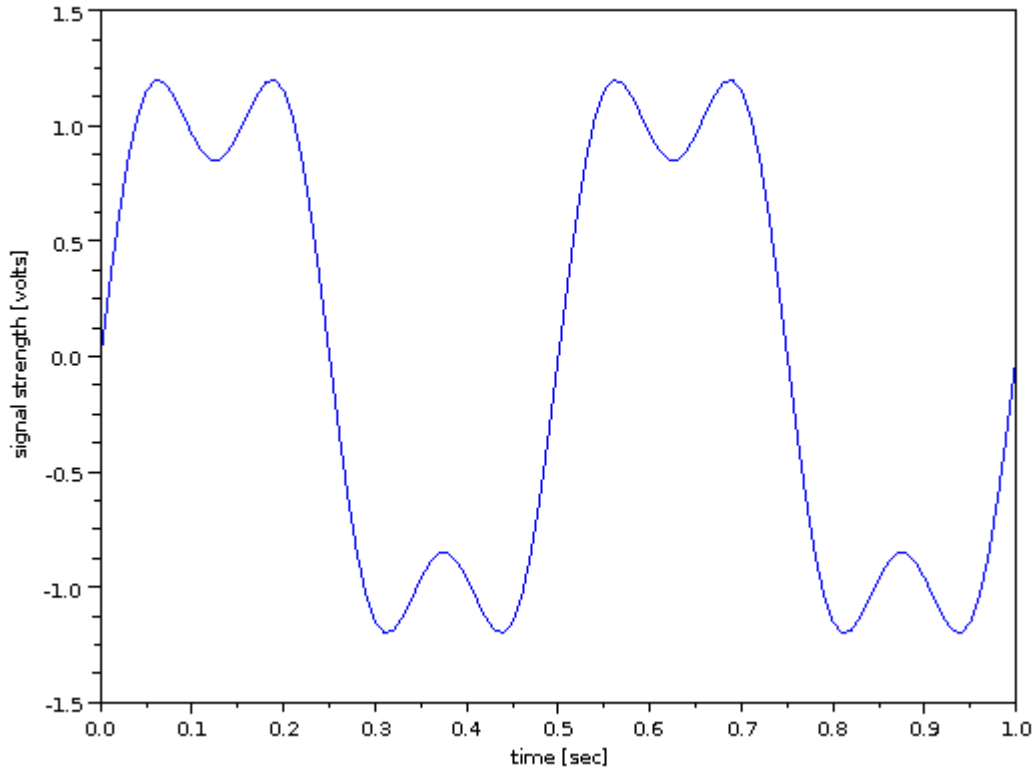
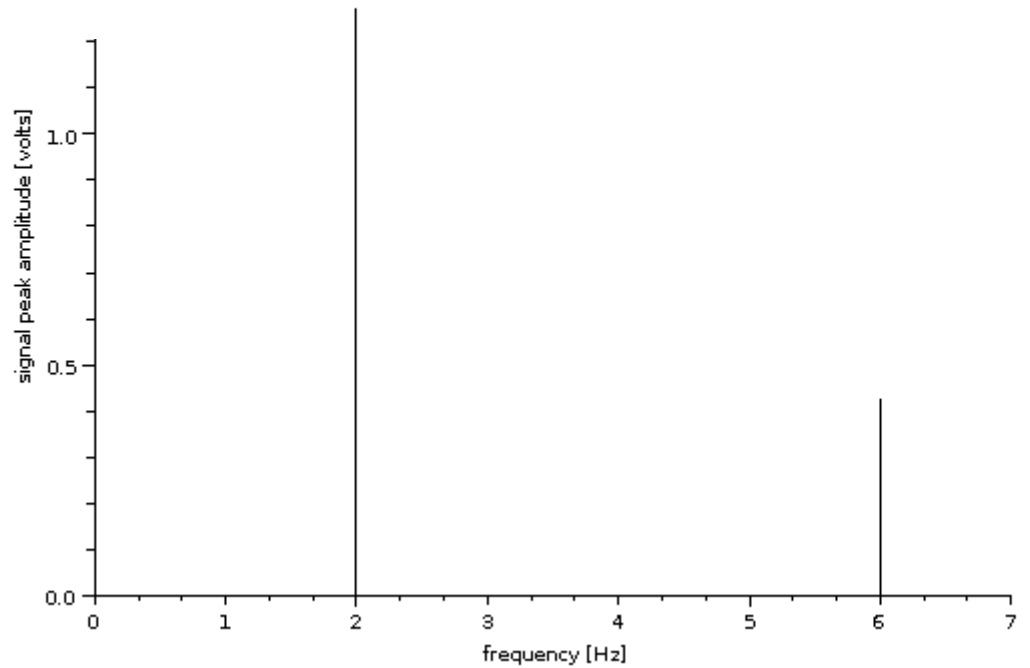


