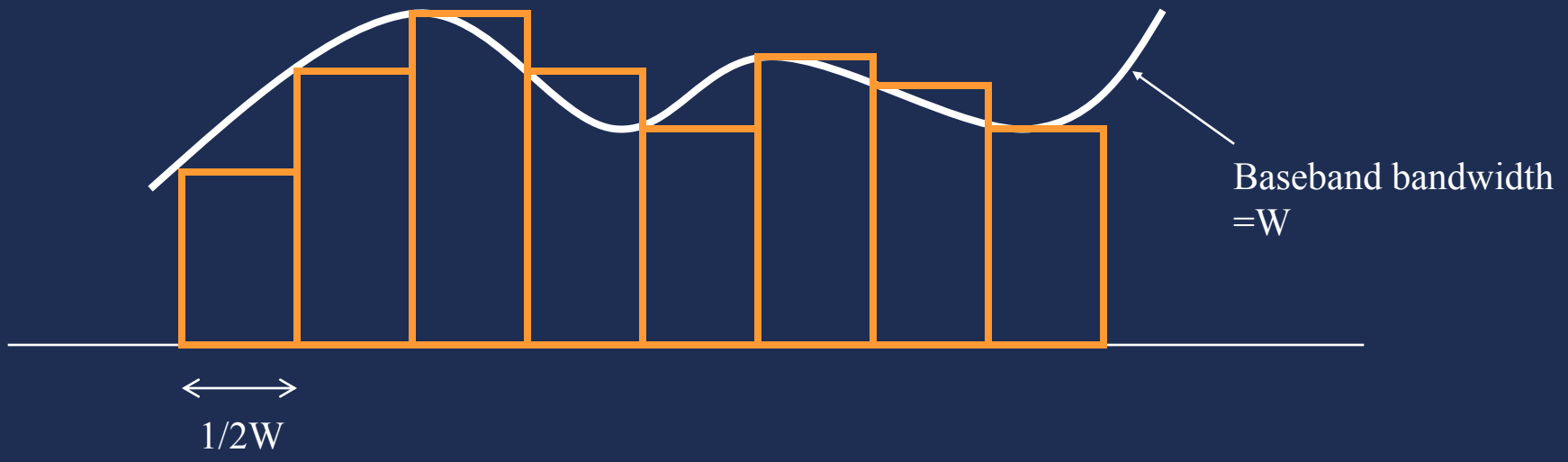
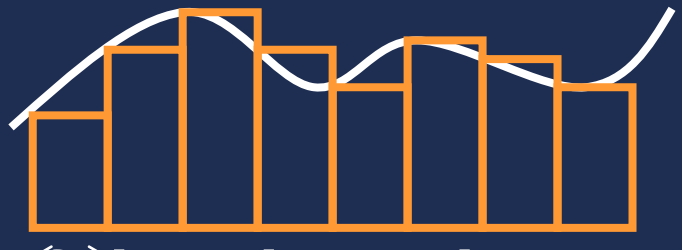
Piece-wise approximation of baseband

- Look at the following representation



Corresponding FM signal



- FM version of the above is an RF pulse for each square pulse.
- The frequency of the kth RF pulse at $t=t_k$ is given by the height of the pulse. i.e.

