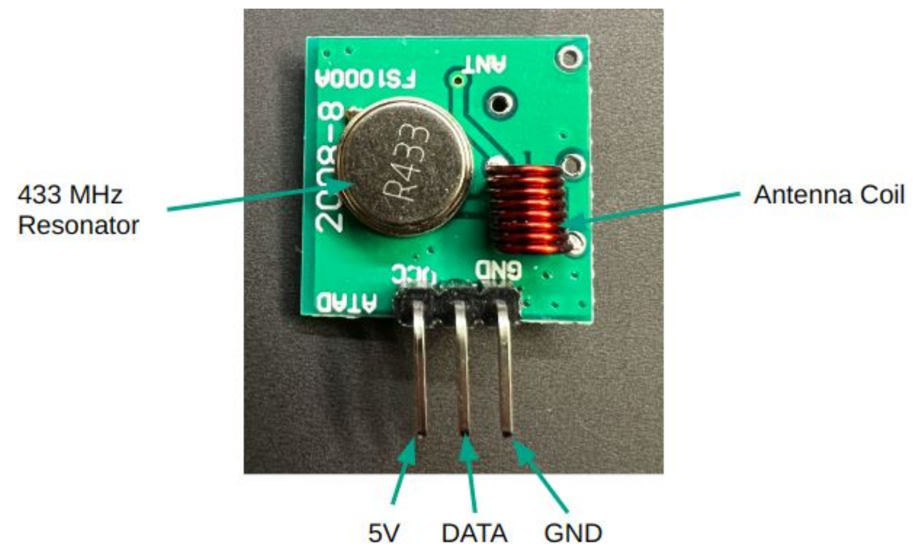
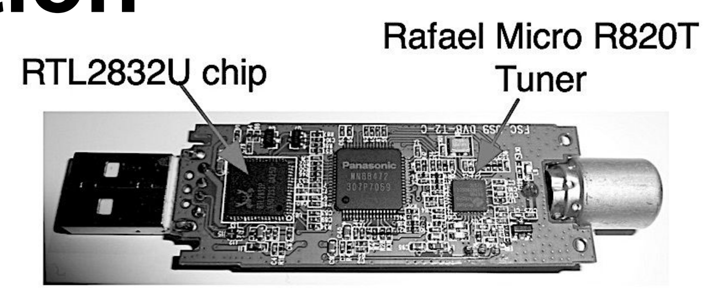
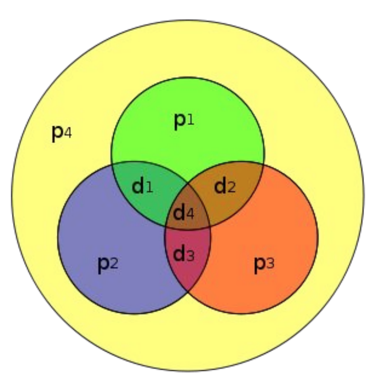
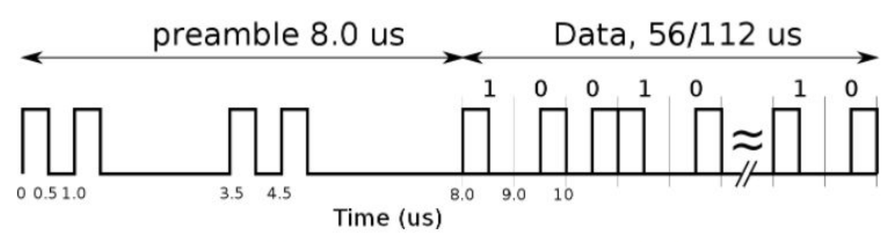
EECS 348 Digital Systems, Prof. Rajit Manohar

