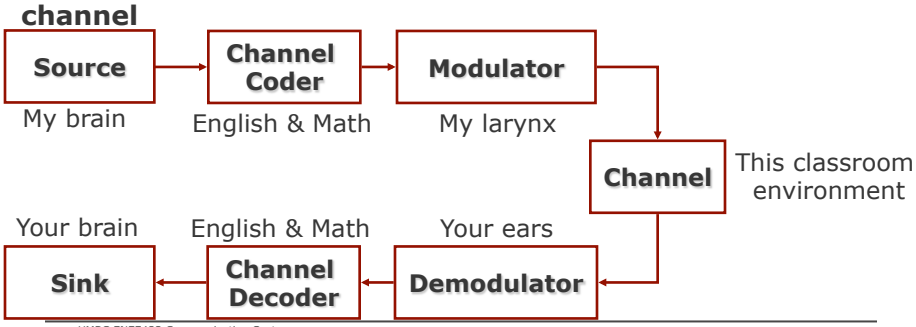
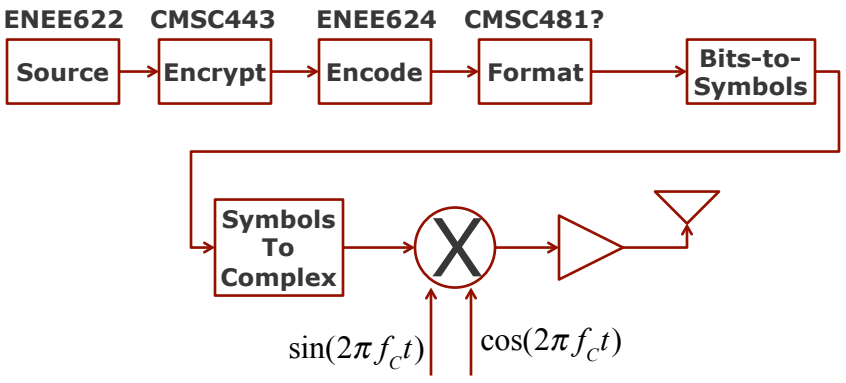
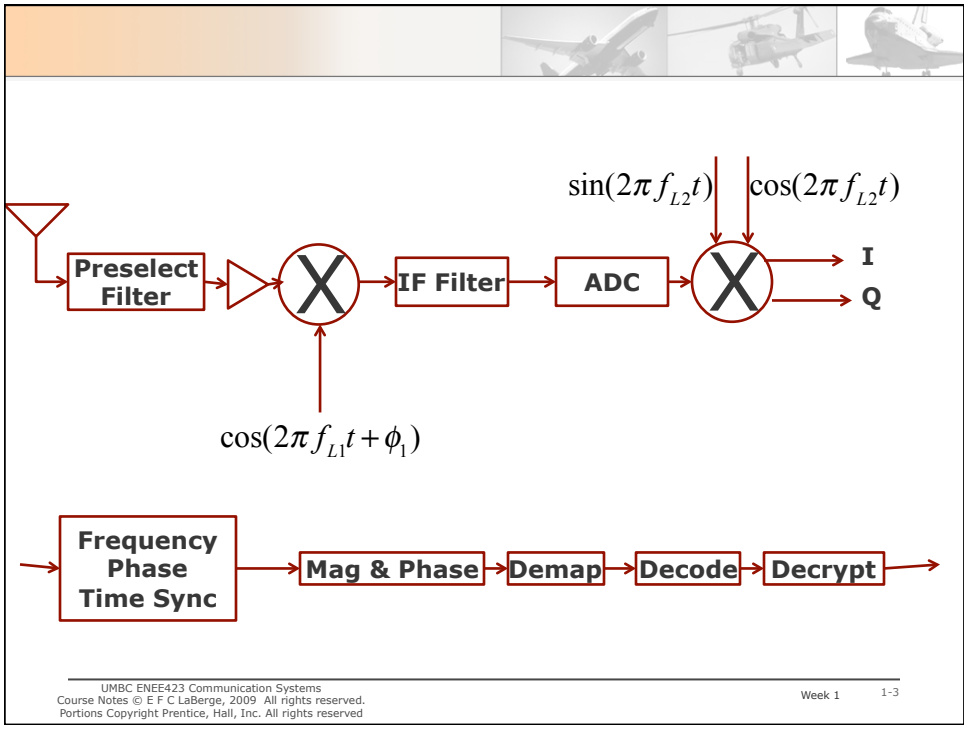
Let's look at the communication process