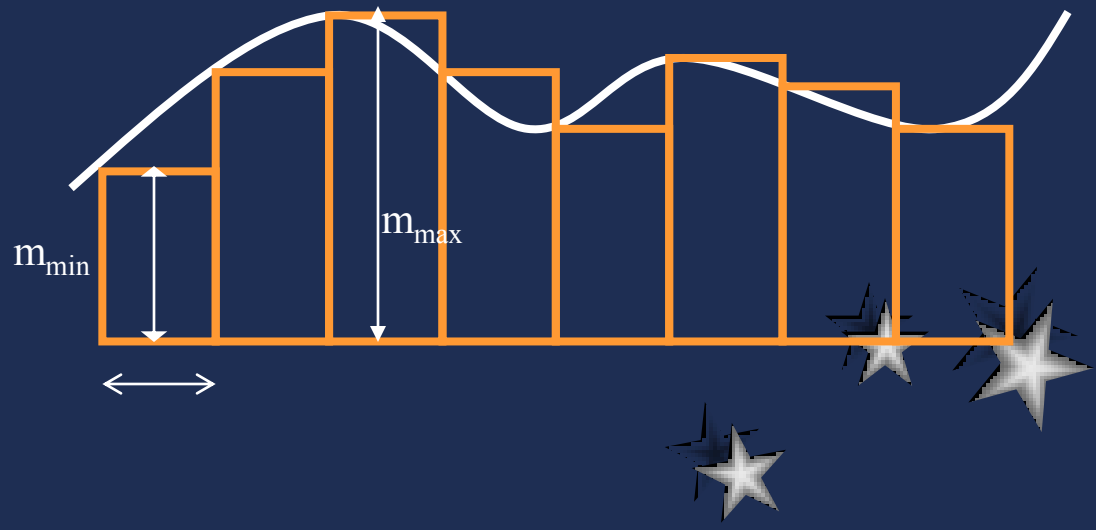
$$f_i = f_c + k_f m(t_k)$$

Range of frequencies?

- We have a bunch of RF pulses each at a different frequency.
- Inst.freq corresponding to square pulses lie in the following range

