MythBusters
In the land of PLC, part 1

PLC splitters are passive devices for optical power distribution, manufactured using planar processing methods and used as main components in fiber-optic access networks such as PON. Until recently considered rather exotic, PLC splitters are now gaining popularity among operators and installers due to the spreading of PONs. The popularisation of PLC splitters is caused mostly by the decrease in their pricing as well as the increase of the suppliers introducing these splitters to their offer. At the moment, PLC splitters became so popular that many operators began to consider them as mass-produced and widely accessible devices, so simple they cannot be malfunctioning. With such an approach the only matter that should be taken into account when selecting the supplier is obviously the price. Is this justified? In this series of articles we shall be exploring the most important myths regarding the splitters. We shall begin with the first two popular theories below.

MYTH 1 – PLC SPLITTERS ARE SIMPLE DEVICES

PLC splitters are constructed using so called planar manufacturing process (the abbreviation PLC stands for planar lightwave circuits). In practice, it means that the central part of the device (and essentially the power divider) consists of a PLC chip not bigger than a pinkie fingernail, in which waveguides and cascaded dividers (usually basic dividers offer 1x2 split configuration therefore the preferred numbers of PLC splitters are 1x2, 1x4, 1x8 etc.) are fabricated on the substrate using microelectronic. PLC chip can be fabricated on a silica glass or quartz substrate and the choice of the substrate may be significant due to the differences in thermal expansion of both materials.

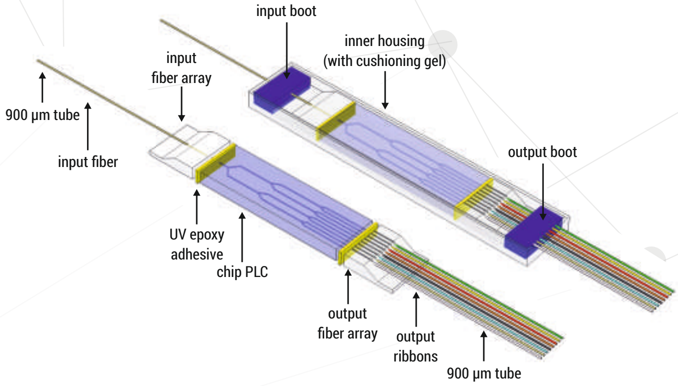

FIGURE 1 – Components of a PLC splitter

Optical waveguides fabricated on the PLC chip have usually a rectangular cross section. **The PLC technology is hybrid** because the chip needs to be coupled with external standard fibers with a circular cross section (which also requires a very accurate positioning). The standard fibers are glued into V-grooves which make for guideways. V-grooves are then covered with a lid stuck onto the surface. The whole element (including V-grooves, fibers and a lid) is called a fiber array. To minimise optical losses, fiber array has to be precisely aligned with the PLC chip so that the light coming out of one of the elements is launched exactly into the center of the fiber in other element. To appreciate the challenge, it is instructive to recall size of the single-mode optical fiber's core – if the beam spot diameter is about 9 µm, it means that **the precision of positioning of the fiber array should be in the region of 1 µm and shall stay stable for 25 years,** regardless the temperature, humidity or stress. What is responsible for such a stability is the carefully selected glue – most often an UV light curable epoxy.

Prepared this way, the yet-unprotected PLC splitters are thereafter glued into the inner housing (usually aluminium, filled with cushioning gel) then two end cap boots are fixed to the endings of the frame and outer tubes (usually 900 µm) are put on. Last but not least, concluding measurements are conducted and we have got a final product.

MYTH 1 CONCLUSION?

PLAUSIBLE

MYTH 2 – FROM THE OPTICAL POINT OF VIEW ALL OF THE SPLITTERS ARE THE SAME

An average user who is trying to compare PLC splitters coming from various suppliers might only look into test reports or technical data sheets. There is virtually no specification that communicates everything – what should we pay attention to then?

