EQUALIZER IN A JOINTING BOX: IMPROVED FLEXIBILITY, MORE COST EFFECTIVE SOLUTION

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Abstract: In high-speed, high-capacity transmission systems, gain equalization and channel pre-emphasis ensure that all the transmitted wavelengths are received with adequate margins. Gain equalization is a combination of gain flattening filters in repeaters, tilt equalization filters used at regular intervals along the system to correct the residual tilt, and shape equalization filters to better flatten the gain spectrum. This paper presents an improved flexibility, more cost-effective solution to implement the tilt correction on high bit rate, long range transmission systems: Tilt equalization filters housing in a joint which design is based on the ASN joint box.

1. INTRODUCTION

Passive tilt equalization filters (also called P-TEQ) were in the past inserted in housings based on repeater sea-case, which presents a number of constraints in terms of assembly schedule and hardware cost.

Alcatel-Lucent developed a new filter housing design, based on the well known, field proven ASN joint box. This solution improves flexibility during SAT (System Assembly and Test) operations and enables an optimized tilt correction, as well as a significantly reduced lead time between selection of filters and final measurement of assembled cables.

This paper presents the benefits of the P-TEQ box new design in terms of flexibility, cost and repair strategies. It details the new P-TEQ box design, its optical and mechanical performances, as well as the specific testing that was undertaken during its qualification to demonstrate its suitability for applications on long haul, deep sea transmission systems. This includes results of mechanical and environmental tests performed on deep sea and armored cable designs.

2. BENEFITS OF THE NEW SOLUTION

Benefits of this new solution are multiple:

The first one is a more flexible system assembly process. Indeed, the P-TEQ filter integration in ASN joint box is done in cable manufacturing plant, so at the same location where the SAT operations are done. As the slope of the P-TEQ filter to be integrated for a given optical path is to be adjusted according to the SAT measurement results for this path, integrating P-TEQ filters at the same location as the SAT operations offers a high flexibility in terms of scheduling/POW and enables an optimized filter tuning process. P-TEQ filters new housing is only closed once SAT measurements including the filters are fully satisfactory. In the past, P-TEQ filters were housed in a repeater sea-case assembled in the repeater manufacturing plant, which did not enable any easy modification of the P-TEQ filter slopes once these slopes had been chosen, no precise tuning process was possible.

By integrating the P-TEQ filters at the same location as the SAT operations, the gain in terms of filter choice and integration lead time is also non negligible (no lead time anymore for P-TEQ housing transportation from its assembly location to the system assembly location).

The third advantage is a reduced cost. By integrating P-TEQ filters in joint box housing rather than in repeater housing, the P-TEQ housing cost is significantly reduced as the size and complexity of the new housing are greatly reduced. This also facilitates Marine operations.

Besides the flexibility, lead time and cost advantages, the P-TEQ filter housing new solution also provides additional benefits in terms of system repair strategies.

The new design has been initially developed for a full capacity of 12 filters, corresponding to the OALC-4 cable capacity. Extending the P-TEQ joint box capacity from 12 to 24 filters provides a new solution in terms of P-TEQ sparing and in terms of tilt management over system lifetime.

For instance, solution for the sparing of a 6 fiber pairs system P-TEQ is to integrate 12 filters with an adequate positive slope, 12 filters with an adequate negative slope and 12 attenuators. Thus for each of the 12 optical paths, the tilt correction can be positive, negative or equal to zero, depending the P-TEQ filter to be replaced.

For systems up to 8 fiber pairs, solution is to cascade two P-TEQ joint boxes. The first 8 fiber paths are dealt with in the first P-TEQ joint box, the 8 remaining optical paths just going through the first joint box without any optical tilt correction. Tilt correction of the 8 last fiber paths is done in the second P-TEQ joint box, the 8 first optical paths just going through the second joint box without any optical tilt correction.

The tilt management over system lifetime can also be managed through the using of adequate P-TEQ filters integrated in a new P-TEQ joint box, this additional joint box then being added to the existing system to correct the effects of system ageing on tilt management.

