Proposal of an approach based on measured fiber data for statistical modeling of OM1 multimode fiber within the IEEE 802.3aq channel modeling ad-hoc committee.

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Purpose of this document

The purpose of this document is to summarize an approach for organizing the statistical modeling of OM1 (FDDI) multimode fiber within the channel ad-hoc committee. This should be viewed as a summary of ideas which supplement and complement the existing 81-profile approach rather than a completely alternate proposal.

The three main points which have been suggested for input to the committee are:

1. the type(s) of index perturbations which should be included in the model for OM1;
2. the suggested probability distributions for the perturbations;
3. whether the 2 nsec/km DMD value is still an important boundary condition for OM1.

Overview of Approach

The approach which is suggested is to rely as much as possible on measured data to inform the choices of index perturbations. OM1 fiber has an OFL bandwidth specification of 500MHz.km at 1300nm and this is the primary constraint on the profile; it also has an 850nm OFL specification of 160-200MHz.km and N.A. and core diameter specifications.

The primary measurements which can give more information about the particular perturbations are the DMD measurement, the refractive near field measurement (RNF) on the fiber, and the refractive index measurement on the glass preform before the fiber is drawn. These measurements are summarized in the book Optical Fiber Measurements by Marcuse and for fiber measurements in various fiber optic standards documents.

The additional measurements are not required for OM1 fibers and because of their added cost they are primarily process control tools. As such they are not measured on every fiber and any data which is available is not a statistical sample of the installed base. For example, a manufacturer might find it useful to measure DMD, and RNF from a fiber from the middle of the blank as well as the index profile from the middle of the preform. However, DMD, RNF and index profiles might have trends of one sort or another and these would not necessarily be studied with measurements on every blank. These ancillary measurements are not necessarily done on every blank.

Data which is available from one or more fiber manufacturers to feed into the OM1 channel modeling work includes:

a. preform refractive index profile data or mode delays calculated from the profiles;
b. 'high resolution DMD' data showing the output pulse as a function of offset position.
c. The mode delay set representing 5000 profiles used in the TIA modeling to develop the OM3 spec.

The data in (a) and (b) can be used to make informed choices about common index perturbations which need to be included. The data in (c) is based on fiber manufacturer knowledge from (a) and (b) and already has this understanding incorporated into the data set.

If the ad hoc committee felt it was important to primarily analyze problematic fibers (fibers representing the "worst 5%"of the distribution) the data from (a), (b), (c) could be scaled so that the predicted -3dB OFL BW was 500MHz.km. If the OFL BW of the fiber is actually known this scaling can be done perfectly.

One point which has been raised is that some members of the committee cannot perform an analysis if given mode delays but require the refractive index. This issue should be discussed by the ad hoc committee but it seems to be a solvable issue with minor changes to the computer programs. It would be much harder to modify a program which uses mode delays so that it starts from the index profile. One other solution is to take mode delays and calculate the smoothest index profile which would generate those delays.

Specific Index Perturbations which need to be included

These are the specific index profile perturbations which need to be included. The corresponding mode delay structures will be summarized in a following paragraph.

Center Index Perturbations. Profiles can have dips, bumps, waves, and flat spots near the center. The 81-fiber set has bumps or dips with a specific Gaussian shape with a specific width. Actual perturbations have different widths. One sometimes sees "ears" with a dip followed by an annular peak at a slightly larger wavelength followed by a dip. These perturbations were included in the OM3 work by including essentially random and un-correlated mode delays for the first 3 or 4 mode groups, especially groups 1 & 2.

Mid-Radial Perturbations. The high-resolution DMD measurements for OM3 fiber have shown that fibers can have abrupt transitions in the mode delay structure, where groups 1-9 (for example) have one mode delay, and groups 10-18 have another. This transition can occur in such a way that the BW if affected with offset launches in the 15-20um range, which typically are very stable launches. Examples of these measurements will be shared with the committee.

Outside Perturbations. These perturbations are the least important because the GeO2 weight percent is reduced and the outer modes have less power. The perturbations included in the 81-fiber set are typical; these could be augmented with measured perturbations. The one caveat is that in modeling OFL BW and comparing it to measured OFL BW the mode power distribution (MPD) which is used is critical. If the outer modes are weighted less than they should the outside has an even smaller effect; if the modes are weighted more than they should the opposite occurs. There is an additional outer index perturbation used in the OM3 modeling where an additional "alpha-break" was allowed on the outside, so that more outer modes could be affected, but not as much as with an abrupt transition.

Suggested probability distribution of the perturbations.

The proposal is to include all these perturbations, scale the perturbations to a 500MHz.km OFL BW, and test whether the EDC procedures allow error-free transmission at 10Gb/sec at certain target lengths. The perturbations which are proposed do occur frequently enough to be considered.

Is the 2nsec/km DMD value still an important 'boundary condition'?

The 2nsec/km DMD value means the maximum variation seen in a centroid DMD measurement from the earliest centroid to the latest. This number arises from a discussion between fiber manufacturers but not a sharing of data. It represents either an average value suggested by manufacturers or the smallest value suggested by manufacturers, and should be taken only as a guideline (i.e. not ½ and not 5).

It is probably a useful benchmark – maybe an important benchmark – but typically outlier fibers (fibers at the ends of blanks) do not have their DMDs measured and it is probably optimistic for the installed base circa 1999.

Additional comments and information forwarded to the task 1 sub-committee.

The details of DMD and index profile data to include and how (if necessary) to generate index data from DMD measurements have not been fully fleshed out by fiber manufacturers. Additional data from John George of OFS will be presented to the committee which is consistent with this proposal.

An additional presentation by John Abbott showing the typical OFL BW distribution tends to a lognormal shape has been forwarded to the task 1 sub-committee.

An additional presentation by John Abbott using index profile data pulled together by Corning at the time of the 1GbE MBI work, showing BW with offset using the Cambridge offset MPDs, has been forwarded to the task 1 sub-committee.