- The purpose of communication is to convey information from one entity to another
- We need to "encode" the information in some agreed-upon way
- We need to "modulate" the data to create a physical waveform
- The modulated waveform travels over a physical channel

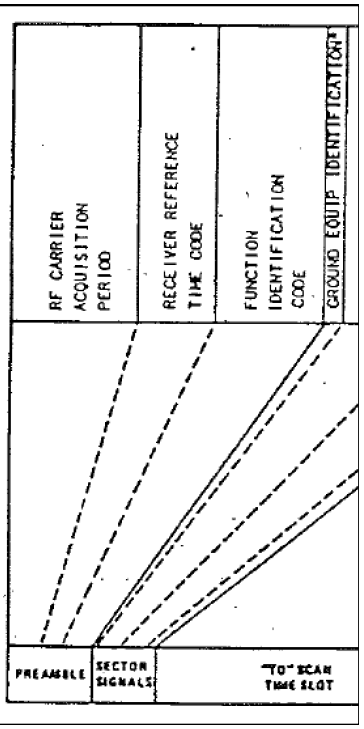






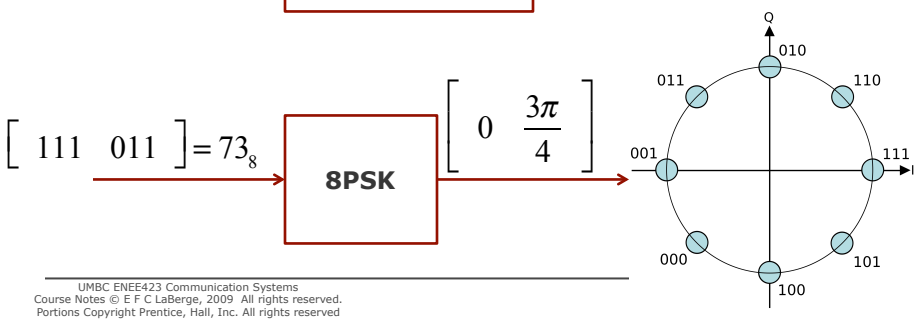
Formatting

- Digital Communications Systems typically include the following
  - Frequency Acquisition
  - Phase Acquisition
  - Time Synchronization
  - Function/Content ID
- This is all overhead that must be done, but doesn't actually convey the source-to-sink information
- Generally assumed that this is all binary, yet to be mapped to the channel symbols
- Generally not encrypted and minimally encoded.

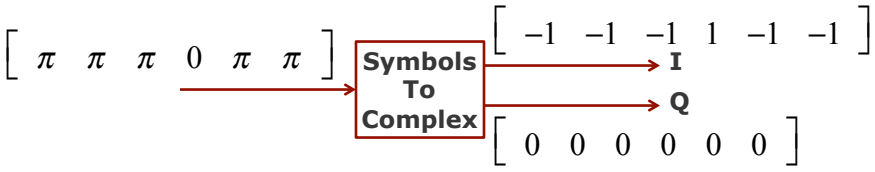


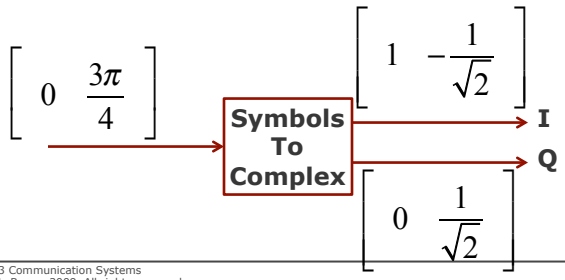
Bits to Symbols

- If modulation is 2-ary (BPSK, BPAM, BPPM) the mapping is one-to-one
- If modulation is M-ary (QPSK, 8PSK, 64PPM, 16QAM, etc), mapping is log2(M) to one



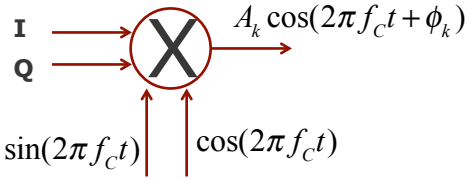
- Now create complex parts…
- …also know as I&Q "in phase" and "quadrature"





The mixing or upconversion

- Impose the modulation on a carrier signal…
- …resulting in a real signal!!!