The most important obviously are **insertion losses**. At first glance, specifications from all of the manufacturers are similar and differ only by a fraction of a decibel. Is this a significant difference or rather not? If an operator had in their network practically unlimited optical power, such figures would not matter. However, if the optical power budget is tight, the mere 0.3 dB could make a lot of difference and sadly, the optical power in the network is more often rather lacking than **exceeding the assumed values**. If the operator is suffering from power budget deficits, they could either reduce the split within the network or acquire components with more favourable attenuation parameters which is equivalent to **higher investment costs**. Similarly, the operator could assume that no extra optical power margin (typically used to make up for components' aging process) is necessary at the rollout stage, which would obviously most likely let to some extra operational costs in quite short time. Finally, the operator could simply made their installers keep on splicing and fixing the network until the link is up, though it results in costs and delays anyways. What is worth mentioning, **the PONs are built to operate for approximately 20-25 years** which means they should be able to support protocols and bitrates of the future. It is unwise to assume that future requirements regarding the signal quality would suddenly decrease – if history tells us anything, it is always the other way around.

No matter how accurate the declared (in specifications and test reports) maximum insertion losses seem, we must not forget that theory does not always go along with practice. It usually suffices to talk with some fellow workers from the industry to learn some funny stories when the declared and actual parameters did not quite align (we shall write more on this topic in Myth 5). Let us assume that the supplier is honest with us and discloses in test reports true values as well as he meets certain specifications for the products. Does it mean the operator could compare two suppliers? Yes, if only the operator would gather enough data to prepare the statistics because testing 2 or 3 splitters from each supplier may not illustrate the actual situation in an objective way. **The attenuation values for ten 1x32 splitters with SC APC connectors coming from 2 suppliers are presented on the histograms below** – the random sample of Fibrain splitters was compared to splitters coming from some cheap and quite popular company Xyyyy. The Xyyyy-branded splitters were kindly provided by some cost-conscious customer, who didn't like overpaying and wanted to know the actual difference. It appears that even if the technical specifications are similar, the actual average attenuation and loss uniformity of splitters coming from the two suppliers vary significantly, which may affect the connection distance, peace of the installers' mind (and their workload) and the total cost of installation and maintenance of the network.

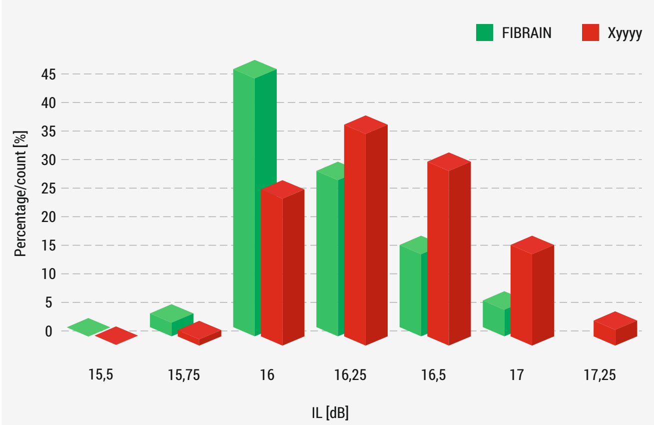

FIGURE 2 – Comparative bar chart of insertion loss of 1x32 splitters (green – FIBRAIN, red - Xyyyy)

An observant user should notice based on the histograms in the Fig. 2 that the average attenuation of splitters from the two suppliers vary by more than 0.2 dB, as well as the **number of outputs with high attenuation is greater for Xyyyy supplier** (not mentioning the outputs with very high attenuation, which do not occur among the Fibrain splitters at all).

Is the insertion loss the only parameter worth watching out for when comparing technical data sheet from various manufacturers? Well, most of the specifications consist of 2 or 3 pages thus very likely this is not the case. An essential, though often underestimated, parameter is the loss uniformity. PLC splitters are nominally symmetrical which means that each output should have the same insertion loss value. In reality they are never precisely identical (this can be clearly seen in the Fig. 2). The difference between the attenuation of outputs with the lowest and the highest loss is called the loss uniformity. The greater the uniformity, the worse splitter. The commonly used norm Telecordia GR1209CORE defines what values of the uniformity are acceptable. An example given, for 1x32 splitters the norm allows for 3 dB uniformity. Many cheaper suppliers still apply such non-restrictive requirements, however, luckily (for operators) most splitters have currently much tighter uniformity.

