University of Cambridge Multimode-Fiber Model Results ***Release 1.2***

Jonathan Ingham, Richard Penty and Ian White *University of Cambridge* 12 October 2004

A statistical method has been adopted to generate a set of results which are intended to be representative of challenging multimode-fiber (MMF) links. The principle of an earlier form of this model is described in detail in M. Webster *et al.*, “A statistical analysis of conditioned launch for Gigabit Ethernet links using multimode fiber”, *Journal of Lightwave Technology*, vol. 17, no. 9, pp. 1532-1541, September 1999. For the purposes of this document, the steps of the method are briefly described by: (i) generate 108 MMF refractive-index profiles with a variety of defects which are to be expected in legacy MMF; (ii) calculate the radially-scanned differential modal delay (DMD) and overfilled-launch (OFL) bandwidth-distance product of each of these fibers; (iii) perform a bandwidth scaling process such that the set of fibers is representative of a desired worst-case DMD value. Please refer to the accompanying document entitled *“Statistical modeling of multimode-fiber links: a supplement to the information provided in the release note of 12 October 2004 in relation to Release 1.2 from the University of Cambridge”* for supplementary information.

For this release, the statistical method has been applied to the following case:

Source wavelength	1300 nm	**OFL bandwidth-distance specification**	500 MHz km
MMF core diameter	62.5 µm	**Worst-case DMD target**	2 ns/km

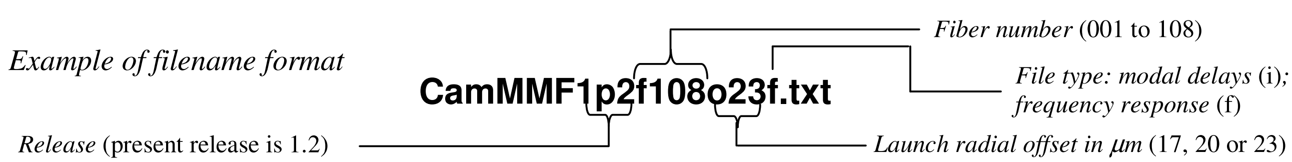
For each of the 108 fibers, the MMF modal delays and power-coupling coefficients are calculated in such a way as to model the range of behavior generated by a Gigabit Ethernet mode-conditioning patchcord. The corresponding MMF link frequency responses are also calculated. Three values of radial offset are considered:

Launch beam type	Gaussian	**Launch radial offset**	17 µm, 20 µm, 23 µm
Launch beam electric-field FWHM	7 µm	**Link length**	300 m

The results are representative of the intermodal dispersion induced by the MMF. *No other fiber phenomenon is modeled. No filtering is performed to model transmitter or receiver effects.* In particular, the effects of intramodal dispersion (chromatic dispersion) are **not** incorporated.

The MMF modal delays and power-coupling coefficients are supplied in 108 × 3 = 324 text files which accompany this document. Each file contains three columns. The first column lists the order m of each mode group supported by the MMF (up to $m = 20$). The second column lists the average modal delay τ_m of each mode group. The third column lists the power-coupling coefficients P_m, which indicate the relative excitation of each mode group. These enable the impulse response of the MMF link to be generated as $h(t) = \Sigma P_m \delta(t-\tau_m)$, where δ is the Dirac delta. Convolve $h(t)$ with a transmit pulse to generate the isolated-pulse response of the MMF link.

The MMF link frequency responses are supplied in an additional 324 text files. The frequency response is calculated by $H(f) = \Sigma P_m \exp(-j\, 2\pi f \tau_m)$. Each file contains two columns. The first column is a frequency axis from DC up to 20 GHz (in increments of 50 MHz). The second column lists the magnitude response in optical dB (dBo). The third column lists the phase response. An example of one of the MMF link magnitude responses is shown in figure 1, whilst a superposition of all 324 MMF link magnitude responses is displayed in figure 2.



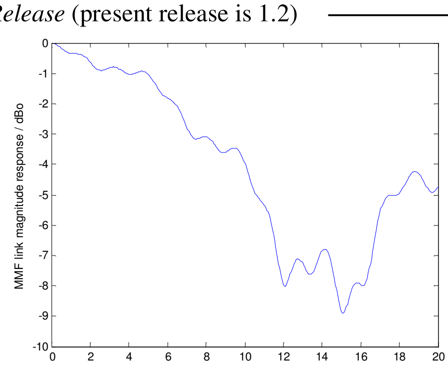


Figure 1 An example of a MMF link magnitude response (contained in file **CamMMF1p2f108o23f.txt**).

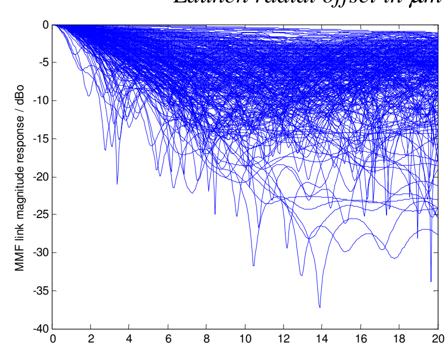


Figure 2 Superposition of all 324 MMF link magnitude responses in this release.