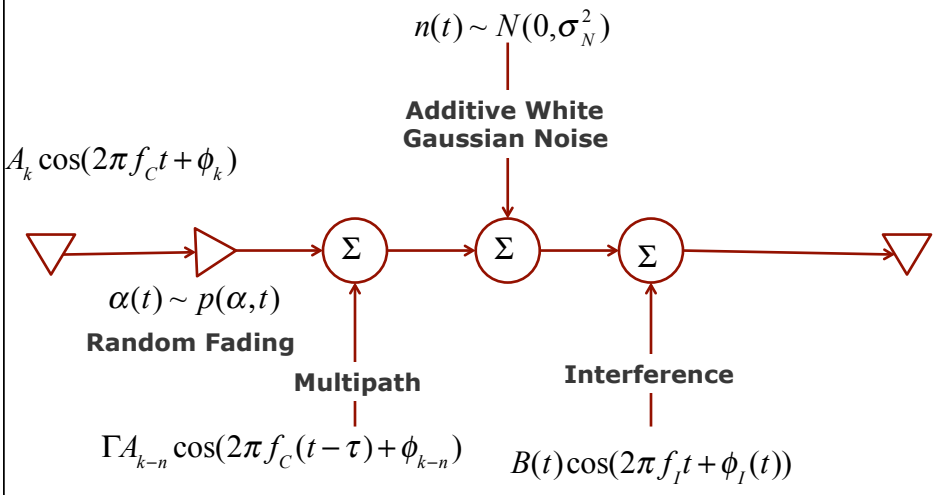


$$A_k\left(\cos(\phi_k) + j\sin(\phi_k)\right) = A_k e^{j\phi_k}$$

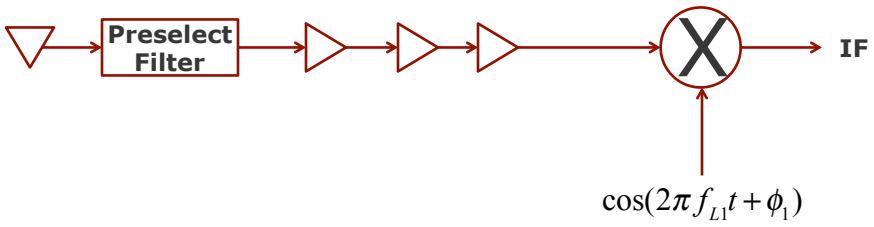
$$\mathrm{Re}\left[A_k e^{j\phi_k} e^{j2\pi f_C t}\right] = \mathrm{Re}\left[A_k e^{j(2\pi f_C t + \phi_k)}\right] = A_k \cos(2\pi f_c t + \phi_k)$$

$$= A_k\left(\cos(2\pi f_C t)\cos(\phi_k) - \sin(2\pi f_C t)\sin(\phi_k)\right)$$

Now through the channel



$$A_k \cos(2\pi f_C t + \phi_k + \phi_{Chan}) + I(t) + n(t)$$



$$s_{IF}(t) = \left(A_k \cos(2\pi f_C t + \phi_k + \phi_{Chan}) + I(t) + n(t)\right)\cos(2\pi f_{L1} t + \phi_1)$$
$$= 0.5A_k \cos(2\pi(f_C - f_L)t + \phi_k + \phi_{Chan} - \phi_{L1})$$
$$+0.5A_k \cos(2\pi(f_C + f_L)t + \phi_k + \phi_{Chan} + \phi_{L1})$$
$$+I(t)\cos(2\pi f_L t + \phi_{L1}) + n(t)\cos(2\pi f_L t + \phi_{L1})$$

$\sin(2\pi f_{L2} t)$ $\cos(2\pi f_{L2} t)$

$$0.5\gamma A_k \cos(2\pi(f_C - f_L)t + \phi_k + \phi_{Chan} - \phi_{L1})$$
$$+H(s)I(t) + H(s)n(t)$$

$$i(t) + jq(t) = gA_k e^{j\phi_k} + he^{j(2\pi f_{L2} t + \phi_2)} I(t) + n_C(t)$$