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Use of Companding to Reduce Isolation Requirements in the Remote Antenna Unit of an OFDM Radio over Fiber Link

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Outline

- Introduction
  - RoF Link dynamic range
  - Crosstalk and amplifier stability issues
  - Downlink path self-interference issue
- Companding
  - Compression of OFDM signals
  - Companding characteristics
- Experimental measurements
- Conclusions and Future work

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RoF link dynamic range

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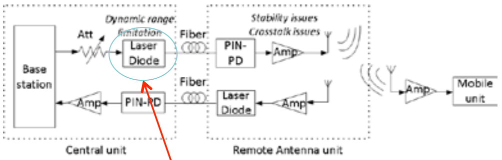

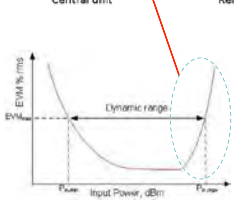

- Link possesses limited dynamic range: main limitation usually laser diode.
- Attenuation implemented prior to laser diode to reduce input signal powers to levels appropriate to power handling capabilities of the laser diode.
- Amount of input power back-off and amount of amplification required in RAU are directly related.
- Sufficient transmit powers required at the RAU in order to achieve the desired wireless ranges.
- Even more challenging for SCM architecture: input power back off must be higher than that for a single channel by a factor of *n* where *n* is the number of multiplexed channels

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Crosstalk and amplifier stability issues

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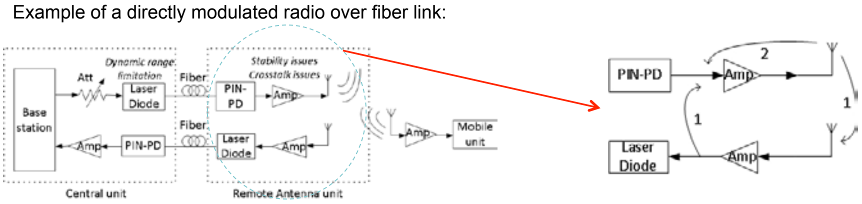
Example of a directly modulated radio over fiber link:



- (1): power transmitted in downlink antenna is received by uplink antenna.
  - In FDD systems, this can be filtered out.
  - In TDD systems, in conjunction with the limited isolation between the laser diode and downlink amplifier ports, it can lead to oscillations [1].
- (2): self-interference crosstalk due to finite isolation between the antenna and the input port of the downlink amplifier. Again, the self-interference signal can lead to oscillations.
- Achievable isolation defines maximum gain that can be provided by the amplifiers in the downlink and uplink sections of the RAU

[1] A. Das, A. Nkansah, N. J. Gomes, I. J. Garcia, J. C. Batchelor, and D. Wake, "Design of low-cost multimode fiber-fed indoor wireless networks," *IEEE Trans. Microw. Theory Tech.*, vol. 54, no. 8, pp. 3426-3432, Aug. 2006.

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Downlink path self-interference issue

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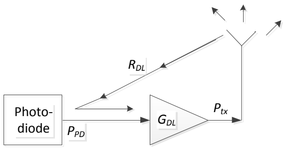
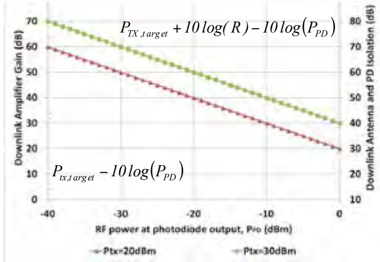
- What amplifier gain is possible without crosstalk signal causing oscillations?
  - Depends on wanted and feedback signal ratio R.



Wanted and feedback signal ratio: $R = \frac{P_{PD}}{R_{DL}}$

Antenna-PD isolation : $I = G_{DL} \times R$

Good compromise for *R* is 10 dB as it leads to minimal increase (~ 0.4 dB) in signal power when crosstalk signal is in- phase and minimal reduction (~ 0.45 dB) when the crosstalk signal is out-of-phase.



Downlink amplifier gain and antenna/photodiode isolation requirements for different levels of RF power at the photodiode output for targeted RAU transmit powers of 20dBm and 30dBm. Antenna-PD isolation also incorporates a targeted wanted and feedback signal ratio (R) of 10dB.

- Results show that amplifier gain G_{DL}, and antenna-photodiode isolation *I* , are inversely dependent on output power at photodiode P_{pd}.
- Reduction of G_{DL} and *I* leads to less expensive RAUs
  - Less amplifiers, ower cost enclosures

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Use of companding for OFDM signals

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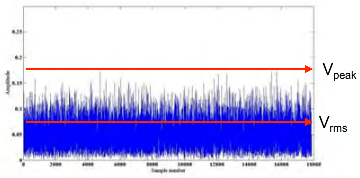
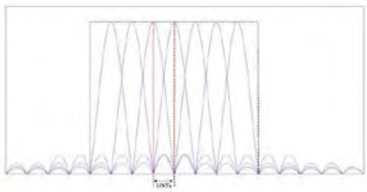
Time domain (IFFT=512):



Frequency domain (illustrative example):



- OFDM signals possess large envelope variations quantified through the peak-to-average power ratio:

$$PAPR = {\max\{x[n]\}^2}/{E\{x[n]^2\}}$$

- Companding can be used to reduce the dynamic range of these signals.

