100.2.4.x   Upstream Wideband Probing

Introduction:

In upstream wideband probing a CNU transmits pilots spanning all active subcarriers. The CNU transmits one pilot per sub-carrier. Each pilot is a predefined BPSK symbol. The OFDM symbol which is used for probing shall be defined as a *probing symbol*. The CLT uses the received *probing symbol* for:

1. *Upstream channel estimation*. The CLT computes the coefficients of the upstream pre-equalizer for each CNU and sends them back to that CNU.

2. *Upstream SNR measurement*. The CLT measures the SNR per sub-carrier and computes the upstream bit loading tables.

Probing symbol pilots

Probing symbol pilots are BPSK symbols.

Probing symbol pilot i is always associated with the i-th subcarrier of the symbol, where:

$$i = 0, 1, ... , 4095 \text{ for 4K FFT}$$

(Subcarriers are numbered in ascending order of frequency starting from 0.)

Probing Symbol

The CLT shall allocate a specific probing symbol to the CNU within the probing frame and instruct the CNU to transmit the probing sequence in that symbol. CLT specifies the probing symbol within the probing frame through the parameter *Symbol in Frame.* The CLT assigns a CNU either all the pilots of the assigned probing symbol, or a subset of (scattered) pilots of the assigned probing symbol.

The CLT allocates subcarriers within a probing symbol by sending two parameters to the CNU: "start subcarrier", and "subcarrier skipping". The range of "start subcarrier" is from 0 to 7. The range of "subcarrier skipping" is from 0 to 7. Figure 1 and Figure 2 illustrate the use of these parameters. The CNU uses the *start subcarrier* and *subcarrier skipping* parameters to determine which subcarriers are to be used for probing transmission, as follows:

- The "start subcarrier" parameter is the starting subcarrier number.

- The "subcarrier skipping" parameter is the number of subcarriers to be skipped between successive pilots. "Subcarrier skipping" = 0 implies no skipping of subcarriers (i.e., all subcarriers are used for probing).

A CNU shall not transmit the probing sequence in an excluded subcarrier. Excluded subcarriers are those subcarriers in which no CNU is allowed to transmit, generally because these are frequencies used by other systems (including guard-band subcarriers).

Start subcarrier = 0
Subcarrier skipping = 0

Figure 1 – 4K FFT example, all subcarriers used for probing, no skipping
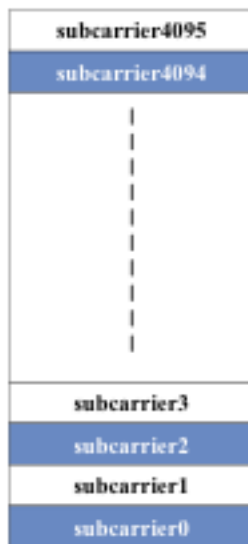
Start subcarrier = 0
Subcarrier skipping = 1

Figure 2 – 4K FFT example, alternate subcarriers used for probing

To schedule a single CNU in a probing symbol without skipping subcarriers, the CLT does the following:

1. Allocate a specific probing symbol to a single CNU.
2. Set "subcarrier skipping" to zero.
3. Set "start subcarrier" to the number of the first subcarrier.

To schedule a single CNU in a probing symbol with skipping sub-carriers to create nulls (as illustrated in Figure:2), the CLT does the following:

1. Allocate a specific probing symbol to a single CNU.

2. Set "subcarrier skipping" to a non-zero positive integer value.

3. Set "start subcarrier" to the number of the first subcarrier.

To schedule multiple CNUs in a probing symbol (as illustrated in Figure 3) the CLT does the following:

1. Allocate the same probing symbol at any given time to more than one CNU.

2. Assign a different "start subcarrier" number to each CNU.

3. Assign the same "subcarrier skipping" value to every CNU within the probing symbol.

This method can be used with or without skipping subcarriers to create nulls. To create nulls, specify a "subcarrier skipping" value equal to, or greater than, the number of CNUs in the pattern.
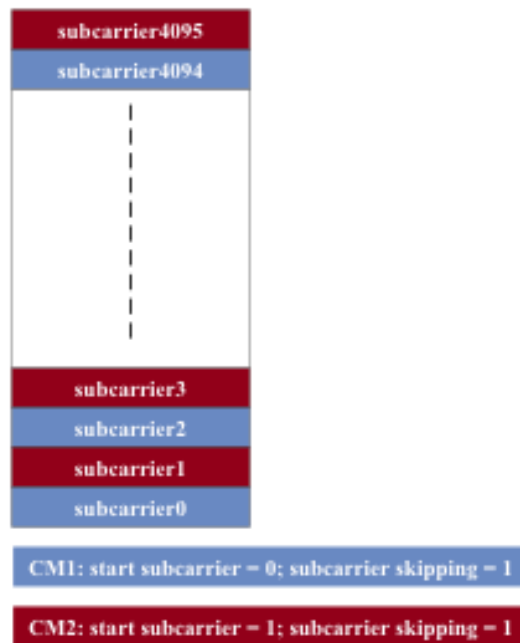