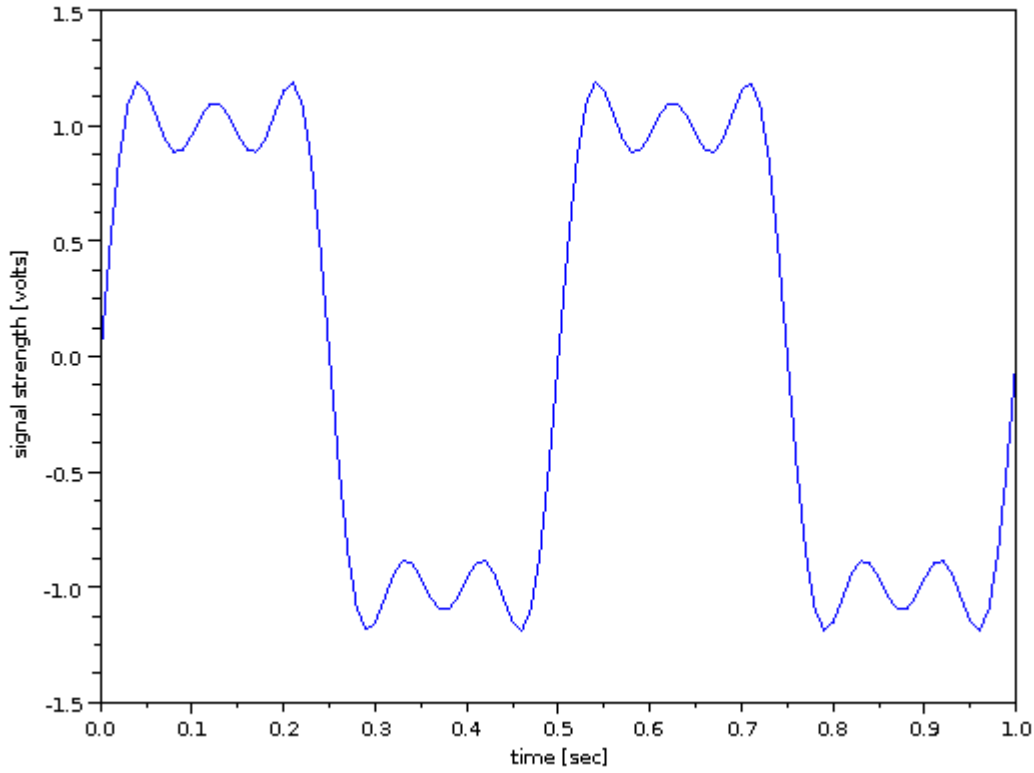
frequency = 2Hz; absolute bandwidth = 4Hz; data rate = 4b/s



