Modal launch conditions – measurement and control

Introduction

It has been known for many years that modal launch conditions have a major affect on the attenuation and bandwidth measured in multimode cabling systems. As the bandwidth of local area networks is pushed ever higher to meet demand, loss budgets are squeezed ever tighter. This has led to an increasing amount of attention being paid to minimizing the insertion loss in multimode cables and connector components. For example, the IEEE 10Gbit/s short wave specification over 300m (10GBASE-S) specifies a maximum channel loss of 2.6dB, which includes 1.5dB for connector loss. So, for example, in a link with two connections the maximum allowed loss on each connection is 0.75dB.

The biggest contributor to discrepancies in loss measurements is that different light sources may have very different modal launch conditions. The loss in a connection can vary by several tenths of a dB, depending on the modal distribution launched. Fortunately, standards bodies and equipment suppliers have responded to this challenge, providing launch specifications which can ensure that measurement accuracy to at least 0.08dB may be obtained, which is approximately one tenth of the maximum loss allowed per connector.

Dealing with insertion loss

Multimode fiber cable has a major advantage over singlemode in short haul applications, where its larger core diameter and higher NA mean it is much easier to get light in and out of the cable and it is much more tolerant to imperfect splicing, connectorization and general cleanliness and handling. There are also cost benefits in installing multimode networks instead of singlemode ones, although not in the cost of the cable itself but in system equipment.

Insertion loss is arguably the most fundamental parameter of an optical fiber cable. It has been shown in a number of studies that controlling modal launch conditions is by far the most significant contributor to variations in insertion loss measurements in multimode fiber cables and connectors. If you measure the loss of a cable using two light sources with different modal launch conditions you will get a different answer. If the sources have the same launch conditions you will, within acceptable limits, get the same result.

It is important to point out here that this says nothing about the ACCURACY of the insertion loss measurement. In a Light Source/Power Meter (LSPM) type measurement the accuracy is determined by a number of factors such as stability of the light source, wavelength accuracy, quality of reference patchcords, noise in the detector electronics, etc. If due care is taken, the measurement accuracy can be very good. The difference in loss measured here is real; the cable loss does actually depend on the modal distribution in the fiber.

Modal distribution and standards

So what exactly do we mean by “modal distribution"? Due to the electromagnetic properties of light, optical power travelling in a multimode fiber is restricted to certain discreet paths, or modes. In a typical multimode fiber with a 50µm core operating in the 850nm window, there are around 380 individual modes which can support light transmission. If every possible transmission mode in the fiber is occupied the fiber is referred to as “fully-filled”. However, in a practical fiber this never happens. In any practical fiber, light transmitting in so-called “high-order” modes is following a path which forces it close to the outside of the fiber core, making it susceptible to losses as the fiber is bent, or at small offsets such as at connectors or splices. By contrast, the “low-order” modes stay close to the centre of the fiber core and are much less lossy. So using this simple analysis, it is clear that if the light which is launched into the fiber contains a lot of power in the “high-order” modes, by the time the light exits the fiber it will have lost more power than a fiber where only “low-order” modes are present.

Therefore the solution is really quite simple. The loss measured depends on the balance of low and high order modes present at the input to the cable. So, if all parties use the same launch distribution, loss measurements immediately become much more consistent. This leads to fewer discussions between fiber makers, cable makers and system installers, and fewer problems at the user's premises.

Measuring Modal Launch Conditions

Of course, to standardise modal distributions we need to be able to accurately measure it. There are a number of ways to define and measure modal distribution but over the last few years the Telecoms industry has moved towards a parameter called “Encircled flux”. Encircled Flux has been used for several years for the characterisation of fiber-pigtailed VCSELs and is described by IEEE standards such as IEEE802.3aq. More recently, the TIA (TIA/EIA-455-203) and IEC (IEC 61280-1-4) have described the measurement technique in some detail. As the name suggests, the method involves measuring the light intensity at a planar surface parallel to the optical axis of the fiber, for example at the surface of a connector. This 2D map of the optical power is processed to calculate the optical power, or flux, contained in circles of increasing diameter, starting from the optical centre of the fiber.