Figure 3 – Scheduling two cable modems in the same probing symbol

Staggering

The probing can use a staggering scheme in which a group of CNUs share a probing frame in accordance to a specific staggering pattern. A probing frame is a group of contiguous probing symbols.

The CNU receives the following parameters, *st, start subcarrier*, and *subcarrier skipping* from the CLT. Where "*st*" is the staggering bit.

The CNU shall support staggering pattern for probing, when the staggering bit "*st*" is set to one. When "*st*" is set to zero, the staggering is off.

Total number of OFDM symbols in each staggering pattern is given by *subcarrier skipping +1*

The starting subcarrier of a CNU in the first OFDM symbol of the pattern is given by the parameter *start subcarrier*. The starting subcarrier of a CNU, in each successive OFDM symbol within the pattern, advances by one.

The CNU shall skip transmission in all excluded sub-carriers, but continue the pattern as if the excluded sub-carriers were not skipped.

Figure 4 shows an example of the staggering pattern. The Black row is the excluded sub-carrier, where there is no transmission from any of the CNU.

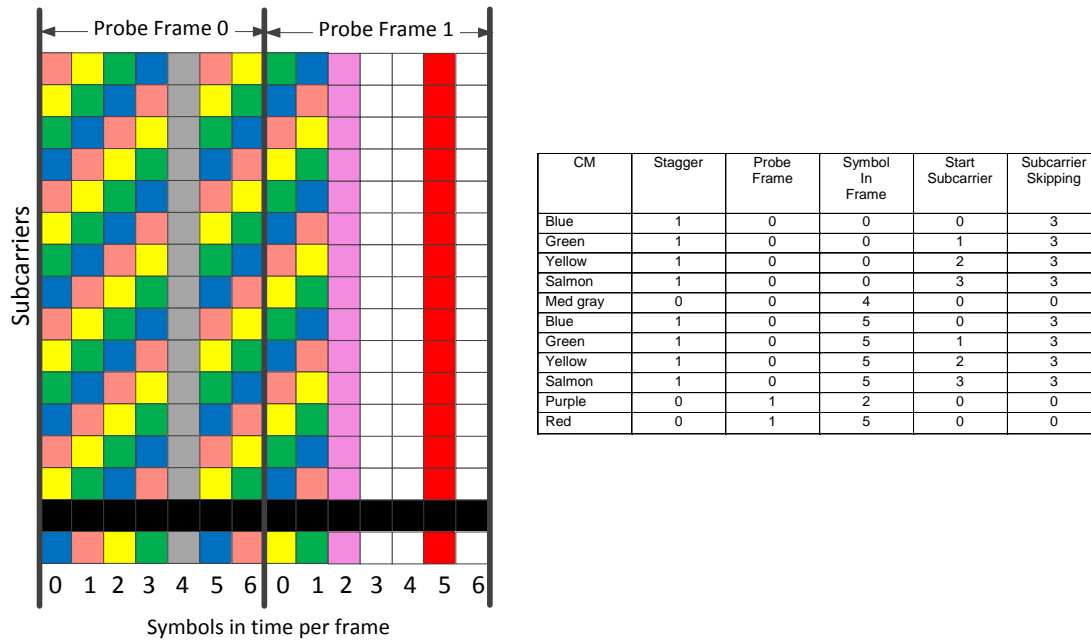| CM	Stagger	Probe Frame	Symbol In Frame	Start Subcarrier	Subcarrier Skipping
Blue	1	0	0	0	3
Green	1	0	0	1	3
Yellow	1	0	0	2	3
Salmon	1	0	0	3	3
Med gray	0	0	4	0	0
Blue	1	0	5	0	3
Green	1	0	5	1	3
Yellow	1	0	5	2	3
Salmon	1	0	5	3	3
Purple	0	1	2	0	0
Red	0	1	5	0	0

Figure 4   Example of staggering pattern.