Introduction



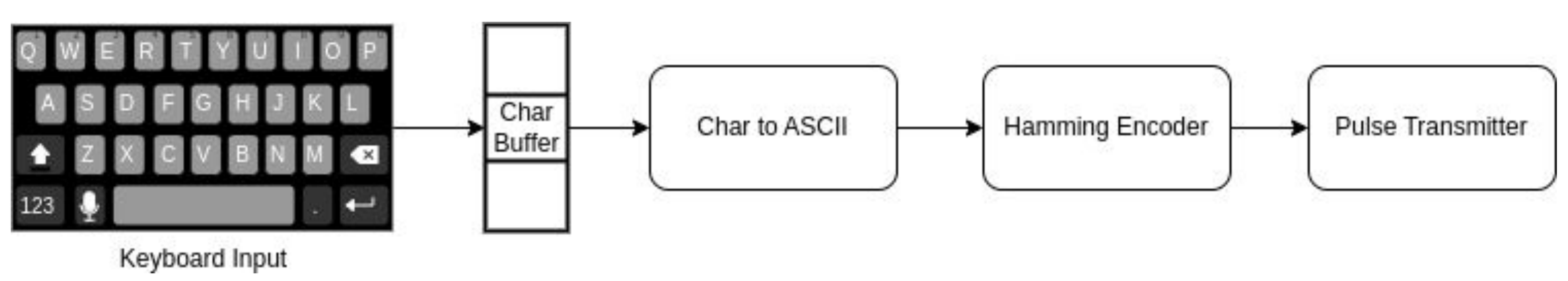




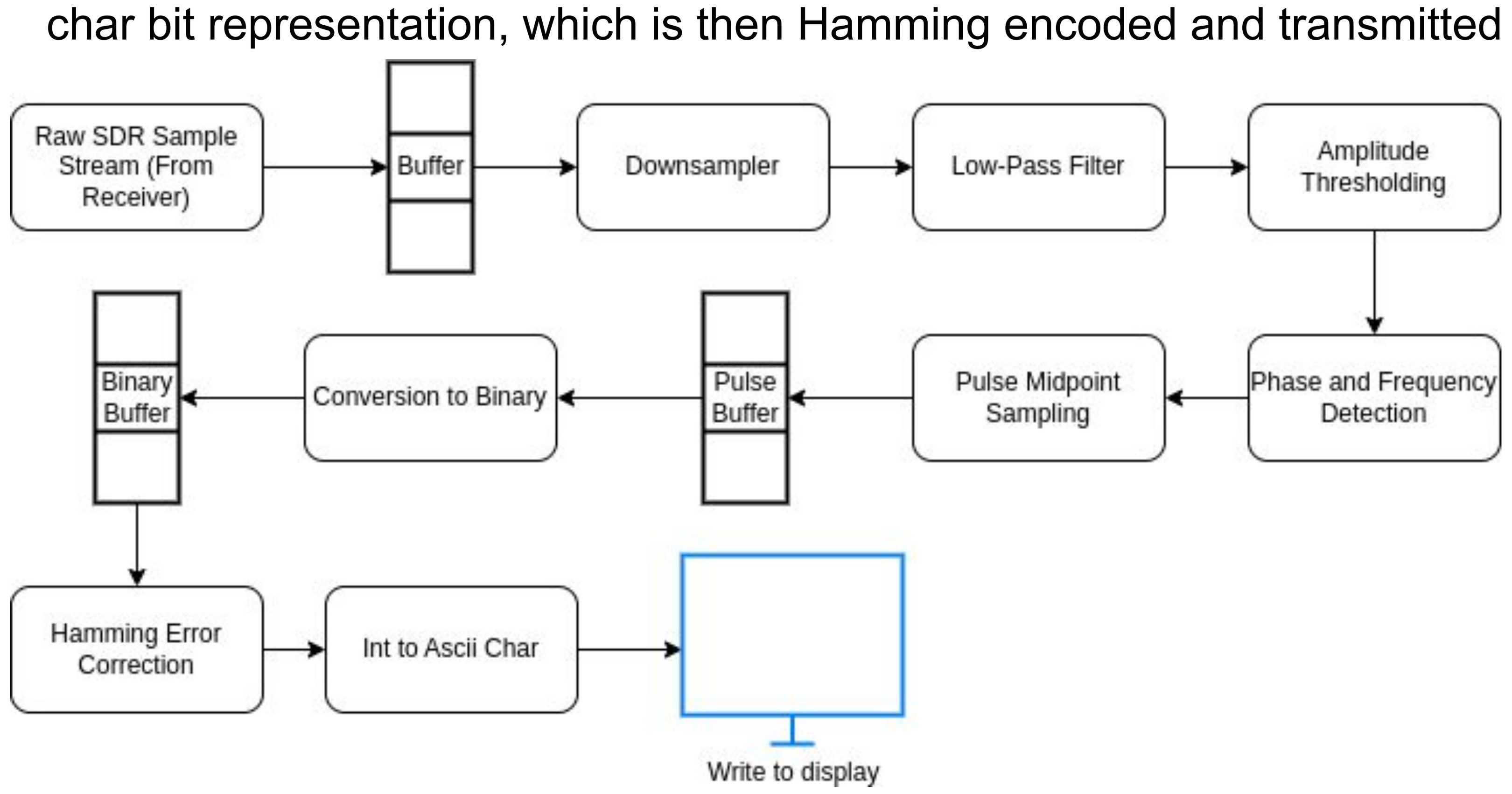


Clockwise from top left: ASK transmitter, software-defined radio receiver, Fourier transform of our signal, ADS-B packet header, Hamming diagram