Loss uniformity is crucial from the operator's perspective because splitters with poor uniformity make the correct design of the network difficult (e.g. because one of subscribers in a GPON network could have in the end twice as much optical power as the other subscriber). Moreover, splitters with poor uniformity make it hard to maintain and repair the network. Imagine the situation when a Smith, living next door to a Jones has the available power greater by 3 dB – it is more than likely that the technician called to address the problem would focus on this difference and spend the next few hours looking for a problem that actually does not exist (besides having poor quality splitters). Dear operator, if you still have any doubts, please show the Fig. 3 to your installers and ask them which splitter they'd prefer to use.

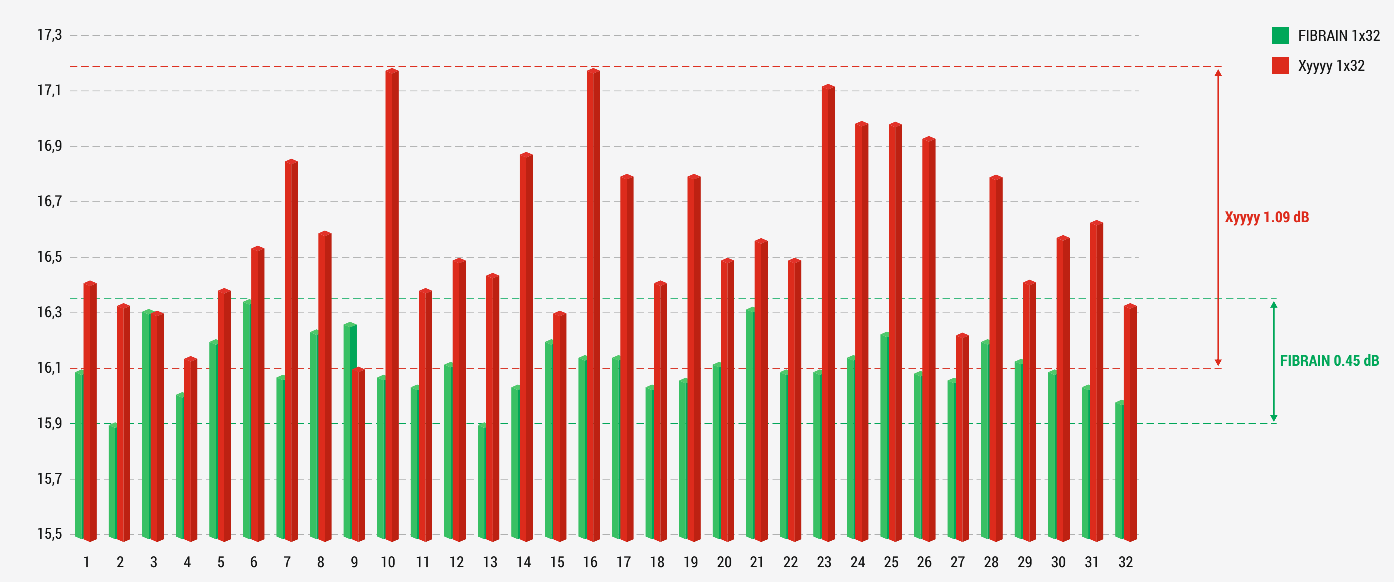

FIGURE 3 – Loss uniformity of 1x32 FIBRAIN - and Xyyyy-branded splitters

The occurrence of differences in loss uniformity for individual PLC splitter's outputs is caused firstly by the quality of the PLC chips and fiber array elements (mainly due to precision in defining the channel pitch) and secondly, by the **precision of positioning the elements in question** (thus by the quality of manufacturing equipment used for the production of PLC modules). Any offset of the waveguides in the chip in respect to the position of fibers in the fiber array module will affect attenuation, because a fraction of optical power is lost at the point of coupling. For example, if some of the channels in fiber array have the pitch of exactly 250 µm while other have the pitch of 252 µm and the PLC chip on the other side is precise and has the pitch of exactly 250 µm for every channel, the perfect positioning of the splitter's elements will not be possible. This means that each channel will have different attenuation. Within the last few years first PLC chips manufactured