FIBRAIN
Fiber Optic Solutions

MythBusters
In the land of PLC, part 2

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. It is time for the second part of our mini-series, dedicated to the aging of PLC splitters.

MYTH 3 – SHOULD I CHOOSE REASONABLY GOOD COMPONENTS AND SUCCESSFULLY FIRE UP THE NETWORK, NO HARM EVER WILL COME MY (AND MY NETWORK'S) WAY

Let us assume, dear operator, that you had a careful look at test reports and inspected specifications very thoroughly. Even more, assume you have even measured spectral profiles of your splitters and plotted attenuation charts and histograms yourself, so you now feel impossibly proud and ready to go for deserved vacation. Surely nothing can possibly go wrong now. Or can it?

Unfortunately, we have got some bad news for you – the game's only about to start. Let me guess, all measurements you have conducted were done in room temperature, right? Well, that's not good enough, as **most of the PLC splitters will be exposed to extreme weather and/or temperature conditions**. After all, it stands for a reason that every supplier announces in their specification that for their splitters the working **temperature range is -40 to +85 °C**.

You may say (maybe urged by friendly sales guys from the slightly cheaper suppliers who, by the way, probably put the -40 °C limit in their own specs themselves, not having tested it really) that the probability of having the temperature of -40 °C in your local environment is as good as zero. Remember, though, that **tests conducted at such low temperatures are meant to simulate accelerated aging**. It is very likely that the same effects will be observed at -15 °C as at -40 °C, only 4 years later (and let us reiterate that the network is built for 20 years). To test this issue, our test lab team comes forward with a mighty myth-busting machine – the environmental chamber.

FIGURE 1 – The A-Team is arming the Death Star

We put all ten Xyyyy-branded 1x32 splitters into the **chamber** (the same splitters that we used to verify Myth 2). The testing procedure consisted of good old temperature cycles as per the European norm **IEC 61300-2-22**. Now comes the moment of truth (actually 3 temperature cycles were sufficient, instead of the normally required 12 cycles) – **7 of 10 tested splitters increased their attenuation significantly** (depending on the specimen, between 2 and more than 7 dB). The results for one of these 7 splitters are shown in Fig. 2.

It may seem comforting that at least three splitters have not increased their attenuation and passed the test, right? Well, not really, as they simply **broke the casing apart** – fibers receded into the housing in low temperatures and pulled the boots out. What to choose of those two evils? In the Fig. 3 we can see one of the splitters, which was unlucky enough to have its boots strongly glued into the housing, so the glue held and macrobends resulted. For comparison, Fig. 4 presents its compatriot (from the same batch) which was given less love (we mean less adhesive) – it managed to break free from his cage.

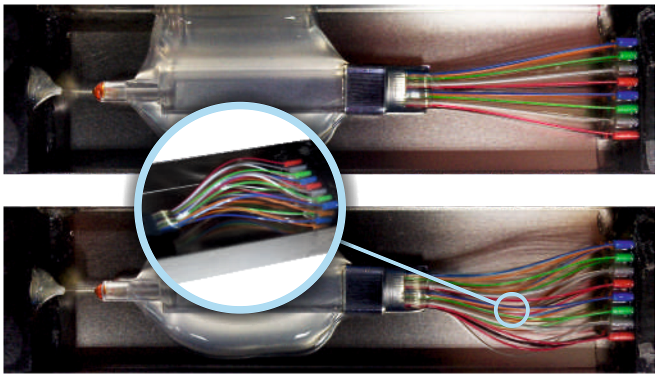

FIGURE 3 – Xyyyy-branded 1x32 splitter containing the correct amount of adhesive before (above) and after (below) testing in the environmental chamber. A receding fiber and macrobendings are evident.

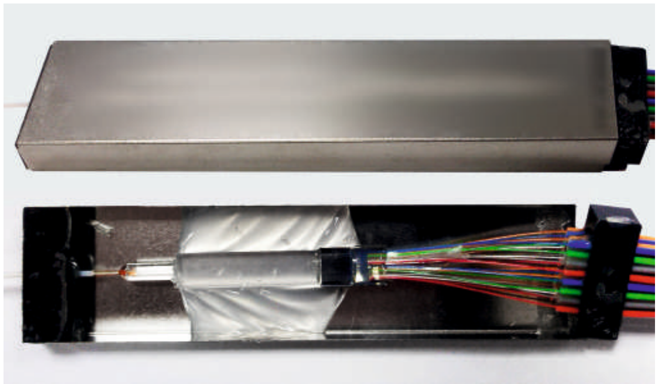

FIGURE 4 – Xyyyy-branded 1x32 splitter containing the insufficient amount of adhesive after testing in the environmental chamber.