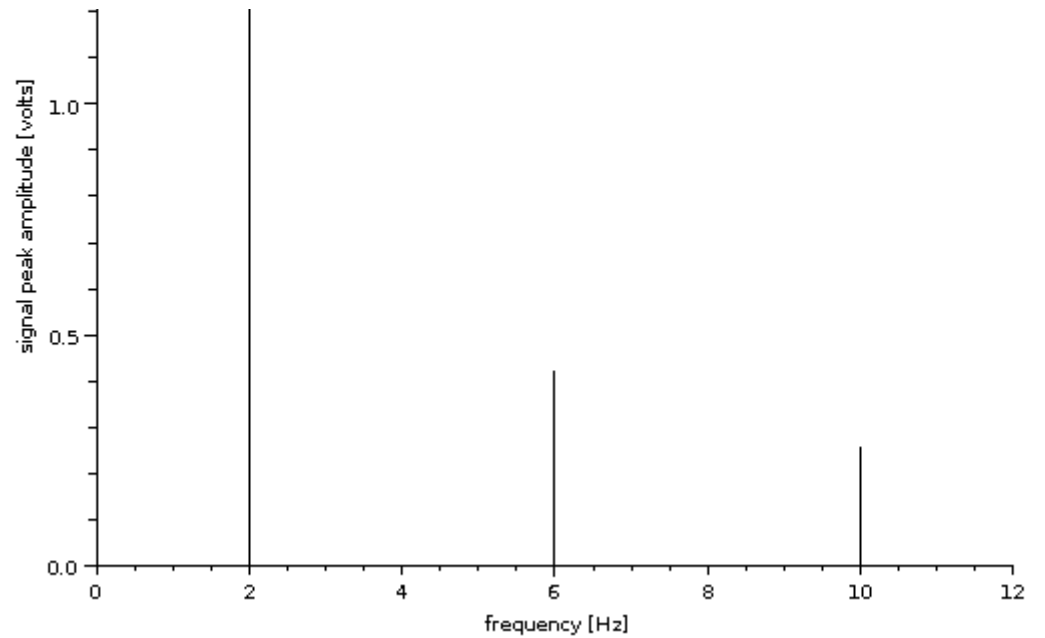
$$s(t) = \frac{4}{\pi} \left[ \sin(4\pi t) + \frac{1}{3} \sin(12\pi t) \right]$$



frequency = 2Hz; absolute bandwidth = 8Hz; data rate = 4b/s

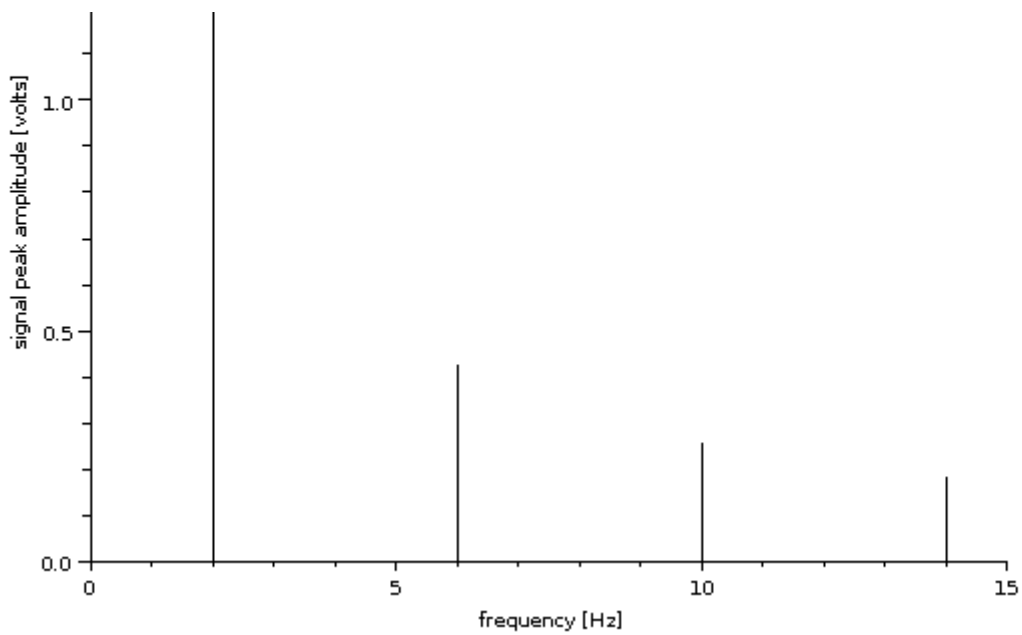
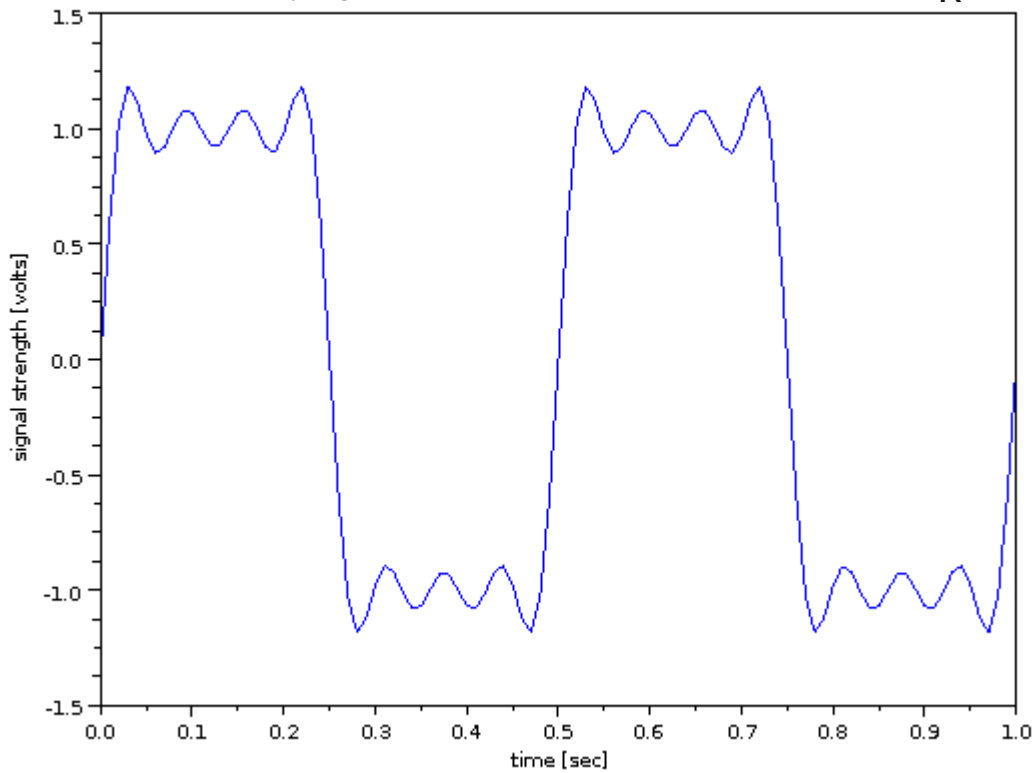


