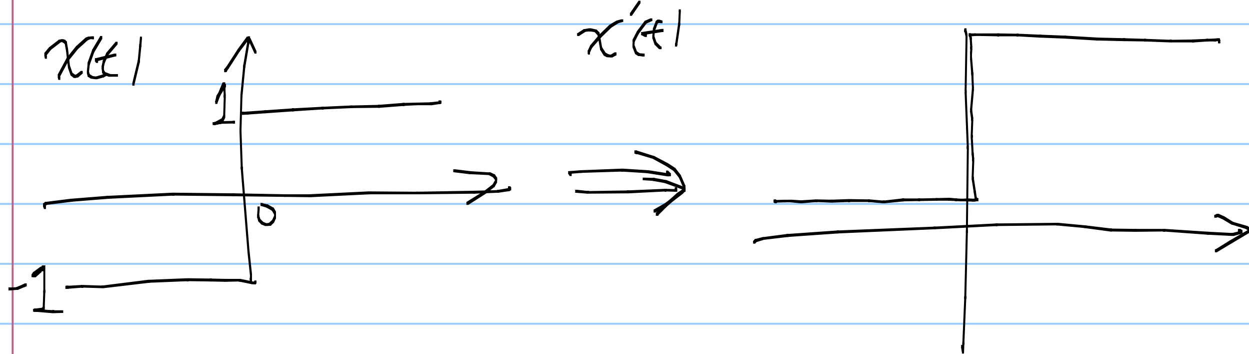
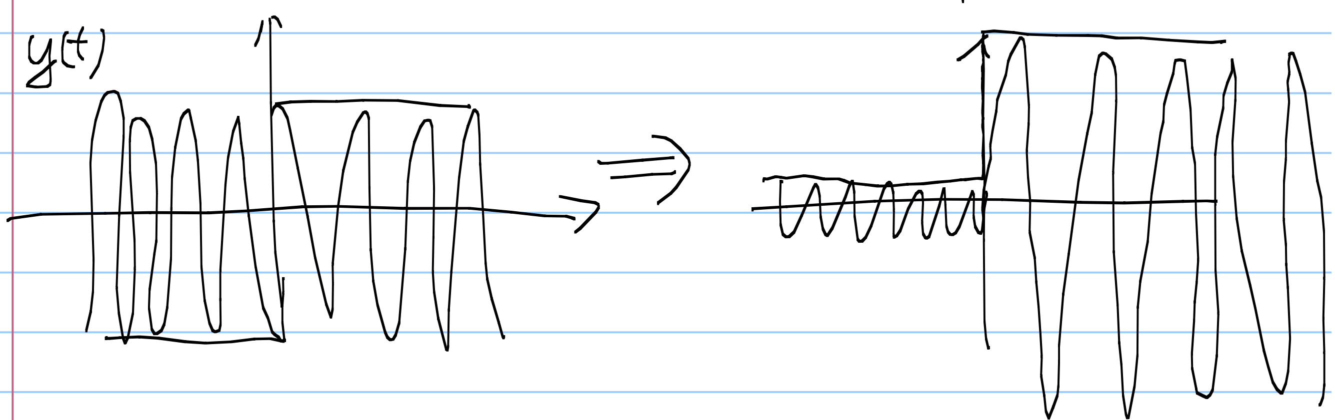
How to fix this problem?

Ans: Add some DC component to shift the original $x(t)$ to be above zero

$x'(t) = x(t) + K$, $\quad y(t) = x'(t)\cos(\omega_c t) = (x(t) + K)\cos(\omega_c t)$





What is the "price" of adding some DC component?
Ans: We need additional transmission power at the radio station.

Note: Nowadays, asynchronous demodulation is seldom used.

