MAXIMIZING THE BENEFITS OF HIGHER DELIVERED OSNR OF MODERN WET PLANT

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Abstract: ASE noise generated by passive coupling of multiple SLTEs to a wet plant can have a large impact on the received signals OSNR. On new generation trans-Atlantic system, the amount of ASE noise generated by the wet plant is small enough to make the noise generated by the transmitting terminal a significant factor of received OSNR. ln this paper, we present the concept of wet plant OSNR for use when characterizing the noise contribution of the wet plant, versus the associated terminal equipment . We will also use actual data measured over a transatlantic cable to show how noise funneling caused by broadband upgrade couplers can significantly reduce the received OSNR. Consequence on achievable capacity will be evaluated and ways to avoid such transmit OSNR reduction are explained.

1. TRADITIONAL UPGRADE COUPLING

Figure 1 shows the functional building blocks found on a typical SLTE. The head end part of the SLTE (i.e.: the closest to the wet plant access ports) supports the Supervisory and High loss loopback functions. The building block that comes after contains the broad band upgrade coupler that are commonly used to connect an upgrade SLTE to the incumbent SLTE.

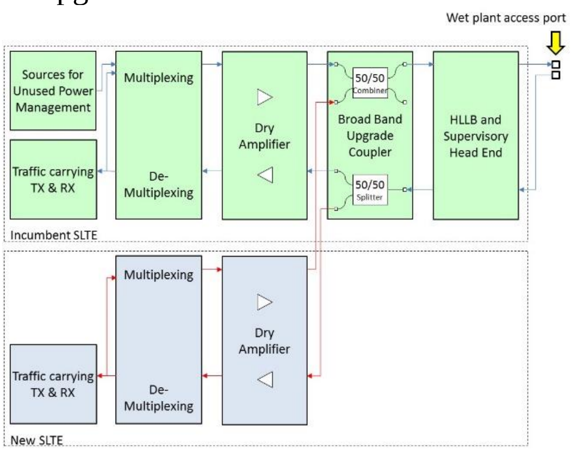

Figure 1: Upgrade Coupling on a typical SLTE

In the transmit direction, the full amplified spectrum from the incumbent dry amplifier is combined with the full amplified spectrum from the new SLTE. This leads to an important reduction of the transmit OSNR because the broad band noise from both terminal are combined. This is illustrated in Figure 2.

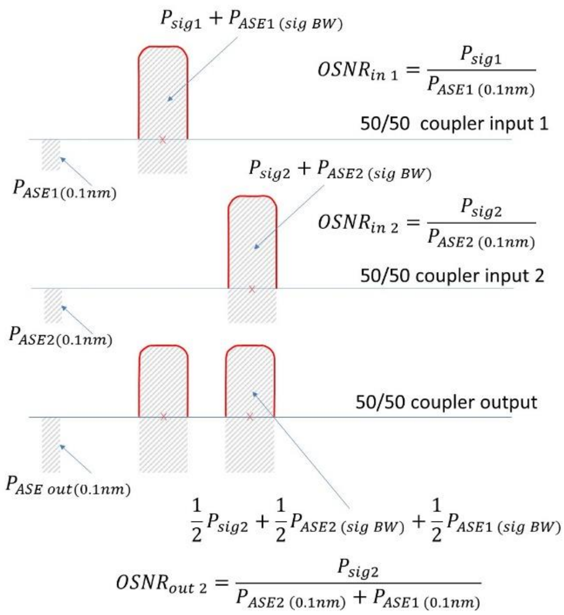

Figure 2: OSNR reduction due to ASE overlap

Typically, the TX OSNR reduction caused by this approach is on the order of 3 dB but it may vary slightly (for better or worse) if the broad band coupler ratio is not 50/50, if the OSNR or power density on both coupler inputs are not the same.

2. WET PLANT OSNR

The noise and signal power present at the input of the system are affected by the transmission through the wet plant in the exact same manner (represented by the K constant in the equation below). All the repeaters of the wet plant will add a certain amount of ASE noise represented by P_{ASE_Wet} in the equation below.

$$P_{Sig\_Out} = KP_{Sig\_In} \quad \text{eq.1}$$

$$P_{ASE\_Out} = KP_{ASE\_In} + P_{ASE\_Wet} = K\frac{P_{Sig\_In}}{OSNR_{In}} + P_{ASE\_Wet} \quad \text{eq.2}$$

The OSNR at the output of the wet plant can thus be expressed as:

$$\frac{1}{OSNR_{OUT}} = \frac{P_{ASE_{Out}}}{P_{Sig_{Out}}} = \frac{1}{OSNR_{In}} + \frac{P_{ASE\_Wet}}{KP_{Sig\_In}} \quad \text{eq.3}$$

If there is no noise at the input of the system, $OSNR_{In}$ becomes infinite, and the expression simplifies as:

$$\frac{1}{OSNR_{OUT}} = \frac{P_{ASE\_Wet}}{KP_{Sig\_In}} \quad \text{eq.4}$$

Defining, the wet plant OSNR as the OSNR at the output of the wet plant when there is no noise at the input, provides a simple expression of the output OSNR as a function of the input OSNR.

$$\frac{1}{OSNR_{OUT}} = \frac{1}{OSNR_{In}} + \frac{1}{OSNR_{Wet\_Plant}} \quad \text{eq.5}$$

The wet plant OSNR is also the figure of merit used to quantify the wet plant noise contribution. It can easily be determined with measures of the OSNR at the input of the wet plant and OSNR at the output of the wet plant (see Figure 3).