$$s(t) = \frac{4}{\pi} \left[ \sin(4\pi t) + \frac{1}{3} \sin(12\pi t) + \frac{1}{5} \sin(20\pi t) \right]$$

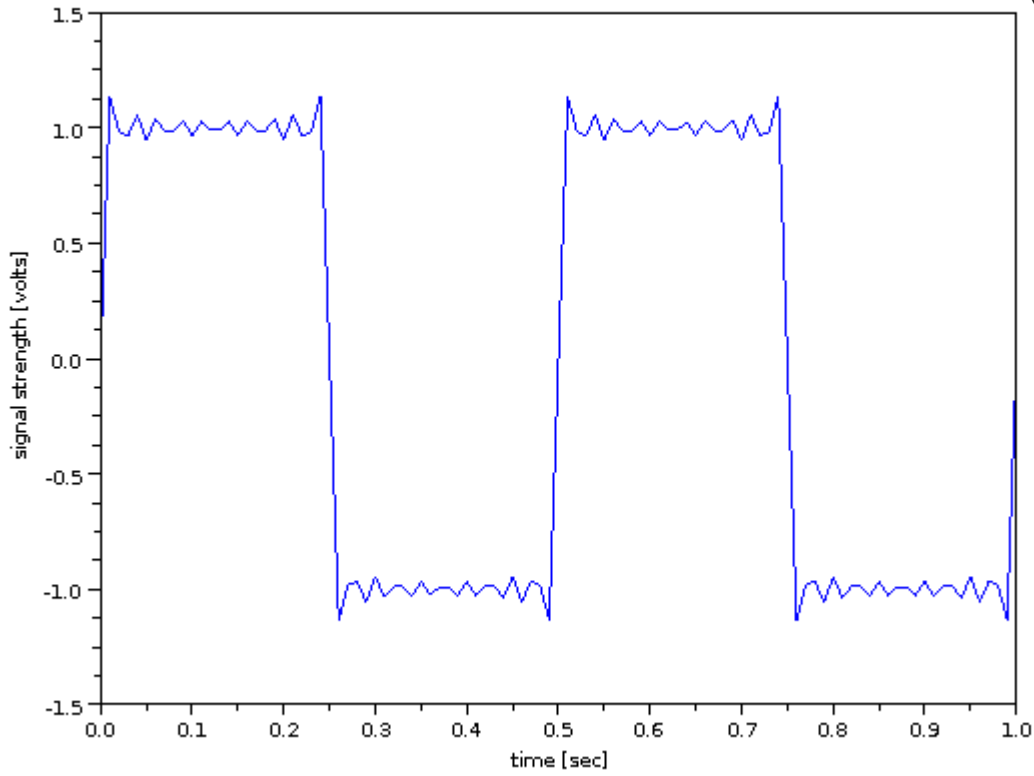


frequency = 2Hz; absolute bandwidth = 12Hz; data rate = 4b/s

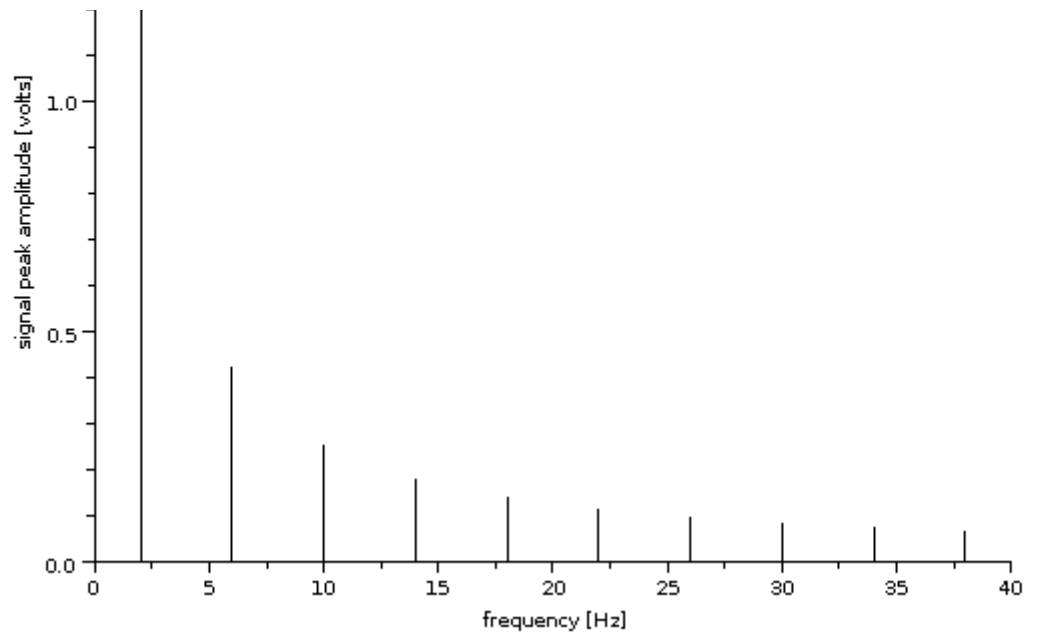