Software Architecture

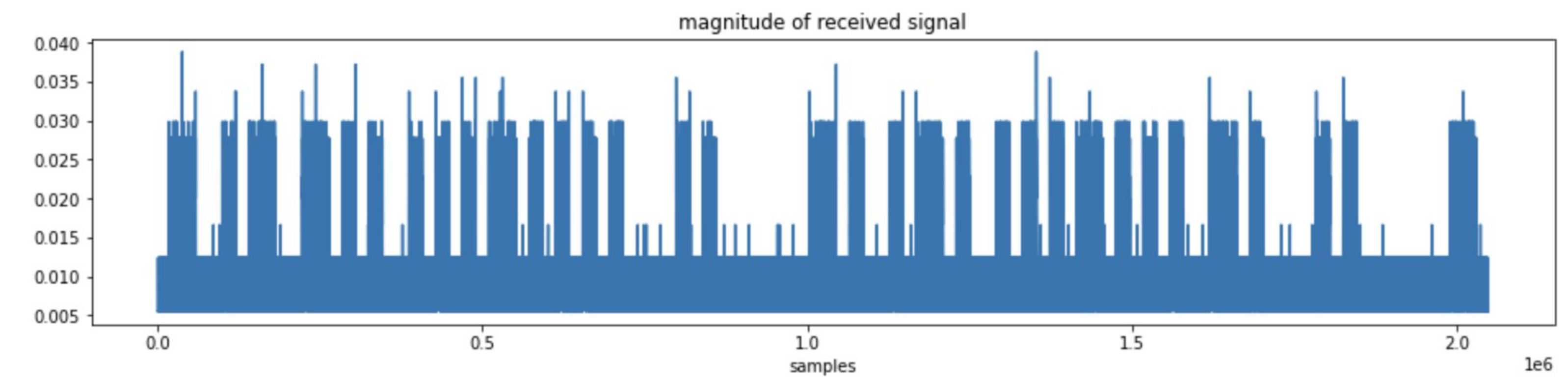


Transmitter: keyboard input is fed into a buffer and converted to ASCII char bit representation, which is then Hamming encoded and transmitted