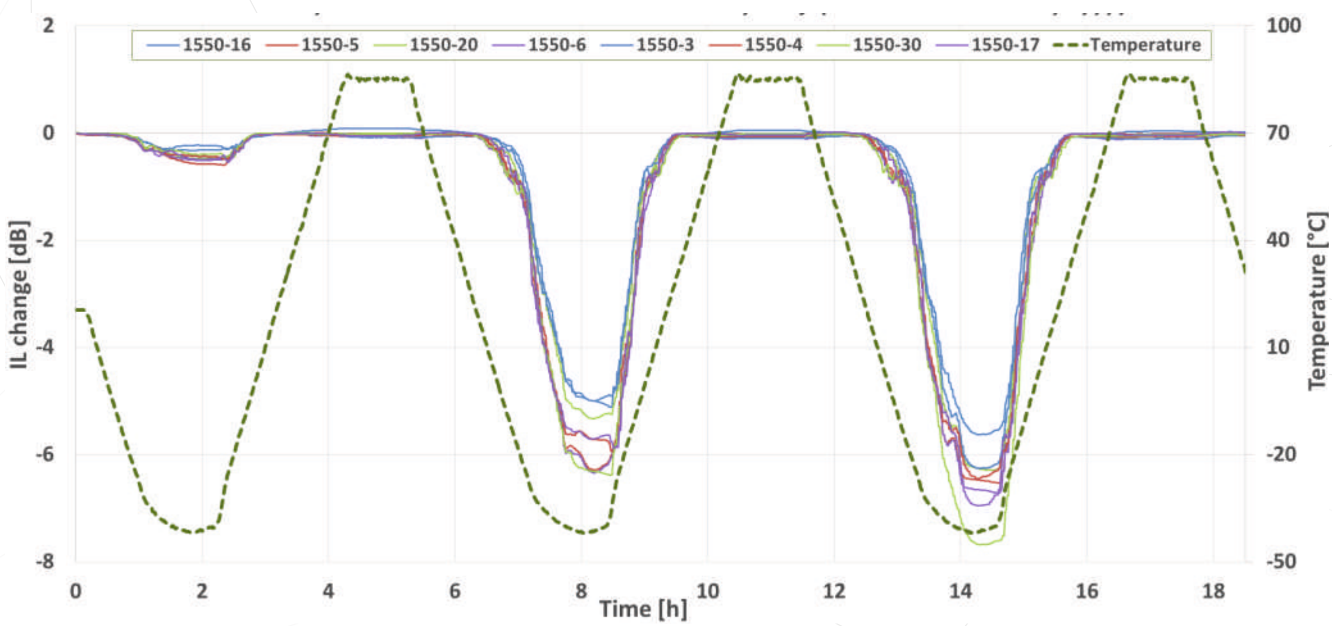

FIGURE 2 – A sample Xyyyy-branded 1x32 splitter vs. the environmental chamber – changes in attenuation by approx. 8 dB are evident.

To make sure everyone is treated fairly and equally, we have also tested the 1x32 splitter from the AAA supplier (mentioned in the part 1 of our trilogy) under the same conditions. Frankly speaking, this individual was way more interesting, as every single output exhibited a different behaviour after being subjected to temperature – the attenuation varied between 2.5 and 9 dB (as shown in the Fig. 5).

If you already feel down that surely your network will very likely die in the next semi-frosty winter, worry not, **for there indeed are PLC splitters that can work in the full temperature range of -40 to +85 °C!** To prove this bold claim to you, we present in Fig. 6 the changes in insertion loss vs. temperature for a Fibrain 1x8 splitter. Under extreme temperature conditions the attenuation varies by no more than 0.2 dB. As we can see, stable splitters are possible to achieve, though not easy to come by.

A curious reader may enquire about **the reason for such significant changes in attenuation at extreme temperatures**. We can name a few, all seemingly trivial:

- **incompatibility of thermal expansion indexes of the PLC chip** and the fiber array module (likes to happen when all elements are purchased separately with the lowest component price as the only priority);
- wrongly selected, cured or portioned UV epoxy adhesive, which keeps the PLC chip and the fiber array together (no wonder it often happens, as a good-quality **UV epoxy** may represent about 15% of the total material cost for a splitter!);
- the use of a **cheap 900 µm tube** with large thermal contraction;
- **large thermal contraction** of the metal housing (over 40 times larger than the contraction of glass), affecting the splitter through wrongly selected glue.