$$s(t) = \frac{4}{\pi} \left[ \sin(4\pi t) + \frac{1}{3} \sin(12\pi t) + \frac{1}{5} \sin(20\pi t) + \frac{1}{7} \sin(28\pi t) \right]$$



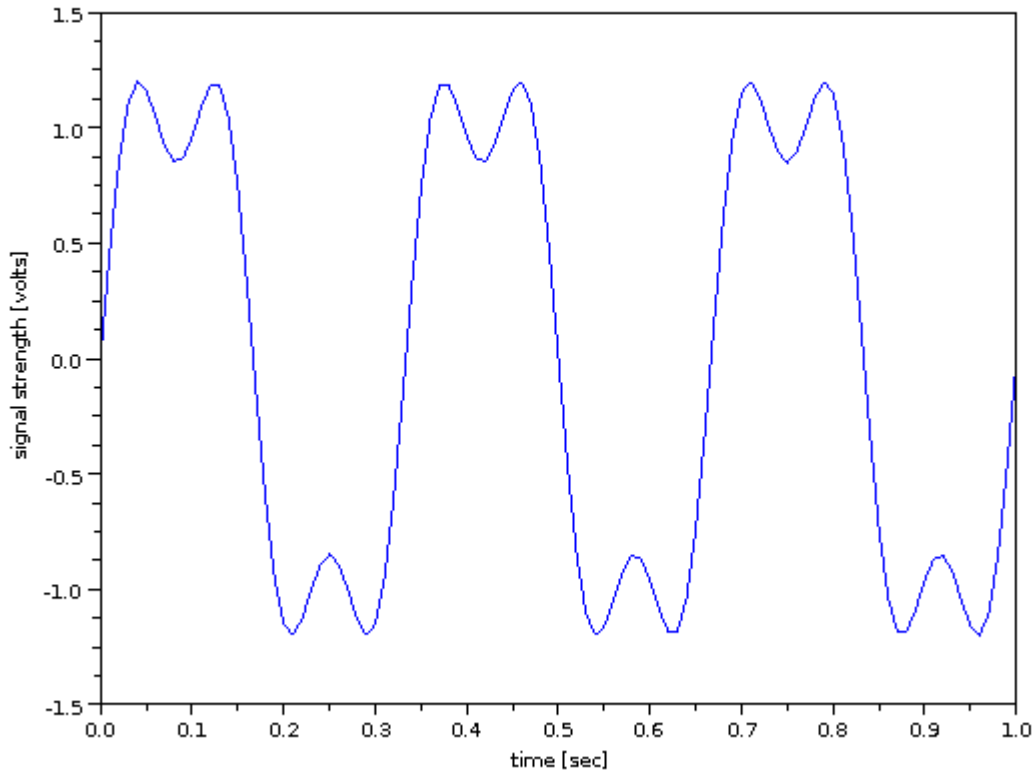
frequency = 2Hz; absolute bandwidth = 36Hz; data rate = 4b/s