The extension of the P-TEQ joint box capacity is an on-going development in Alcatel-Lucent. This product will be tailed with 36 fibers OALC-7 cables, and stored in frames as for spares repeater.

3. P-TEQ FILTERS NEW HOUSING DESIGN

The P-TEQ filters new housing design is based on the well known ASN joint box, into which is incorporated a filter protection module.

Figure #1 is a 3D view of the P-TEQ joint box design for a full capacity of 12 filters.

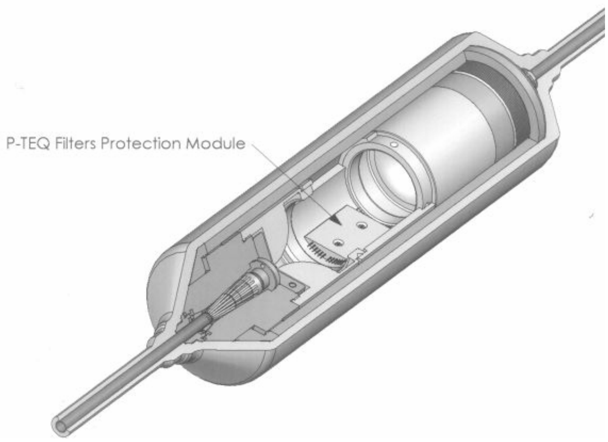

Figure #1. P-TEQ Joint Box 3D View

P-TEQ joint assembly sequence begins with the assembly of the joint box housing. Once selected based on the assembled cables measurement results the filters are then placed inside the protection module, and the module is fixed inside the joint box. If needed (cf. paragraph §4), attenuators are placed in the joint box core, but outside of the filter protection module. Filters and attenuators are then spliced to line fibers, and excess fiber length is coiled in dedicated tanks located on each side of the joint as for a standard jointing box. Optical measurements are done before and after fiber coiling. Joint box is then closed and molded.

Thanks to the filter protection module, filters are protected against potential trapping by splices or attenuators in case of fiber movement. Filters are straight as they are inserted inside the protection module, and the fiber extra length coiled in the storage devices acts as a buffer to isolate the filters from the cable.

4. PRODUCT PERFORMANCES

As P-TEQ joint box design is based on the standard ASN cable joint box, its mechanical performances are the same as the standard joint box ones; its ultimate tensile strength is equal to 90% of the UTS value of the corresponding considered cable protections (light weight, light weight protected, single armor, double armor cables) ; its depth limitations are those of the corresponding considered cable type ; its bending around the sheave performances are the same as the current ASN cable joint box ones ; the maximum pressure applicable to the P-TEQ joint box is 1000 bars as for standard ASN cable joint, which covers cable maximum deployment depth.

The optical characteristics of the P-TEQ joint box are those of the P-TEQ filters themselves as their packaging in the box does not alter their properties, plus additional attenuation brought by the splicing to the line fibers. The filters allow positive or negative slope compensation over the corresponding system bandwidth. In case there is no need for any slope compensation over a particular fiber path, the filter is replaced by an attenuator spliced to the corresponding line fibers. As an example, typical splice values between P-TEQ filter fiber and NZDSF line fibers are given in table #1:

Splice Combination	Splice Typical Value (dB)
P-TEQ fiber to type A line fiber	0.3
P-TEQ fiber to type B line fiber	0.4

Table #1. Typical Splice Values for NZDSF Fiber Splicing to P-TEQ

P-TEQ joint box electrical characteristics are those of the standard ASN joint box, qualified for a 25 years operation under 15 kV d.c.. Overall product has been designed to ensure total reliability for a 25 years lifetime.

5. QUALIFICATION TESTING

A six months qualification program has been undertaken in order to validate the P-TEQ new design housing (12 filters initial full capacity) on ASN OALC-4 cables, including mechanical and environmental testing. P-TEQ filter component had already been qualified through a specific, dedicated component qualification program. The housing qualification program only dealt with the potential impact of its housing on the filters. Optical measurements were performed on the filters before and after tests on the entire C band throughout the testing program.