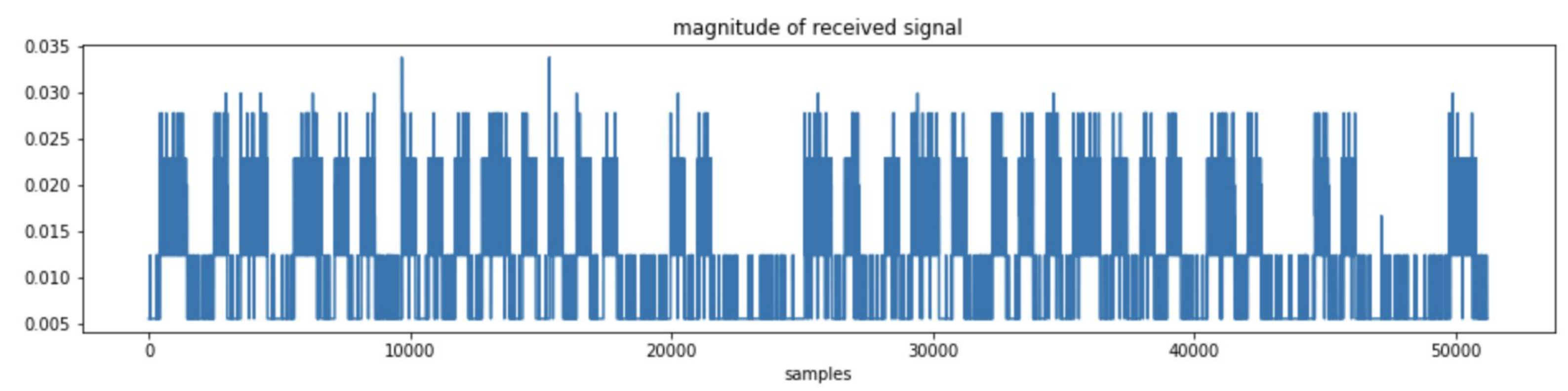


Receiver: Raw I/Q samples are buffered, downsampled, and noise removed via low-pass filter, then thresholded, midpoint-sampled, decoded, and converted to char and displayed to the user.

