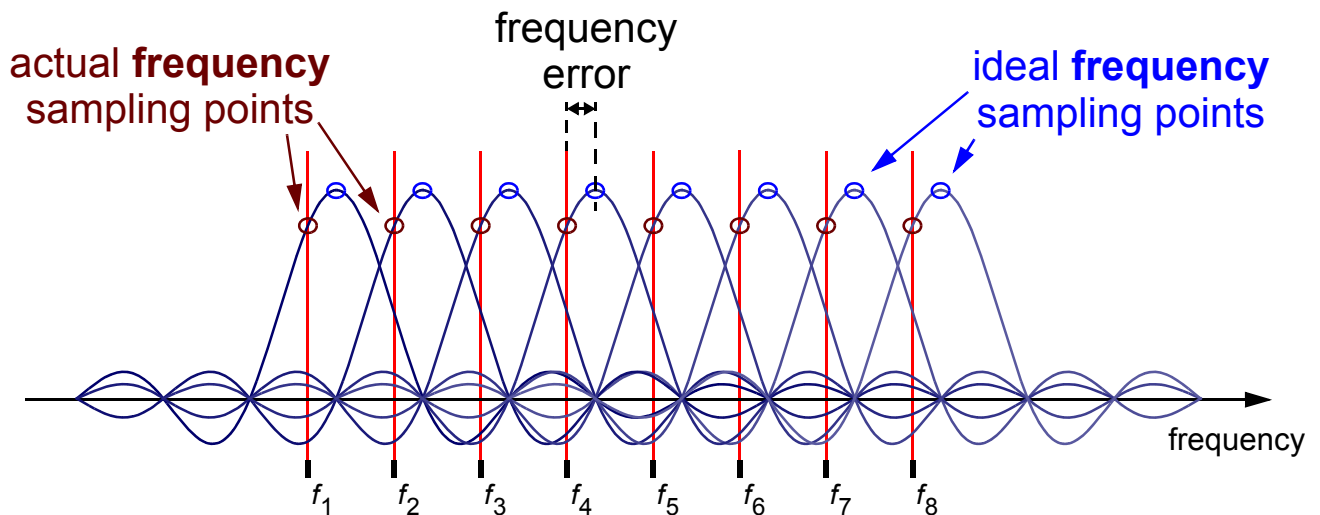


Sensitivity to Frequency Offsets

2.8

- A frequency offset **destroys the orthogonality** between subcarriers
- Frequency domain sampling occurs at the **wrong frequencies!**
- Therefore **Inter-Carrier Interference (ICI)** occurs

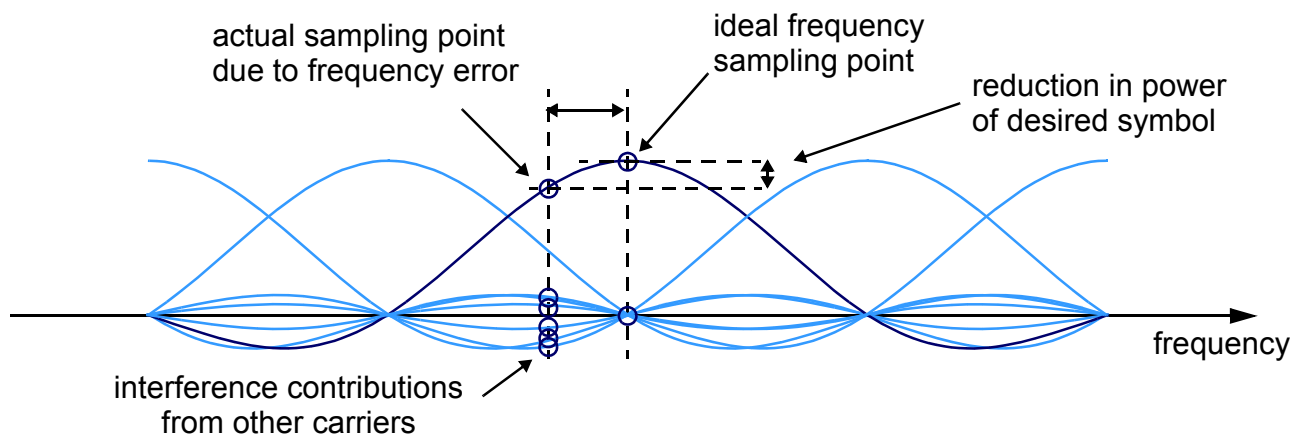


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Notes:

