EPON Protocol over Coax

Carrier Frequency Offset and Initial PLC Acquisition

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Abstract

- The purpose of this presentation is to give an overview of Carrier Frequency Offset in OFDM and discuss how it can impact initial PLC acquisition
- There are no Motions in this presentation

Carrier Frequency Offset

- The CLT and the CNU each include an oscillator
- The Task Force will need to specify the required accuracy of these oscillators
  - An implementation may implemented with an oscillator whose accuracy is better than that required by the standard
- The CLT utilizes its oscillator to generate the downstream carrier frequency, and the error in the CLT oscillator results in a downstream carrier frequency error
- Initially (before PLC acquisition) the CNU uses it oscillator to generate its local downstream carrier frequency
  - After PLC acquisition the CNU carrier frequency can be corrected based on the received downstream

Carrier Frequency Offset

- Oscillator accuracy is typically specified in terms of parts per million (ppm) to the worst case frequency error

CLT

- Oscillator accuracy in ppm is labeled: OSC_{CLT}
- If the carrier frequency is f_c (in MHz) then the worst case CLT frequency error (in Hz) is $\Delta f_{CLT} = f_c \times OSC_{CLT}$

CNU

- Similarly the worst case CNU frequency error is given by $\Delta f_{CNU} = f_c \times OSC_{CNU}$

Carrier Frequency Offset

- The carrier frequency offset, which is the worst case frequency difference between the CLT and CNU carrier frequencies, is the sum of the two worst case frequency errors

$$\Delta f = \Delta f_{CLT} + \Delta f_{CNU}$$

$$\Delta f = f_c(OSC_{CLT} + OSC_{CNU})$$

- The downstream band is between 54 and 1212 MHz, so we have the carrier frequency is less than 1212 MHz
- Use 1212 MHz as worst case carrier frequency

Worst Case Example

- The oscillator accuracy for the CLT and the CNU have not yet been specified
- Here we work out a worst case example

$$OSC_{CLT} = 100 \text{ ppm}$$

$$OSC_{CNU} = 100 \text{ ppm}$$

$$\Delta f = 1212\,(100 + 100) = 242.4 \times 10^3 \text{ Hz} = 242.4 \text{ kHz}$$

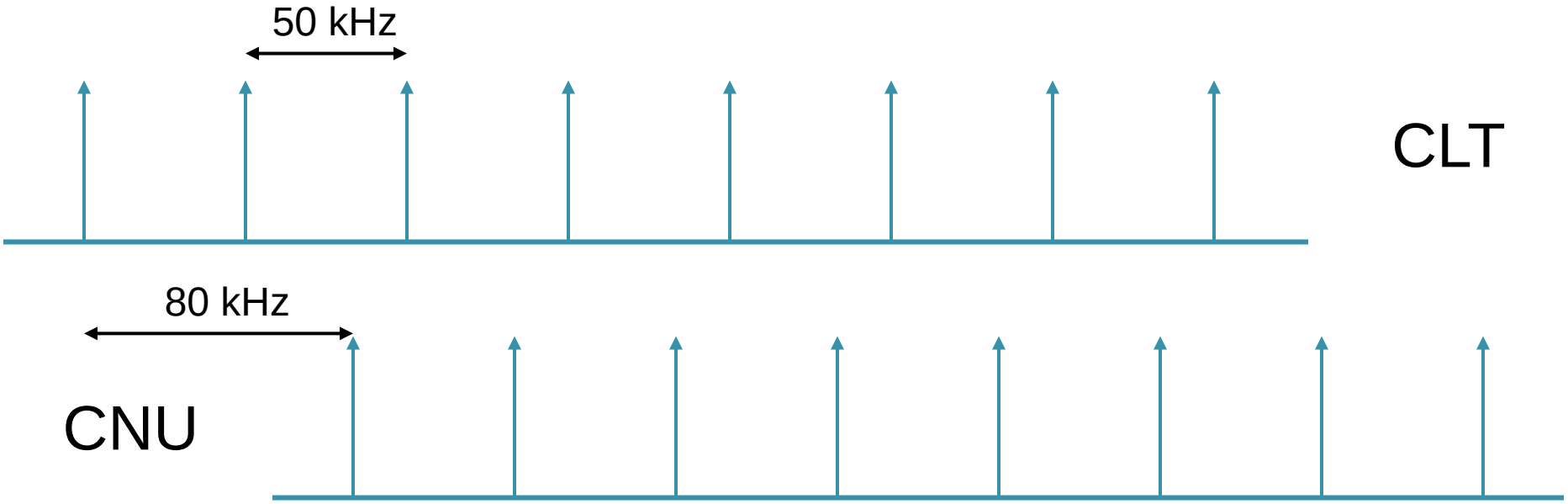
- If more accurate oscillators are used the carrier frequency offset will be lower

OFDM Tone Ambiguity at Acquisition

- At start up the CNU must search for the downstream
- It searches for the PLC on multiple frequencies
- When it tries a given frequency there will be some frequency offset between the downstream transmitter and the downstream receiver
- This frequency offset can lead to a tone ambiguity between if the carrier frequency is more than half the tone spacing
- EPoC has a 50 kHz tone spacing (4K FFT)

OFDM Tone Ambiguity at Acquisition

- Illustration of Tone Ambiguity
- For illustration purposes the FFT size in this example is 8 (small enough to draw)



- In this example the CNU tone ambiguity can be up to two tones on either side
- There are 5 possible tones which could be the correct tone

Tone Ambiguity for Worst Case Example

- In our worst case example (100 ppm in both the CLT and the CNU) the tone ambiguity can be up to 5 tones on each side of the correct tone
- So there are 11 candidate tones for the correct tone to frequency align with the CLT
- The number can be reduced by requiring more accurate oscillators, but has an impact on the implementation
- May need some way to disambiguate the tones

Tone Disambiguation

- Method #1: Preamble Design
  - Null every M-th Tone in a portion of the preamble to increase tone spacing for that section (method used in 802.11 OFDM PHY)
  - Must increase non-zero tone spacing in this portion of preamble to eliminate tone ambiguity
- Method #2: Utilization of continuous pilots
  - Method suggested by Leo (in email)
  - If the continuous pilots are in known tones relative to the PLC they could be used to disambiguate tones
  - Since the tone location is configurable, I am not sure if their location to the PLC is known *a priori* by the CNU

Next Steps

- The Task Force needs to specify the oscillator accuracy for both the CLT and the CNU
- The Task Force needs to evaluate the various methods to disambiguate the tones and decide which method to use