Three P-TEQ joint boxes have been assembled for this purpose, one on an OALC-4 cable tube sample, one on an OALC-4 light weight sample and one on an OALC-4 double armor sample. Each of them included 12 filters.

The tube sample was submitted to a mechanical tensile test in straight line. No significant attenuation filter slope change was observed after test. No movement was observed on the filters and filter fibers during the test.

- The light weight sample was submitted to a series of mechanical tests:

- Fixed gyration tensile test up to cable NTTS: Filter slopes have been checked before and after test. No significant attenuation slope change was measured.

- Fatigue test at cable NOTS: Filter slopes have been checked before and after test. No significant attenuation slope change was measured.

- Sheave test up to cable NTTS: Filter slopes have been checked before and after test. No significant attenuation slope change was measured.

The light weight sample was then submitted to a series of environmental tests:

- Bumps and vibrations testing: Filter slopes have been checked before and after test. No significant attenuation slope change was measured.

- Thermal cycling test between -20°C and +65°C: Filter slopes have been checked before and after test. No significant attenuation slope change was measured.

The light weight sample integrity after qualification tests completion was checked. The sample was submitted to a hydraulic pressure test and to a high voltage test with successful results. The sample dissection after tests did not reveal any anomaly inside the joint core.

The double armor sample was submitted to the following mechanical tests:

- Free gyration tensile test up to cable NTTS: Filter slopes have been checked before and after test. No significant attenuation slope change was measured.

- Torsion test in both clockwise and anti-clockwise directions: Filter slopes have been checked before and after test. No significant attenuation slope change was measured.

The double armor sample integrity after qualification tests completion was checked. The sample was submitted to a hydraulic pressure test and to a high voltage test with successful results. The sample dissection after tests did not reveal any anomaly inside the joint core.

In order to better assess the product performances, and as part of product characterization testing, an accelerated ageing test has been performed on an additional OALC-4 light weight sample containing 12 filters, to simulate a 25 years ageing. Filter slopes have been checked before and after test. No significant attenuation or attenuation slope change was measured.

In parallel to the housing qualification test program, splicing qualifications have been carried out between P-TEQ filter fiber and system line fibers. Optical tests, mechanical tests (torsion and tensile tests), thermal and ageing tests have been performed on several samples, with successful results.

In order to validate the product industrialization, several SAT operators have proceeded to the assembly of P-TEQ joint boxes, integrating 12 filters with optical measurements after filter splicing and after fiber coiling in the joint box. Each of the operators has also been asked to replace one of the filters, once all of them had been integrated in the joint box, to check the defined filter replacement procedure. All these tests demonstrate the P-TEQ joint box product was well designed to face industrial conditions.

6. CONCLUSION

The tilt equalization filters integration in Alcatel-Lucent cable joint boxes has been successfully designed and qualified. The improvements this new product brought in terms of system assembly flexibility, system assembly lead time and product cost have been confirmed since its qualification performed in 2004. Indeed, several tilt equalization filters joint boxes have been successfully implemented since then on two high bit rate, long range transmission systems.

The product capacity extension will provide additional solutions for the management of system tilt once installed, both in terms of P-TEQ sparing and system ageing tilt variations management.

7. GLOSSARY

P-TEQ: Passive Tilt Equalizer – Optical filters integrated in the system to correct to attenuation slope over the system bandwidth

SAT: System Assembly and Test

NZDSF: Non Zero Dispersion Shifted Fibers

OALC: Optically Amplified Line Cable

NTTS: Nominal Transient Tensile Strength - maximum tension that can be applied to the cable during a cumulative period of one hour, without significant reduction of NPTS/NOTS

NOTS: Nominal Operating Tensile Strength - maximum tension that can be applied to the cable during the time necessary to make cable joints, without significant reduction of NPTS

NPTS: Nominal Permanent Tensile Strength - maximum tension that the cable can withstand during the system lifetime without any impairment of fibers nor degradation of the overall cable performance

UTS: Ultimate Cable Tensile Strength - maximum tension that can be applied to the cable without causing cable break.