A frequency offset in OFDM is akin to a timing offset in an amplitude modulation communication system where sinc or raised cosine pulse shaping is used. In such a system, sampling a symbol at the correct point results in no interference from the other symbols due to the Nyquist property of the pulse shaping waveform. However, sampling at the wrong point leads to a reduction in the power of the desired symbol power **and** introduces interference from adjacent symbols.

In OFDM a similar phenomenon occurs in the frequency domain. The FFT in the receiver effectively performs sampling of the frequency domain. If the wrong frequency point is sampled then the orthogonality between carriers is lost thereby introducing interference from other carriers. Additionally, there is a reduction in the desired signal component due to the shape of the sinc spectrum.

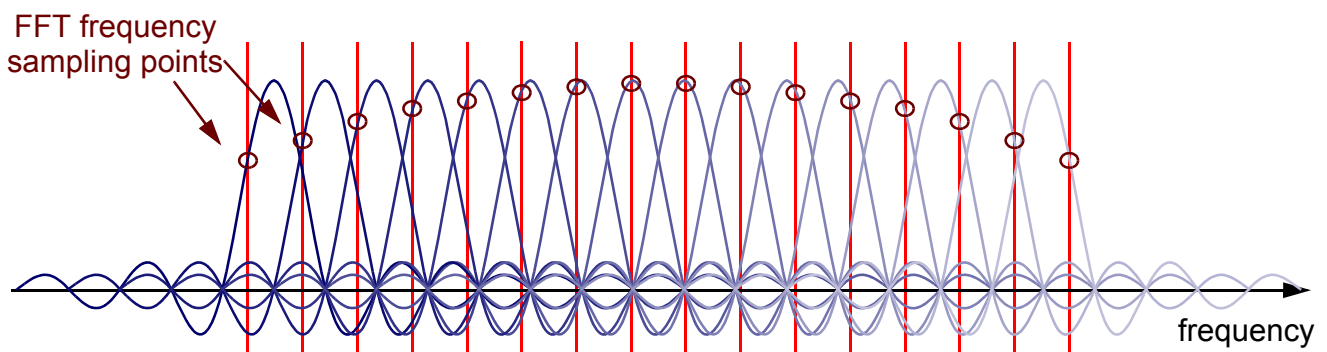


In the time domain one condition for orthogonality is that each carrier must have an integer number of cycles within the FFT window. In the presence of a frequency error this is no longer the case since the subcarriers are demodulated to the wrong set of baseband frequencies.

Sampling Clock Frequency I

2.9

- In any practical situation, the transmitter and receiver sample clocks will have a small frequency offset
- The effect of this is that the receiver observes a **different frequency scale** from the transmitter
- The example below shows what happens when the receiver clock is running **faster** than the transmitter clock.



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Notes:

If the receiver sampling clock is running slightly faster than the transmitter sampling clock, then the receiver will *perceive* the received frequencies to be slower than the transmitter intended. As an example consider the following scenario:

The transmitter sample clock has a frequency of R_{tx} Hz and the receiver sample clock has a frequency of R_{rx} Hz. Assume that R_{rx} is faster than R_{tx} by a factor of P parts per million. Therefore

$$R_{rx} = R_{tx} \left(1 + \frac{P}{10^6} \right)$$

If the transmitter sends a tone of (what it perceives to be) f_c Hz then to the receiver this will appear as a frequency of f'_c Hz where

$$f'_c = f_c \cdot \frac{10^6}{P + 10^6}$$

The frequency error is

$$f_{c, \text{err}} = f'_c \cdot \frac{P}{10^6}$$

Since the frequency error is dependent on the frequency, the result is that the receiver observes a slightly *compressed* version of the frequency domain. If the receiver clock is running faster than the transmitter then the result will be a slightly *stretched* version of the frequency domain.