Section 8.3 Freq division multiplexing (FDM)

An even more practical scenario:

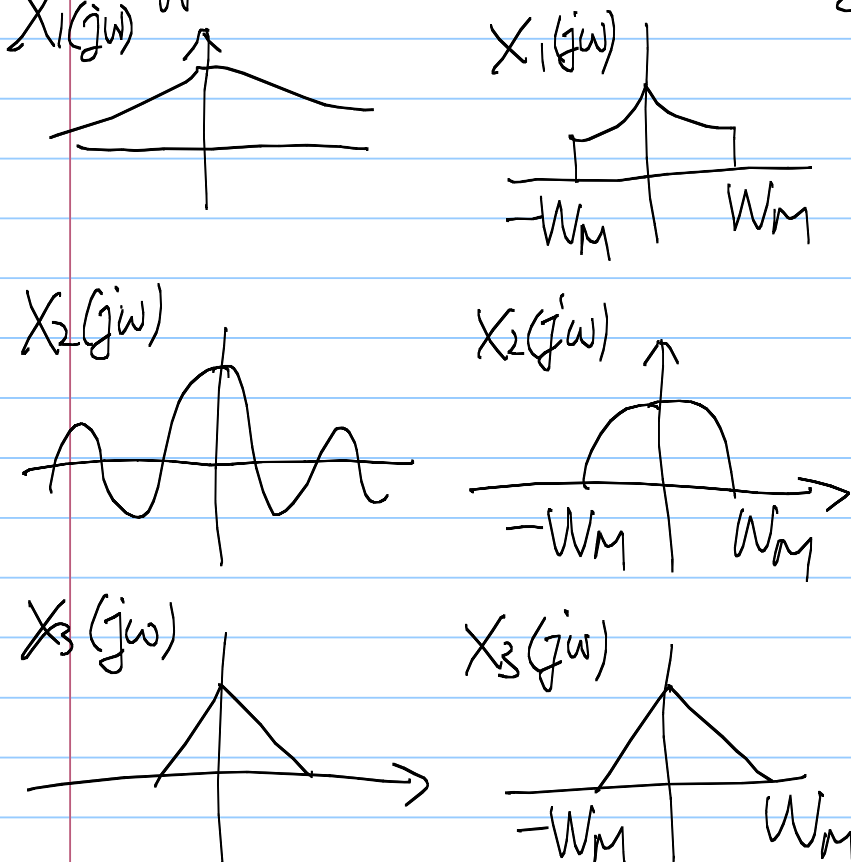
An antenna tower may like to broadcast several radio stations at the same time. How to achieve this goal?

Ans: Frequency-Division Multiplexing (FDM)

Multiplexing: Different users/signal sources would like to "share" the same media with minimal quality degradation.

FDM: A special type of multiplexiing such that mutlplexing is achieved by dividing the usage of the media by "frequencies."

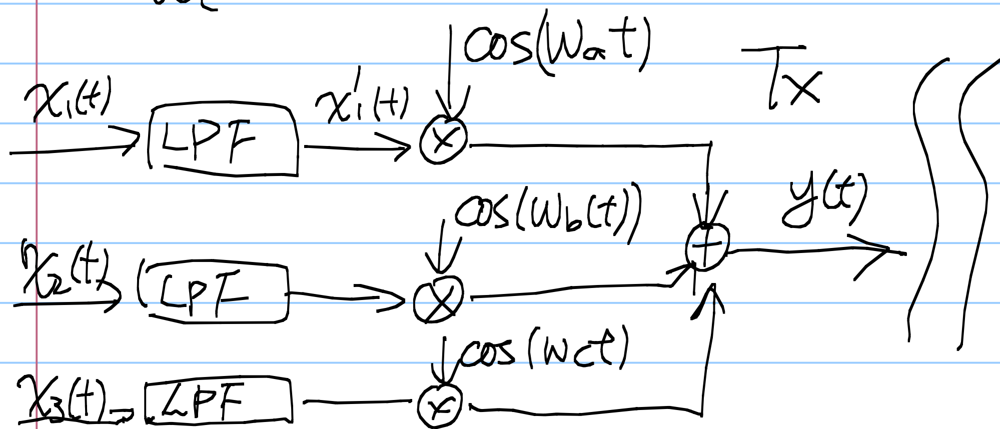
Suppose we have three signals to transmit



To avoid unnecessary freq overlap, $x_1(t)$ $x_2(t)$ & $x_3(t)$ have to be converted to "band-limited" signals first.