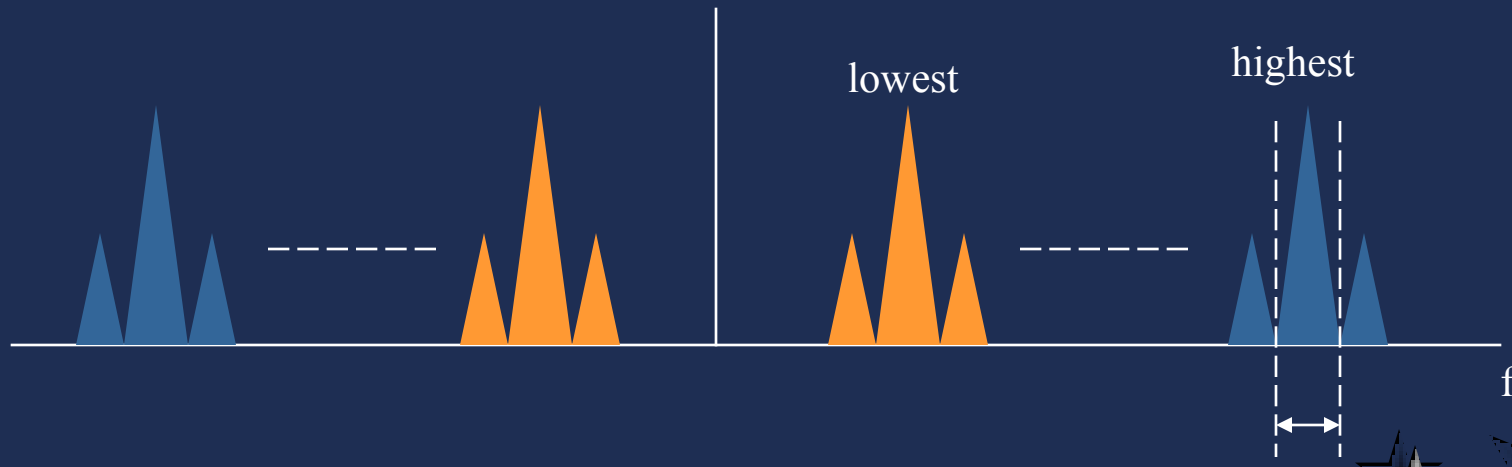
$$f_i|_{\max} = f_c + k_f m_{\max}$$

$$f_i|_{\min} = f_c + k_f m_{\min}$$



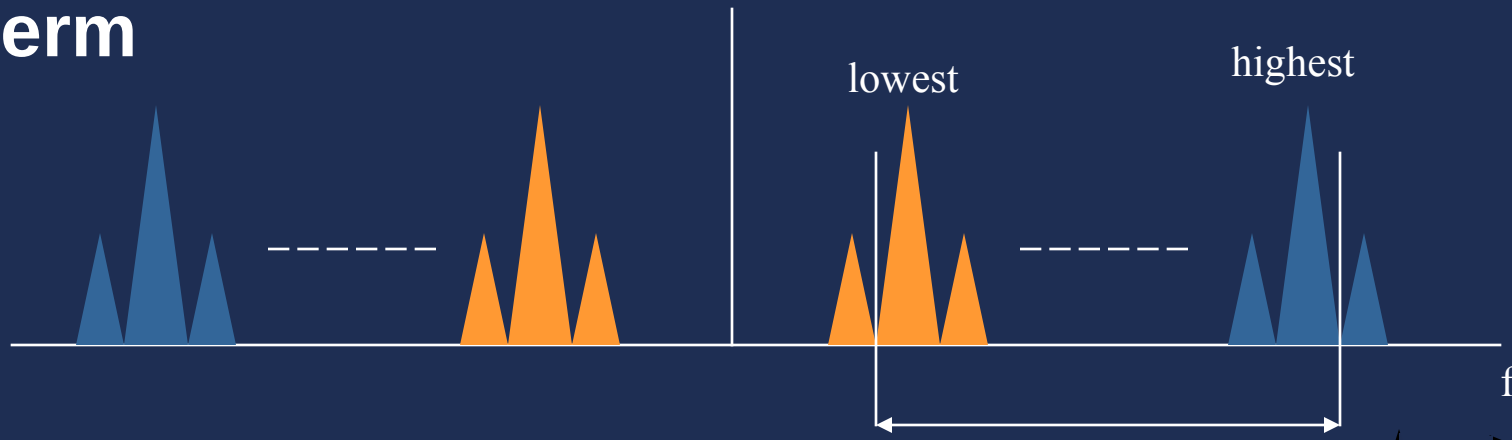
A look at the spectrum

- **We will have a series of RF pulses each at a different frequency. The collective spectrum is a bunch of sincs**



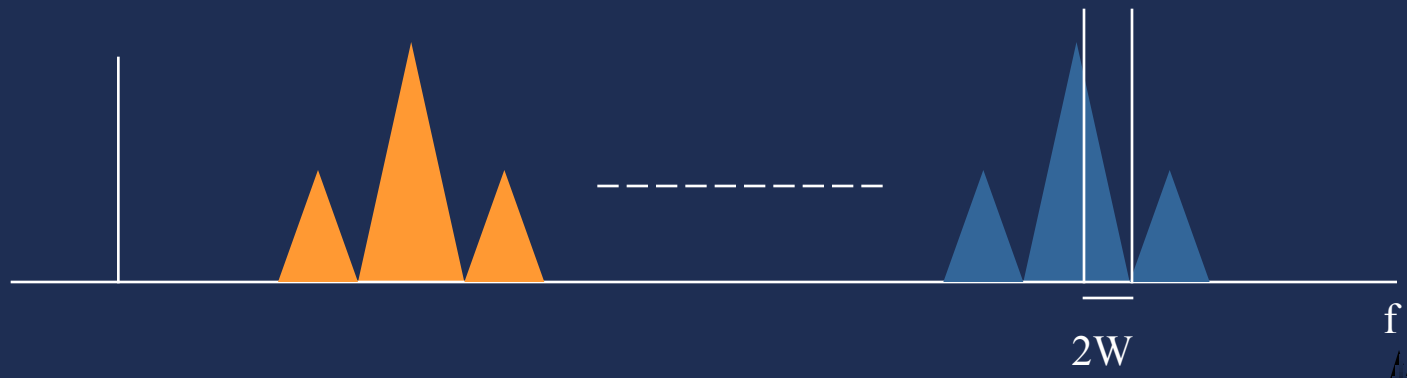
So what is the bandwidth?

