Link Consideration of 10GbE over MMF

Stefano Bottacchi
Infineon Technologies, AG

IEEE 802.3, Vancouver, BC, Jan. 11-15- 2004

Content

1. Introduction
2. Link Components and Key Parameters
3. Conclusions

Introduction

Stefano Bottacchi
COM FO MOD

New Standards for Old Technologies

- Development of 10GbE standard over MMF has two principal targets:

  1. To achieve at least 300 meters link length using existing multi-mode fiber plant.

  2. Low cost technologies and testing procedure are fundamental requirements due to potentially large volume market revenue.

The Technology Scenario

- To match the *first* target, the old-installed MMF must be used every where they are available, regardless manufacturing date and related bandwidth performances
- To match the *second* target, low cost optical technologies and proper packaging must be used:
  1. Existing MMF must be used instead of new installations.
  2. VCSEL and PIN diodes are low-cost reliable optics.
  3. High density silicon System-on-Chip (SOC)
  4. Plastic packages and optical receptacles

Link Components and Key Parameters

Stefano Bottacchi
COM FO MOD

Content

- 10GbE Link Diagram
- 10GbE TOSA
- Multi-Mode Fiber Link
- 10GbE ROSA

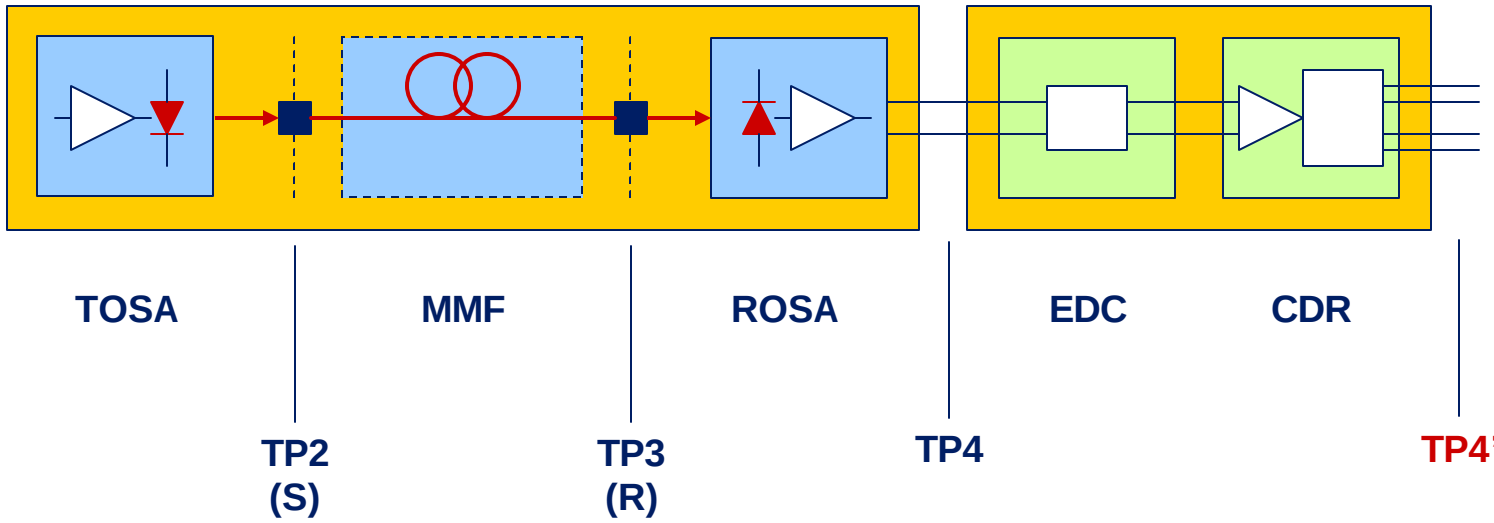
Stefano Bottacchi
COM FO MOD

Scope

- In the following the components of an MMF link with their drawback and options for improvements are discussed.
- Options for improvements are intended to increase the link budget and therefore increase the margin for ISI.
- Some of the improvements are challenging for low cost or direct modulation sources.