$$\frac{1}{OSNR_{Wet\_Plant}} = \frac{1}{OSNR_{SLTE\_RX}} - \frac{1}{OSNR_{SLTE\_TX}}$$

eq.6

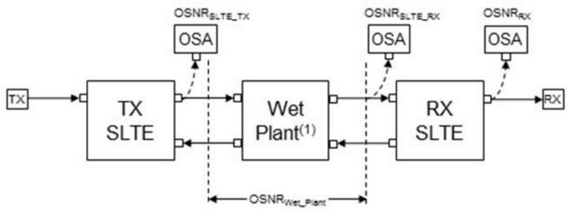

Figure 3: principle of wet plant OSNR measures

For low values of wet plant OSNR, the second term in equation 5 can become large enough for a reduction of TX OSNR by a factor 2 not to have a significant impact on RX OSNR. Similarly, if TX OSNR value is high enough, even a reduction by a factor of 2, may not make the first term in equation 2 to be large enough to have a significant impact on the RX OSNR.

On new systems, one or both of these conditions are likely not to be met. First, the introduction of flexible grid multiplexing is accompanied by a certain TX OSNR reduction when compared with a classic filtered fixed grid multiplexing. Also, wet plant OSNR tends to get higher on new uncompensated large core PSCF systems.

3. MEASUREMENTS ON THE MAREA CABLE

Wet plant OSNR derived from measurements performed over the MAREA cable are shown in Figure 4. These measurements were performed in December 2017 using power equalized, 125GHz spaced and 62.5GHz wide ASE probes distributed over the available system bandwidth. The signal to noise ratio shown in Figure 4 have been calculated using the same integration bandwidth of 12.5GHz to compute the signal power and the noise power. This differs slightly from the noise integration bandwidth of 0.1nm used in the common OSNR definition. The MAREA cable supports eight fiber pairs. The results shown in figure 4 have been averaged over these eight fiber pairs.

Three curves are shown on the graphs of Figure 4. The top curve is the wet plant SNR. The two other curves are the received SNR for a transmit SNR of 22.2 dB and for a transmit SNR of 19.2 dB (3 dB lower). A transmit SNR of 22.2 dB in 12.5GHz is equivalent to a transmit OSNR of 27dB in 37.5 GHz, a typical value for a flexible grid terminal.

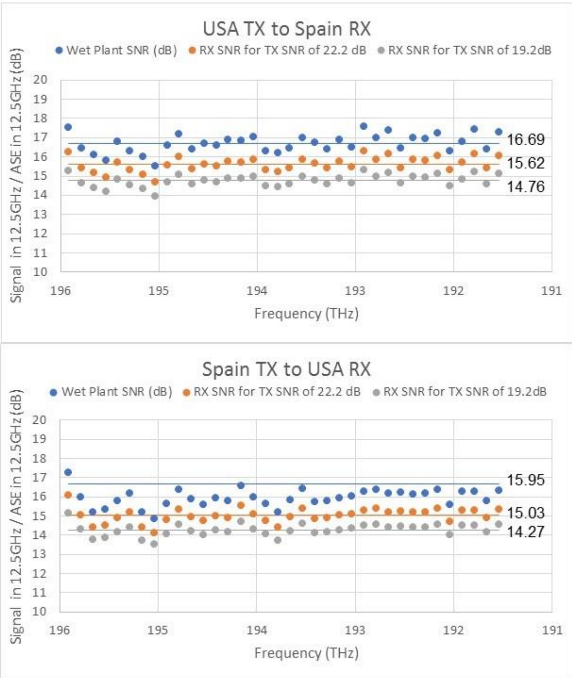

Figure 4: Wet plant OSNR measurements

On average, a 3 dB reduction in the transmit SNR will cause a reduction of the received SNR of 0.86 dB in Spain and of 0.76 dB in USA. In terms of Shannon capacity, this would lower the ultimate theoretical capacity by 6.9Gbit/s for every slices of 12.5 GHz in the Spain RX direction and by 6.1Gbit/s for every slices of 12.5 GHz in the USA RX direction.

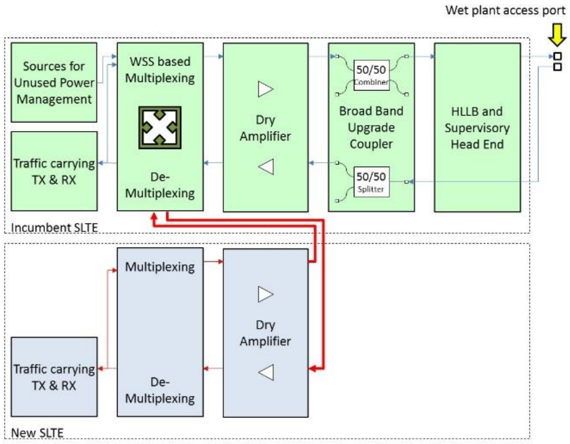

Figure 5: WSS based upgrade coupling

4. CONCLUSIONS

As explained above, given the high performance of the new generation of wet plants and the introduction of flexible grid terminals, broad band noise overlap caused by traditional upgrade coupling would significantly impact the ultimate system capacity.

Broad band noise overlap can be avoided by filtering the output of each terminals before combining them together. The simplest way to achieve this consists in connecting the upgrade SLTE to the incumbent SLTE through a WSS instead of the broad band coupler. This is illustrated in Figure 5.

This solution also brings all the benefits associated with having one central point of control for channel add or delete operations regardless of the channel origin.