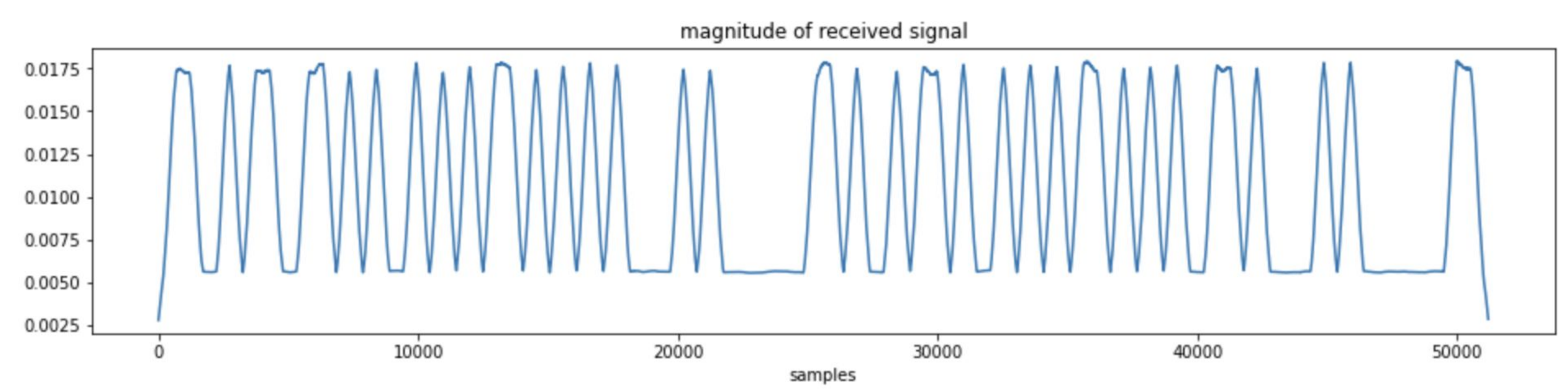
Signal Processing Algorithm



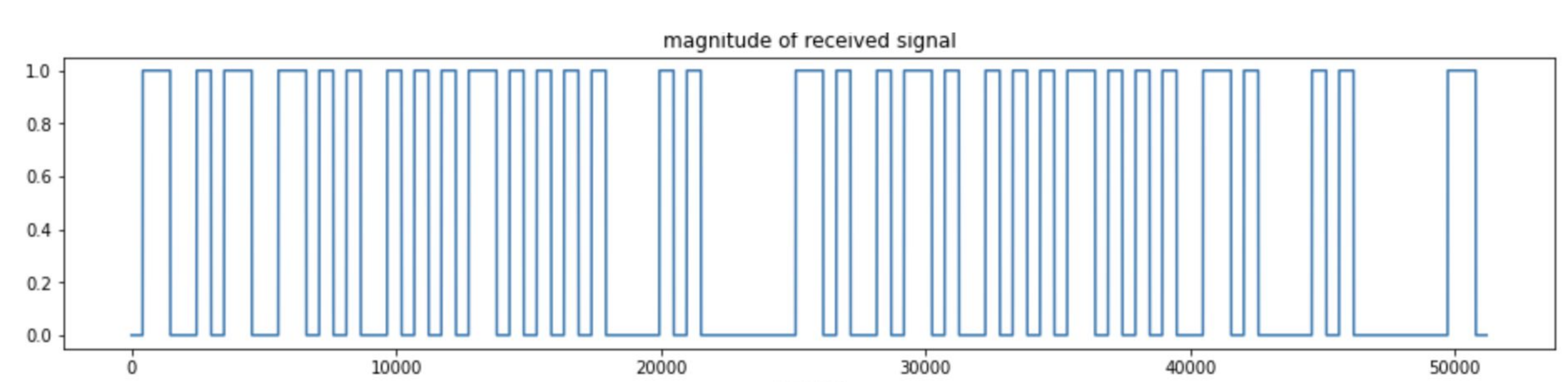

```
def downsample(sample, orig_freq, new_freq):
```




```
def smoothing_filter(samples):
```

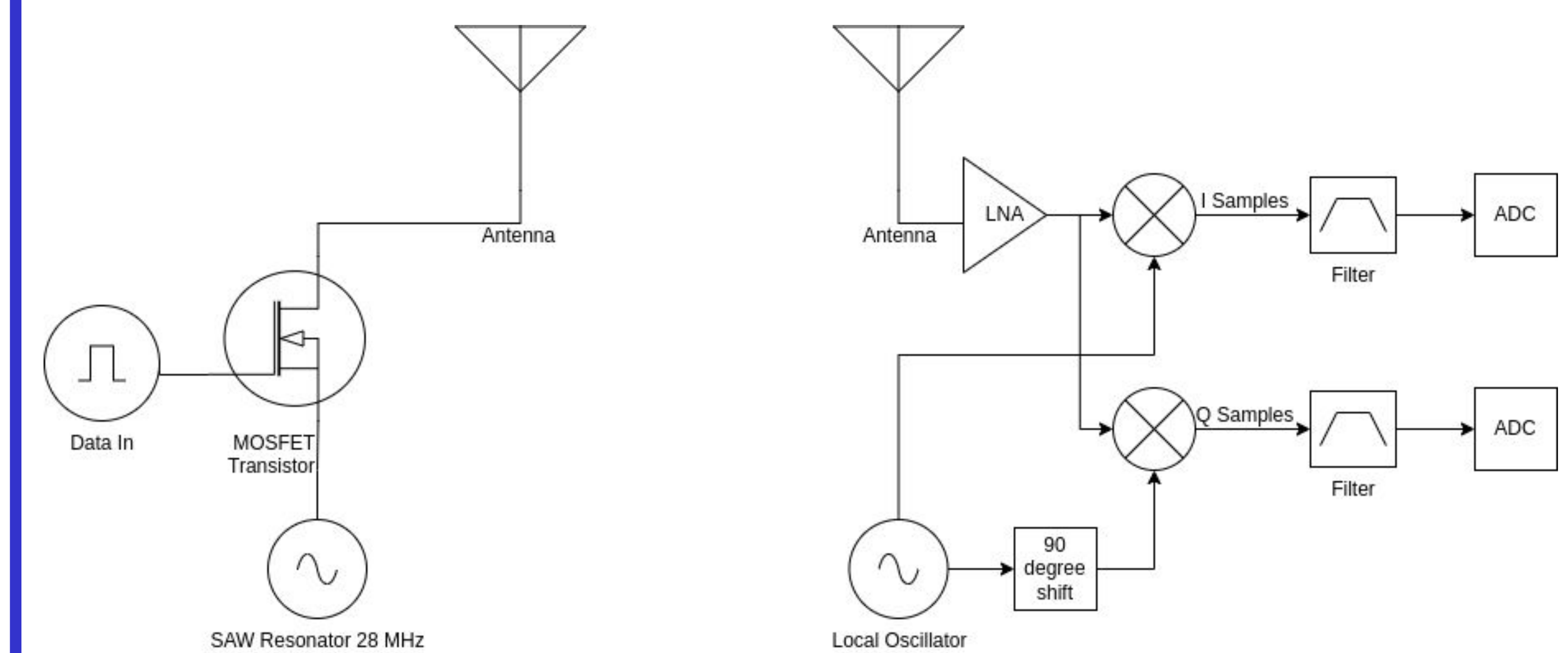



```
def digitize_samples(samples, threshold):
```