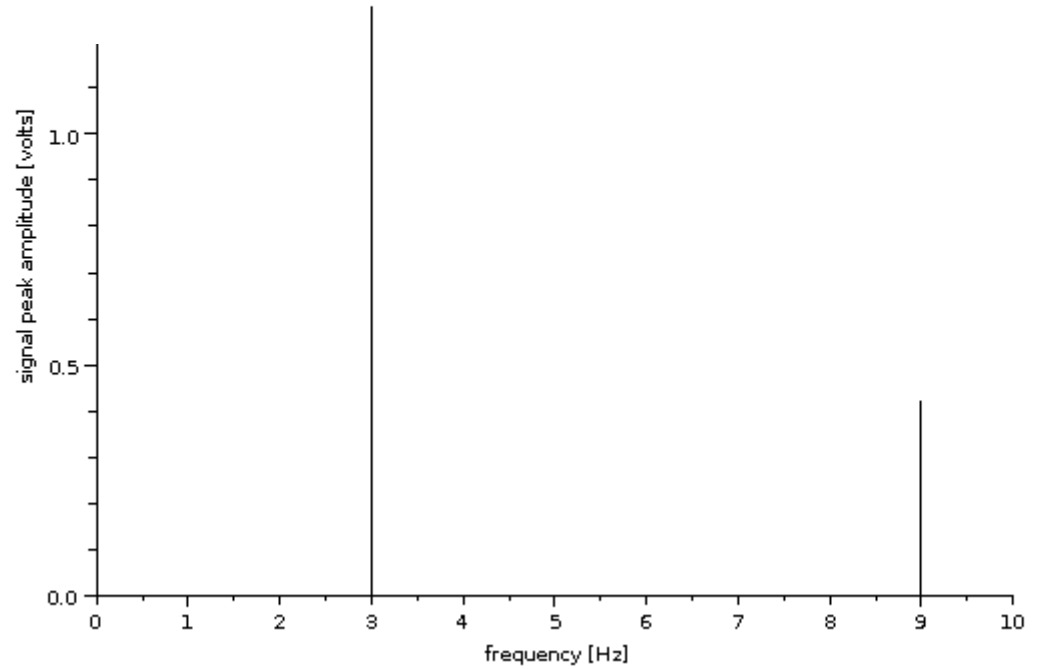
$$s(t) = \frac{4}{\pi} \left[ \sin(4\pi t) + \frac{1}{3} \sin(12\pi t) + \dots + \frac{1}{19} \sin(76\pi t) \right]$$



frequency = 3Hz; absolute bandwidth = 6Hz; data rate = 6b/s



$$s(t) = \frac{4}{\pi} \left[ \sin(6\pi t) + \frac{1}{3} \sin(18\pi t) \right]$$



# Summary

- Advantages
  - Increased bandwidth → increased accuracy (less errors)
  - Increased frequency → increased data rate
- Disadvantages
  - Increased bandwidth → increased cost
  - Increased frequency → increased complexity (cost)
- Different frequencies have different characteristics
- A standard/regulation normally limits available frequency and bandwidth
  - A designer chooses a signal that maximizes data rate, minimizes errors and minimizes cost