- For RoF applications only limited work has been carried out (companding transform in [2]).

[2] Fan Li, Jianjun Yu, Zizheng Cao, Jiangnan Xiao, Hongxian Chen, Lin Chen, "Reducing the peak-to-average power ratio with companding transform coding in 60 GHz OFDM-ROF systems," *J. Opt. Commun. Netw.*, vol. 4, no. 3, pp. 202-209, Mar. 2012.

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Companding characteristics

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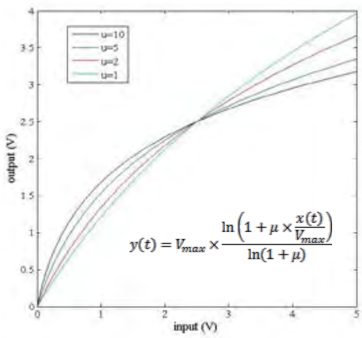

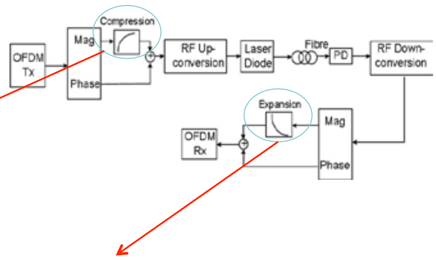

$$x(t) = \frac{V_{max}}{\mu} \times \left[(1+\mu)^{\frac{y(t)}{V_{max}}} - 1\right]$$

- Compression and expansion functions based on μ-law companding.

- Compression of magnitude of in-phase and quadrature components.

- Compression and expansion functions form nverse pair.

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Experimental measurements (1)

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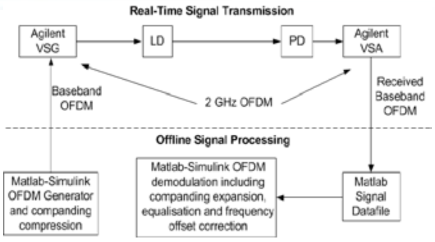

•IFFT size 1024 (840 data subcarrier and 184 null).
•Cyclic prefix of 1/8 of symbol duration.
•Symbol rate of 9 MSps.
•Root-raised cosine filter of alpha=0.25.

PAPR values for different μ parameters when V_{max}=1/4. The PAPR of the uncompanded signal is 11.8 dB:

μ(for V_{max} =1/4)	PAPR (dB)
1	7.2
2	6.15
10	4

- Comparison performed between the un-companded optical link and link with companding in terms of input and output powers of RoF link.
- PAPR of baseband OFDM signal which consisted of 100 OFDM symbols was found in simulation to be 11.8 dB.
- 1 dB input compression point of laser at 2GHz = 15 dBm.
- Input EVM for the optical link without companding started rising at average input power of approximately 3 dBm, i.e. at around 12 dB below compression point.

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Experimental measurements (2)

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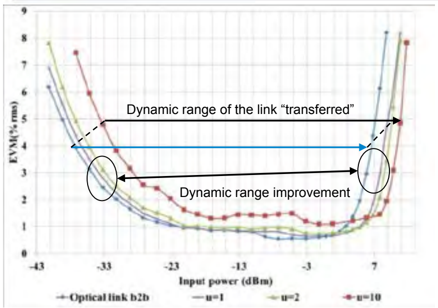

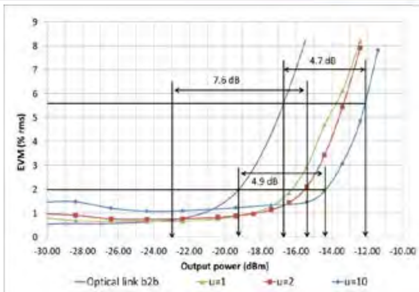

- Stronger compression: noise floor increases due to expander expanding added channel noise
- Higher μ values: EVM floor rises due to reduction in mean power at output of the compressor.
- Small values of μ, dynamic range improvements (in terms of EVM percentage limiting points)
- Improvements in output power are approximately 4.7 dB and 4.9 dB, at 5.6% and 2% EVM respectively.
- In terms of EVM turning point, difference is approximately 7.6 dB :close to the PAPR reduction value for μ=10.

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Conclusions

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- Demonstrated the use of companding in a RoF link
- Different parameters in the companding function were used, showing the feasibility of using companding for obtaining higher powers at the output of the RoF link.
- The increase in output power possible through companding means that the amplification (and isolation) requirements in the RAU decrease
- In terms of EVM turning point, the reduction in amplification requirements is approximately equal to the PAPR reduction.
- The dynamic range of the link at the output is effectively "transferred" to a range more appropriate for meeting potential transmitter power requirements
- The system with the use of companding can retain negligible BER

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Future work

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- Practical implementation of the companding function n the DAC at the transmitter section.
- Separatel compression of the In-phase and quadrature components
- Investigation of he effects of bandwidth expansion as companded signals can potentially violate spectral mask requirements.
  - Previous work has shown that bandwidth expansion caused by the companding function is not very high and relatively insensitive to the choice of μ parameter.
  - More important in SCM systems.
- Investigation into the effects of variations between the compression and expansion parameters: these variations can lead to signal distortion
  - Link gain information can be provided by use of pilot tones.

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Thank you

Any questions?

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Futon

SEVENTH FRAMEWORK PROGRAMME