- Measure the width from the first upper zero crossing of the highest term to the first lower zero crossing of the lowest term

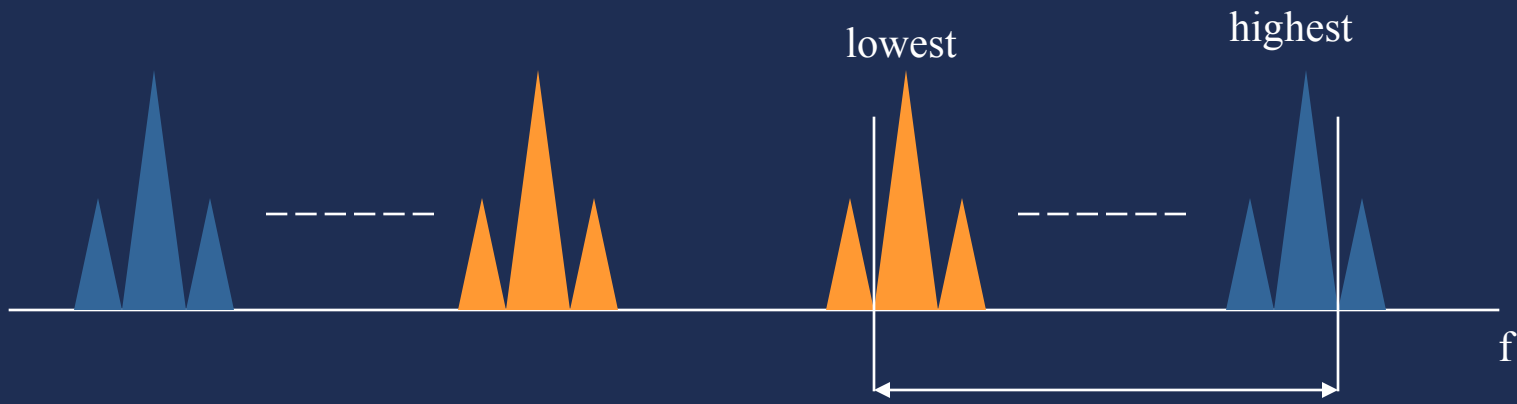


Closer look

- The highest sinc is located at $f_c+k_fm_p$
- Each sinc is 1/2W wide. Therefore, their zero crossing point is always 2W above the center of the sinc.



Range of frequenices



- **Above range lies**

$$<f_c - k_f m_p - 2W, f_c + k_f m_p + 2W>$$

FM bandwidth

- The range just defined is one expression for FM bandwidth. There are many more!

$$B_{FM}=4W+2k_f m_p$$

- Using $\beta=\Delta f/W$ with $\Delta f=k_f m_p$

$$B_{FM}=2(\beta+2)W$$

Carson's Rule

- A popular expression for FM bandwidth is Carson's rule. It is a bit smaller than what we just saw

$$B_{FM}=2(\beta+1)W$$

Commercial FM

- **Commercial FM broadcasting uses the following parameters**
  - Baseband;15KHz
  - Deviation ratio:5
  - Peak freq. Deviation=75KHz

$$B_{FM}=2(\beta+1)W=2x6x15=180KHz$$

Wideband vs. narrowband FM

- **NBFM is defined by the condition**
  - $\Delta f << W$ ⇒ $B_{FM}=2W$
  - This is just like AM. No advantage here
- **WBFM is defined by the condition**
  - $\Delta f >> W$ ⇒ $B_{FM}=2\,\Delta f$
  - This is what we have for a true FM signal

Boundary between narrowband and wideband FM

- **This distinction is controlled by β**
  - If β>1 --> WBFM
  - If β<1-->NBFM
- **Needless to say there is no point for going with NBFM because the signal looks and sounds more like AM**