Stefano Bottacchi
COM FO MOD

10GbE Link Diagram



Stefano Bottacchi
COM FO MOD

10GbE TOSA

- Principal TOSA optical signal drawbacks are:

1. Minimum average output power is -8.2dBm
   - Improvement to higher average power ⇒ -5dBm
2. Minimum extinction ratio for direct modulation is 3.5dB
   - Improvement to higher Extinction Ratio ⇒ >6dB
3. Laser limited Modulation Bandwidth to less then 10GHz at 1310nm and not-symmetrical rise-fall time generate skewed optical eye diagram with eye opening penalty.
   - Improvement to higher BW ⇒ >15GHz
   - Improvement to $T_{rise} \sim T_{fall} < 30ps$
4. High Relative Intensity Noise peak, RIN>-128dB/Hz, can degrade high power (>-3dBm) detected signal.
   - Improvement to lower RIN<-135dB/Hz

MMF Link Characteristics

- Signal impairment over legacy MMF is due to:
  - Attenuation
    - 850nm ⟹ 4 dB/km
    - 1310nm ⟹ 2.5 dB/km
  - Modal Bandwidth (OFL)
    - 850nm ⟹ 160 MHz km
    - 1310nm ⟹ 500 MHz km
- Attenuation is of minor relevance due to short link length
- Dispersion is the link length limiting factor for 10GbE over legacy MM fiber.

MMF OFL Bandwidth

- Standard multimode fiber bandwidth is specified under OFL condition which assumes a broad far-field light source, like LED.
- Under OFL condition, all bound modes are fully excited and the MM fiber bandwidth results quite repetitive and fits with Gaussian
- Typical OFL condition refers therefore to LED sources.
- 10GbE needs for high speed directly modulated semiconductor *laser* sources like VCSEL, FP, DFB, which *under-fill* fiber modes.

10GbE over MMF

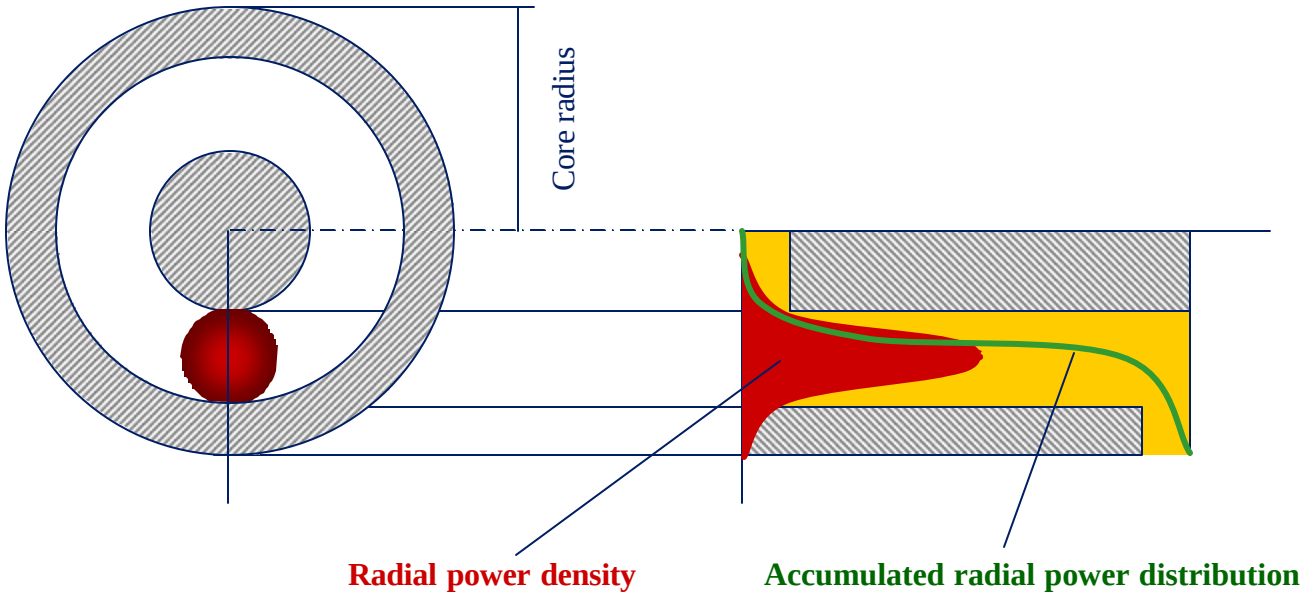
- Due to relative narrow far-field of laser beam, just few mode are excited, limiting the light propagation to some mode groups.
- Missing OFL conditions makes the fiber bandwidth and the impulse response strongly dependent on the launching radial coordinate over the fiber cross-section.
- Using laser sources, the fiber bandwidth can be lower or even higher then measured under OFL conditions.