in China emerged on the market and they are gradually overcoming the monopoly of Japanese, Korean and Israeli producers. However, these chips are often not preferred even by the well-established Chinese manufacturers of PLC splitters because of their questionable precision, nevertheless they have one fundamental advantage – they are approx. 2.5 times cheaper than Korean chips and 3 times cheaper than Japanese ones.
Considering 1x8 splitter, the cost of good-quality PLC chip makes for 20-25% of the total material costs thus one of the secrets of the low cost of

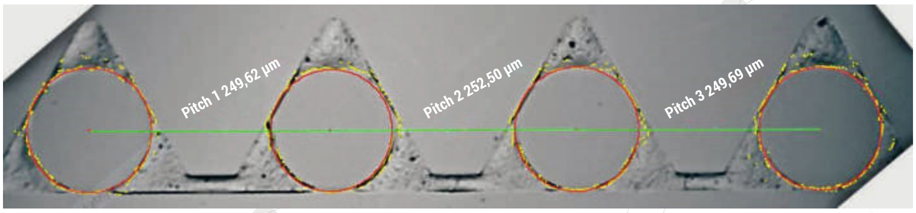

FIGURE 4 – Fiber array element extracted from Cccccc splitter –over 2 µm channels' misalignment is evident

PLC splitters has been unveiled (and it is worth to remember that fiber array elements may also vary in price by up to 100% depending on their quality). Unfortunately, there is no such thing as a free lunch – the approx. 2 µm misalignment of the channels results in almost 1 dB of excess loss! Fig. 4 illustrates the fiber array element extracted from a Cccccc-branded splitter acquired in a similar way to Xyyyy-branded splitters and measured using the measuring microscope – it can be seen that the core pitch is not constant and varies by over 2 µm, which was indeed confirmed during the uniformity measurements (for comparison, good-quality fiber array elements have the pitch tolerance of ±0.5 µm).

Furthermore, the same difference of 1 dB in attenuation may also appear within next couple of years, after a particularly hot summer or frosty winter (more on this matter in Myth 3). Typical fact for splitters made with low-quality chips and fiber array modules is that the values of loss uniformity and attenuation are often worse for 1310 nm wavelength than for the 1550 nm. It is clearly presented on the chart below, representing measurements for the splitter purchased from some other supplier, let's call them AAA.