How to send all three signals simultaneously?

Ans: Use different carrier freq. W_a, W_b, W_c



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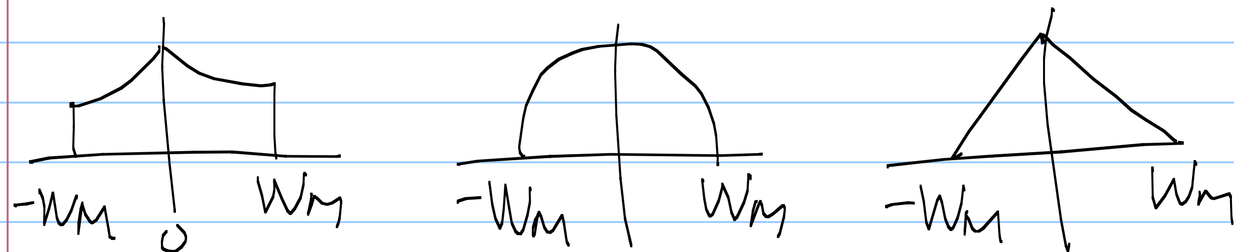
The spectrum of the final transmitted signal becomes

How to squeeze in as many radio stations as possible? (Licensed frequency bands are outrageously expensive.)

Ans: Make w_a, w_b, w_c as close as possible, but not too close.

For example, if the original signals are bandlimited to have freq $-W_M$ to W_M



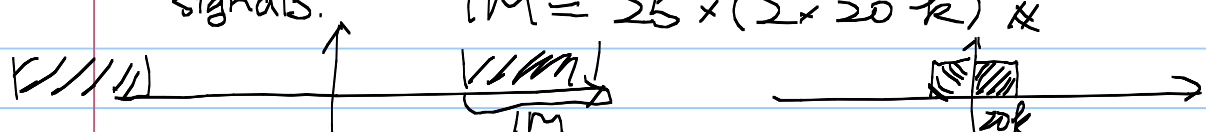
then the freq have to satisfy

$$W_b - W_a > 2W_M$$
$$W_c - W_b > 2W_M$$

usually $W_b - W_a \approx 2W_M(1 + \underline{\underline{10\%}})$

guard band

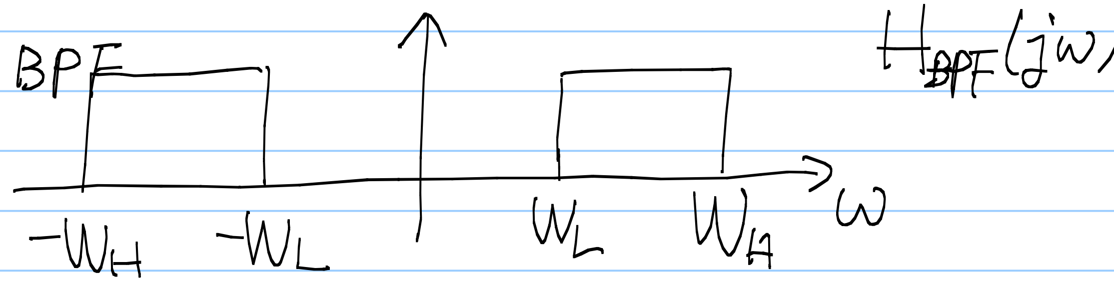
Example: Using this scheme, a licensed 1 MHz bandwith can carry 25 radio stations with each one carry 20kHz band-limited signals. $1M = 25 \times (2 \times 20k)$ *



* Whenever we say ?? MHz bandwith, we always refer to only the positive freq part.