With a little goodwill, knowledge and proper equipment, all of these issues can be eliminated. However, this requires performing a series of tests and having under full control any modification to the technology (such as for examples changing with dose and duration of UV exposure in epoxy curing process, selection of epoxy adhesives etc.), with regular tests in the environmental chamber. All this testing is unfortunately money- and time-consuming. It is worth noting that the mere use of a better-quality tube with lower thermal contraction (and slightly more expensive, typically by 4 cents per running meter) means that the manufacturing cost of a 1x32 splitter with 2 meter input and output fibers rises by some 3 USD. It is inevitable, simply a better quality must cost more.

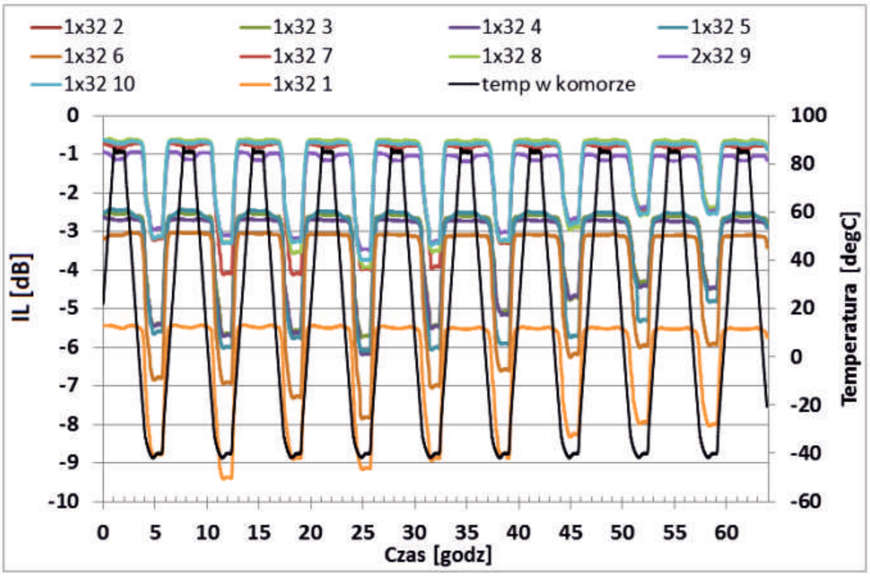

FIGURE 5 – Changes in insertion loss value for selected ports of AAA-branded 1x32 splitter during testing in the environmental chamber – fluctuations in attenuation value from 3 up to 9 dB

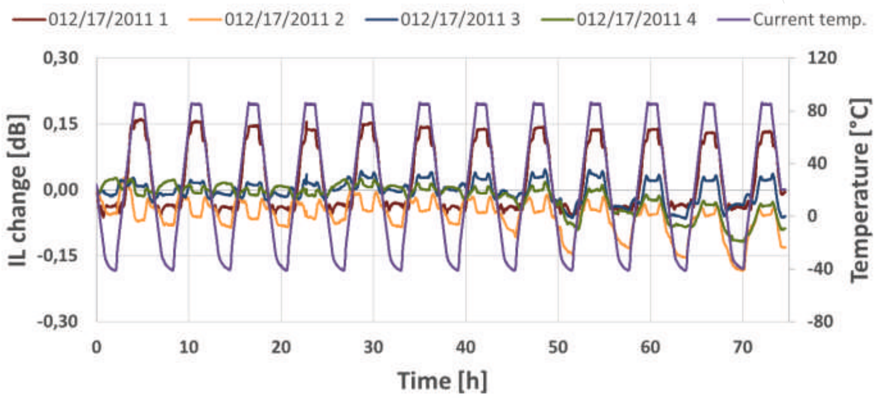

FIGURE 6 – Changes in insertion loss value for selected ports of Fibrain 1x8 splitter during testing in the environmental chamber