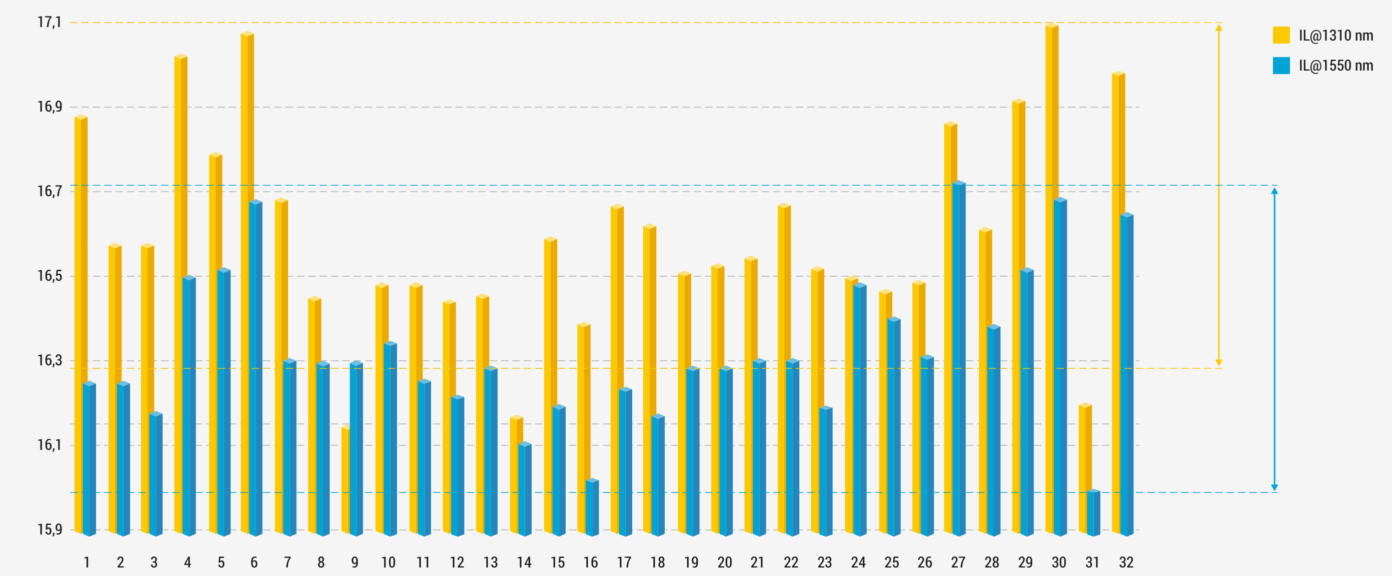

FIGURE 5 – Insertion loss of AAA-branded 1x32 splitter, measured at 1310 and 1550 nm

Is this all regarding the optical parameters? Not really. Almost every supplier of PLC splitters *declares the spectral working range of 1260-1650 nm*. Obviously, the test reports contain only the results measured in the 1310 nm and 1550 nm optical transmission windows (sometimes also for 1490 nm), because it is simply impossible to feature a full attenuation spectrum or tables with the values of insertion loss for other wavelengths (not mentioning the fact that most of the smaller suppliers cannot afford the more advanced equipment so that they are not able to measure the attenuation for any other wavelengths apart from the very basic transmission windows). Thus regarding this matter, the average operator is basically reaching a dead end and is forced to take a supplier's word for it. What does it mean in reality? We tried to reveal this secret. In this case, we had run our tried and true EXFO IQS-12008 analyser equipped with a tunable laser with the 1250-1650 nm wavelength range and therefore perfectly fitted for this purpose. We had tested another splitter (this time 1x8) coming from the aforementioned AAA company, a rather popular one. The supplier declares of course splitter's functionality in the full spectral range of 1250-1650 nm. Fig. 6. Proves, however, the actual situation. Even though the attenuation for the centre wavelengths of 1310 and 1550 nm (both **measured and reported** by the supplier) remains at the assumed level, **it increases drastically for wavelengths larger than 1570 nm**. In this particular case the increase of attenuation is being observed in the wavelength range that is not widely used in typical PONs yet (unless the operator had already introduced Docsis-PON DPON network with 1610 nm return path), but it's a rather small consolation. Let us reiterate what has been already said – optical-fiber network is set to operate for approx. 20 years and **new services will likely occupy new wavelength ranges** in the future thus the passive infrastructure must be designed and built with this perspective in mind. Otherwise the ostensible investment savings may soon be followed by unpleasant consequences.

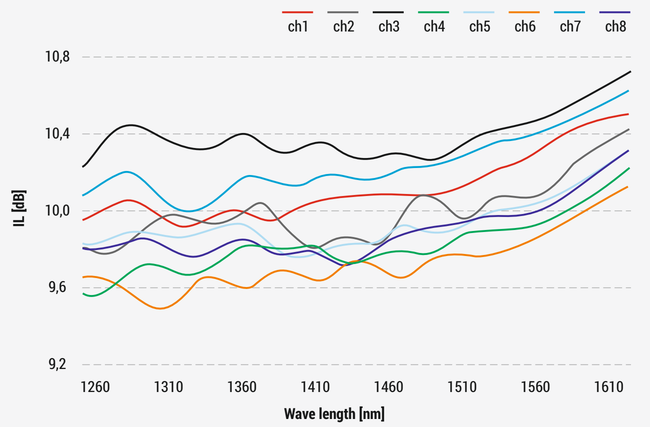

FIGURE 6 – Spectral profile of AAA-branded 1x8 splitter's insertion loss – increase in attenuation at over 1570 nm is evident

MYTH 2 CONCLUSION?

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