Demodulation of (AM) FDM signals

Step 1: Pass it through a band-pass filter (BPF) to isolate the desired signal



* You need to design an LTI sys with $h(t)$ being

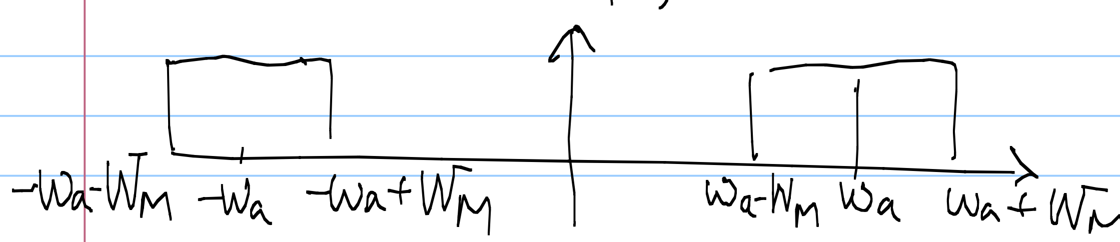
$$h(t) = \frac{\sin(W_H t)}{\pi t} - \frac{\sin(W_L t)}{\pi t}$$

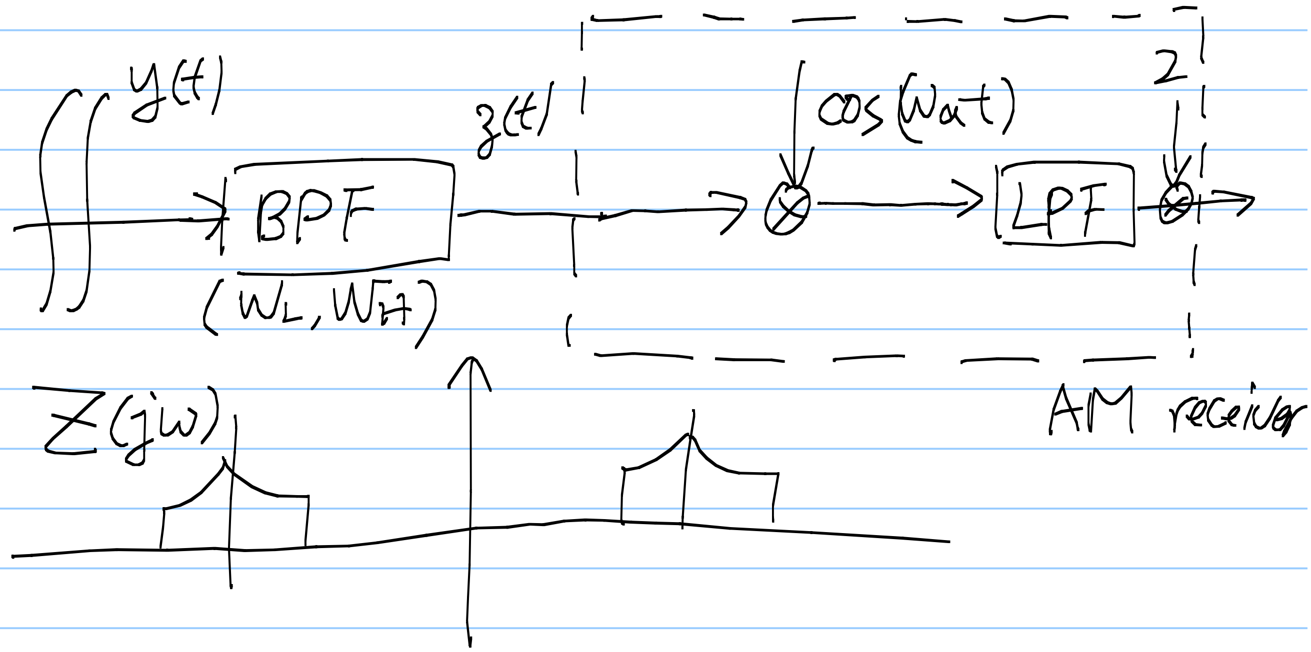
which will have the above BPF $H(jw)$

* We need to "tune the BPF" to the radio freq of your radio station

Ex: If interested in Station A
The pass band of the BPF becomes

$$W_L = \omega_a - W_M, \quad W_H = W_a + W_M$$





Step 2: Multiply $\cos(W_c t)$

Step 3: LPF with the cut-off freq $W_R \approx W_M$

* One thus needs to carefully choose the parameters W_L, W_H (BPF), ω_c (carrier freq) in order to listen to the desired radio station.