Is the temperature robustness the only parameter one should pay attention to? It is enough to open the first randomly-selected telecommunication manhole to see otherwise. Many fiber optic closures are submerged in water. Obviously the closures should be waterproof and protect the splitters but the practise does not always match the theory. Thus, another standard test is for **water resistance**. The main effect of the exposure to water is the corrosion of adhesive joints. Obviously, the key points here are the bonds within the fiber array itself and between the fiber array and the PLC chip because they are responsible for the stability of positioning the optic fibers (little reminder: 2 µm of the cores' misalignment causes almost 1 dB of extra loss!). Good quality (and expensive) epoxy adhesives for photonic applications must pass strict stability and durability tests according to Telcordia requirements (there are also many other parameters involved, such as matching refractive indexes and high optical power resistance), unlike the cheap substitutes. Let's demonstrate this point. Our laboratory team submerged the fiber array modules from Fibrain splitters and from the suspiciously cheap splitters purchased online **in water at 40 °C for a period of three weeks**. Fig. 7. shows the results of this experiment.

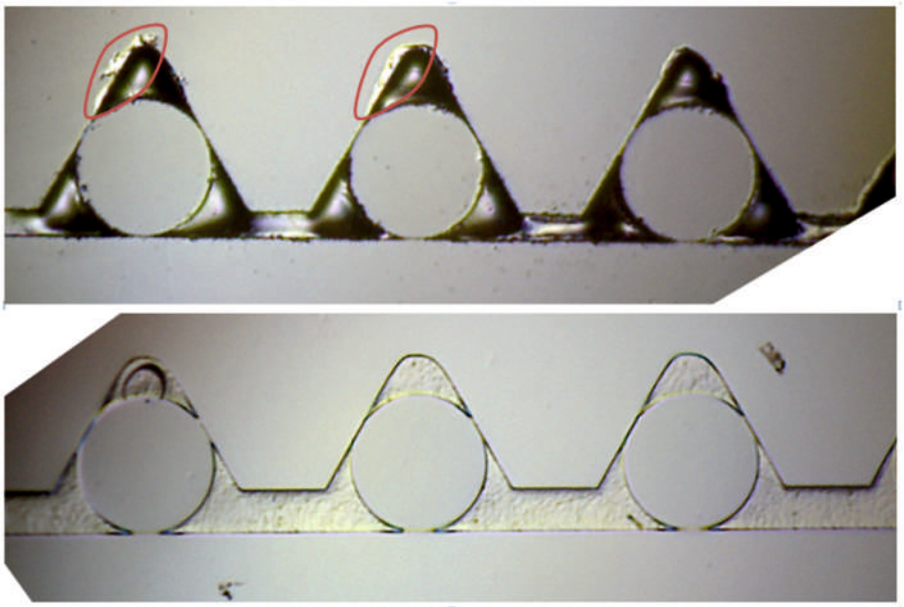

FIGURE 7 – The influence of humidity on fiber array elements coming from various producers. The areas of delamination, marked red, are evident in the photography above

It is evident that the adhesive in the fiber array element coming from the Fibrain splitter (below) has not been damaged, while the other module (above) **shows signs of bond losses and delamination**. This type of degradation leads to the movement of fibers (which normally should be fixed in V-grooves), and in effect to power fluctuations, especially when the splitter is buried by railway tracks. An interesting fact for those having their networks in rural areas is that the degradation of most adhesives is significantly faster in acidic environment (caused e.g. by the usage of fertilisers).

A separate and extensive issue is the influence of temperature and **humidity on fiber optic connectors**. Chinese connectors very often do not comply with norms regarding their geometrical parameters (such as the radius of curvature, the polishing angle, the fiber height and the apex offset) because the interferometers used to measure these criteria are very expensive and also the correct monitoring procedures generate extra costs. To confirm this statement, we measured every output of ten Xyyyy-branded 1x32 splitters using a Data Pixel interferometer – **61% of connectors had incorrect polishing angle** (the norms allow for an angle of 8° ± 0.3°) with the record-holder having an impressive angle of 6.6° (almost 5 times greater deviation than allowed!). Interesting things can be observed after testing those connectors in the environmental chamber – because the adhesive that bonds the optical fiber and the ferrule is incorrectly selected and cured, it does not hold the fiber strongly enough and the fiber flows inside the ferrule with temperature. Among the tested connectors on the Xyyyy splitters, an another record-holder changed its fiber height over 3.5 times, which indeed is a respectable achievement. **Connectors in which the fiber flows inside the ferrule are vulnerable to mechanical damages (as the protruding fibers simply break) and exhibit changes in optical return loss and increase of insertion loss**.

MYTH 3 CONCLUSION?