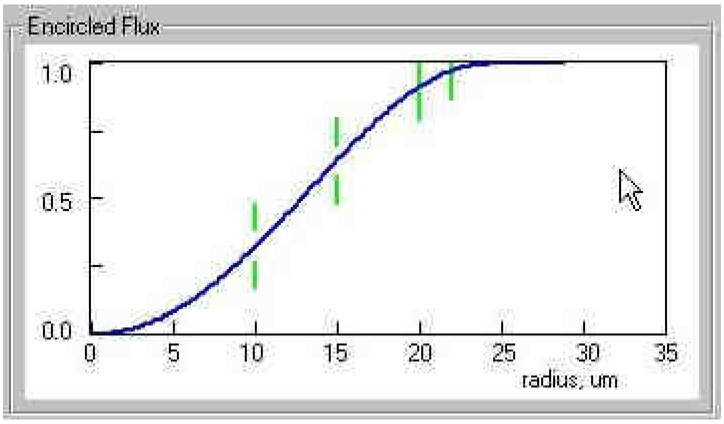

Figure 1 – Typical Encircled Flux plot showing IEC 61280-4-1 limits (in green)

To successfully implement this technique, high quality imaging optics and light detection equipment is needed, as well as traceable calibration of the optical magnification. Fortunately, standards compliant equipment is now commercially available, which enables accurate, real-time, measurements of Encircled Flux to be made (See Figure 2)

Conclusion

International standards are now in place which define the modal launch requirements for measuring multimode cable plant. For example, IEC recently introduced a new version of IEC61280-4-1, which defines in detail the Encircled Flux required in the measurement of cable systems. It defines the modal launch conditions as a series of upper and lower limits at various radial positions. Whilst cable system makers and test equipment makers work hard to make their measurement equipment compliant, at the sharp end installers and users need quick and easy ways to ensure they are doing the right thing when testing and commissioning installed systems. To take care of this, services are available which can measure the Encircled Flux of test sources. If the sources aren't compliant, mandrels may help or commercially available modal controllers, which will produce the right launch conditions from any source.

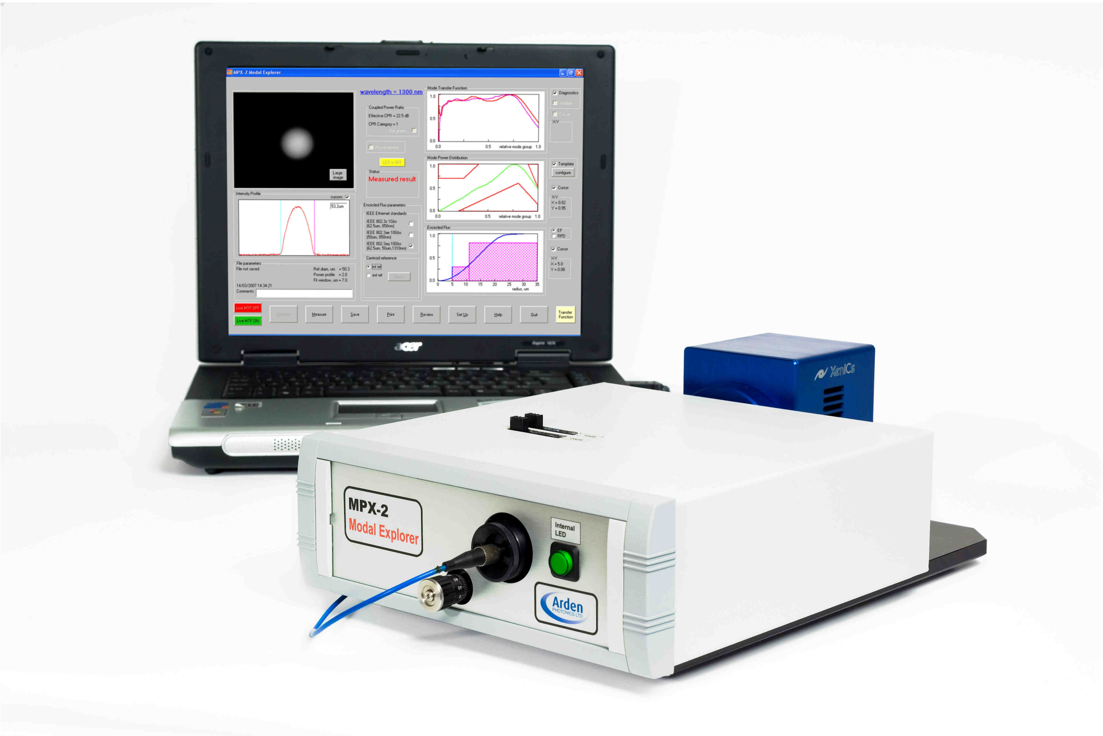

Figure 2 – Commercially available Encircled Flux tester

So, in summary, a major step has been taken by the industry to ensure that multimode fiber based systems can continue to provide cost-effective solutions in short-haul, high bandwidth applications. An international effort over a number of years has resulted in the release of appropriate standards, and commercially available equipment for the measurement and control of modal launch conditions is now available. This will lead to much improved agreement between loss measured in different locations and using different equipment.

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