The Role of Photonic and Electronic Gain in the Design of Analog Optical Links

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Summary
The loss of coax, even moderately high frequencies (e.g. X-band), can be so high as to rule out many important applications. Lower loss means of RF transmission exist, such as waveguides, but the size and weight of such options severely restrict the applications.

RF loss can, of course, be overcome with RF amplification. However, the introduction of amplifiers raises its own set of design trades. For example in antenna remoting applications, a low noise amplifier (LNA) is typically used to raise the antenna signal to the point that the subsequent coax loss does not significantly degrade the noise figure. Although LNAs work well and are cost effective, they are not without their tradeoffs. They do require dc power at the antenna element and their sensitive input stage needs to be protected from damage by high power signals such as transmit signals and jammers.

Historically analog optical links have been viewed as replacements for coaxial cables. Although the loss per unit length of fiber is significantly lower than any RF transmission means, the inefficiency with which the RF signal is imposed on the optical carrier results in significant RF-to-RF loss of the optical link. In turn this has meant that optical links have typically needed to be preceded by an LNA as well.

The first part of this talk will focus on the performance tradeoffs between an intrinsic link (i.e. one without any amplifiers) and a link with pre- and/or post-amplification. The discussion will show that as is the case with an RF amplifier chain, the noise figure of the link plus amplifiers is essentially set by the pre-amplification noise figure and that the preamp gain necessary to achieve this is roughly equal to the link loss [Cox, 2004]. As for spur-free dynamic range (SFDR), an analogous but less well known equation for the intercept point of a system as a function of the intercept points of the components will show that to maintain the link SFDR, the pre-amplifier intercept point must be greater than that of the intrinsic link by at least the link loss [Cox, 2004].

This combination of pre-amplifier parameters – gain, noise figure and intercept point – that one is led to via the above analysis can be quite challenging to achieve. Consequently there is strong technical motivation to develop intrinsic links with lower loss and noise figure.

In previous work we have shown that, at least at low frequencies (a few hundred MHz), it is possible to design an optical link to have RF power gain and low noise figure [Ackerman, et. al., 1998]. In this case the need for an LNA is avoided and the optical link replaces not only the coax but also the LNA. Further there is no degradation of the intrinsic link SFDR by the LNA.

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In this paper we review the conditions under which an optical link can achieve positive gain, as measured by the available power gain. We also review the link design factors that permit the link to have low noise figure and show that there is a fundamental dependence between link gain and noise figure.

Progress is being made in reducing the intrinsic link noise figure and the bandwidth over which noise figure is low. This progress, though encouraging, still falls short of the performance that ultimately will be needed to make an optical link approach competitive with an RF LNA approach. Thus we conclude the talk with prospects for achieving low noise figure in the future.

References:

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