MMF OSL Bandwidth

- The Differential-Mode-Delay (DMD) is highly depending on the subset of excited bound modes.
- Refractive index pin or dip in the axial region makes the pulse propagation mostly distributed among delayed contributions.
- Offset *Launching* (OSL) conditions must therefore be carefully defined in order to guarantee proper MMF bandwidth when laser sources are deployed.
- Joint measurements of OSL conditions over existing MMF plant are needed to guarantee consistency.

Stefano Bottacchi
COM FO MOD

MMF OSL Conditions



- If the coupled laser light satisfies Encircled Flux standards, reasonable bandwidth consistency with OFL conditions, with *repeatable results*, can be achieved.

Offset Launch Drawbacks

- Higher order mode characteristic of OSL excitation are more sensible to perturbations affecting outer core region.
- Depending on the launching radial coordinate the higher order mode group can exhibit low or high value of DMD.
- Any displacement due to connector junctions modifies the launching conditions and then the output pulse DMD.
- Bent radius has stronger effect on the higher order mode component, making the output pulse more sensible to microbending and cable assembling stresses.
- Different MMF samples have different OSL optimum conditions, according to their refractive index profile.

10GbE ROSA

- Principal ROSA limitations and requirements at 10GbE are the followings:

1. Photodetector active area below 40µm makes the output pulse affected by fluctuations due to *modal noise*.
   - Improvement to >60µm active area
   - Design trade-off between large active area and high bandwidth due to junction parasitic capacitance.
2. In order to uniquely define ROSA sensitivity it would be necessary to specify the reference transmitter (the reference TOSA).

10GbE ROSA

4. Transimpedance amplifier linearity requirements for proper EDC operation.
   - Definition of the OMA to achieve 1dB compression in transimpedance gain.
   - At higher received power a reduced linearity is required due higher SNRe available for EDC operation.
5. Frequency response and noise bandwidth matched to back-to-back eye diagram requirements.
   - Properly designed ROSA should not benefit from back-to-back EDC operation (negligible BTB ISI).
   - Negligible eye closure can be achieved with a frequency response (V/W) shaped according to IV-order Bessel-Thompson filter with frequency cutoff at f_c=7.5GHz and phase distortion less then 10% at the bit-rate.

10GbE ROSA

6. Noise density should be almost flat up to at least the bit rate in order to minimize EDC noise enhancements effects.
   - Due to FFE linear filtering, high frequency noise components are enhanced when EDC is working.
7. Differential output swing symmetry and reduced phase skew to avoid EDC false ISI detection.
   - Assuming EDC differential input, any asymmetry in the output signals reflect into false detected ISI and a consequent EDC false action (lock to false compensation)
8. Minimum output swing at optical sensitivity conditions in order to match EDC sensitivity requirements.
   - ROSA output swing at the optical link sensitivity requirement should be at least 3dB higher then the EDC sensitivity in order to avoid overall optical receiver degradation.

Conclusions

Stefano Bottacchi
COM FO MOD

Conclusion

- Components, key parameters and potential improvements have been discussed
- Next question is how to validate improvements
- Decision output, i.e. BER curve etc. is needed to judge a valid link
- Link simulator is needed incorporating references for all link components
- Existing link model might not be sufficient
- Committee to work out link simulator (including non-Gaussian fiber model and standard/reference EDC)
- Existing subsets from several companies need to be merged and aligned to a reference simulation tool.
- Infineon volunteers to contribute on this subject.