Our signal processing pipeline. The raw I/Q samples are collected from the SDR at 2 GHz and downsampled to 50 KHz. A Gaussian low-pass filter is applied to the downsamples and K-means (K=2) clustering to identify signal and noise. Finally the digitized signal is binarized and sampled at the midpoints of the digital signal.

RF Frontend Design



The transmitter transmits at 433 MHz using a signal generated from the SAW resonator, modulated using ASK by a MOSFET transistor. The receiver consists of a low-noise amplifier mixed with orthogonal sine wave and filtered to baseband to extract raw I/Q samples.

Signal Processing Theory

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{x^2}{2\sigma^2}\right),$$

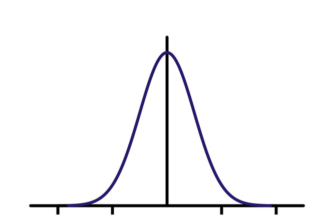
$$K(i) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(i-k)^2}{2\sigma^2}\right)$$

$$\mathcal{F}\{G(x)\} = \frac{1}{\sqrt{2\pi\sigma_f^2}} \exp\left(-\frac{f^2}{2\sigma_f^2}\right)$$

$$\mathrm{SNR} = 10\log_{10}\left(\frac{\text{Signal Power}}{\text{Noise Power}}\right)$$

$$M = \frac{F_s}{F_d} \qquad y(n) = x(Mn)$$

$$\rho = \frac{\sum_{i=1}^{N}(T(i)-\bar{T})(C(i)-\bar{C})}{\sqrt{\sum_{i=1}^{N}(T(i)-\bar{T})^2}\sqrt{\sum_{i=1}^{N}(C(i)-\bar{C})^2}}$$



Gaussian kernel

- The Gaussian filter is a low-pass filter used to reduce the high-frequency noise in a signal.
- The discretized representation of the Gaussian kernel
- Freq. response of the kernel, indicating an exponential dropoff at higher frequencies.
- Gaussian-filtering our signal removes high-frequency noise, improving the signal-to-noise ratio
- We downsample the signal in order to avoid saturating our signal processing pipeline, resulting in dropped packets.
- Template matching is used to detect the presence of a known pattern (preamble) within a signal. In our implementation, we use the correlation coefficient as a measure of similarity between the template, T(i) and the candidate signal, C(i)