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Return Loss Calibration of OTDRs

by

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Abstract

Artifacts for the calibration of OTDRs for return loss are described. These are then used to check the return loss accuracy of two OTDRs over a range of return losses from 30 to 60 dB. This shows that OTDRs are accurate to better than 1 dB below 50 dB but can give higher errors at higher return losses.

Introduction

Spurious reflections can produce undesirable effects in telecommunications systems. For example, light reflected back to a laser transmitter can lead to mode hopping and increased intensity noise. Such effects become increasingly important in high bit rate systems and systems employing optical amplifiers. These reflections can be measured by conventional OTDRs although at present no agreed procedures exist for the calibration of OTDRs for the measurement of return loss, although it is under discussion within the IEC committee on OTDR calibration (TC86, WG4).

Return Loss Calibration Artifacts

Artifacts with return losses in the range 1 to 60dB have been prepared. The low (1 to ~20dB) return loss artifacts were prepared by cleaving the end of fibres ~1 metre long at angles in the range 0 to ~6° and then vacuum depositing aluminium onto the cleaved end. Artifacts with return losses in the range 30 to 60dB were fabricated by cleaving the ends of fibre a few hundred metres long at angles in the range 0 to ~6° and then applying UV curable epoxy to the cleaved ends. After curing the artifacts were heated to 40°C for ~1 hour. The return loss of the artifacts was measured using optical continuous wave reflectometry using a 50/50 coupler (1). Uncertainties in return loss of $\pm 0.3\text{dB}$ up to 45dB rising to ~1.5dB at 60dB were obtained.

The above artifacts simulate the reflection that occurs at the end of a fibre. However, in many cases OTDRs are used to measure the return loss of a joint between two lengths of fibre. To simulate this, the set up of Figure 2 was used. It consists of a 90/10 coupler the 10% port of which is connected via a calibrated attenuator and ~500 metres of fibre to one of the low return loss artifacts described above. The 90% port is connected to ~32dB return loss artifact fibre (~600m long). This produces an OTDR trace such as that shown in Figure 2. The height of the reflection peak can be varied using the attenuator with little effect on the backscatter level as nearly all the backscatter signal comes from the 90% port. The height of the reflection peak can be calculated from the return loss of the artifact, RL, the attenuator value, A, and the splitter coupling coefficients. For a 90/10 splitter the return loss is given approximately by $(10 + \text{RL} + 2A)$ dB. Further, by introducing attenuation by bending the fibre in the 90% arm of the splitter at the same distance from the splitter as the 1 dB reflector, the reflection from a lossy splice can be simulated (2).

OTDR Measurements

Four artifacts with return losses in the range 30 to 60 dB were measured on two OTDRs. Figures 1a and 1b show the difference between the OTDR and CW return loss measurements for the artifacts (OTDR - OCWR). The dotted curve indicates the uncertainty of the calibration of the artifacts. It appears that the error of the OTDR measurement increases with increasing return loss for both OTDRs and that both tend to give too high a value for the return loss. Also in the case of one OTDR (a), the error also increases as the measurement pulse width is decreased. Measurements on artifacts with higher return losses and at shorter pulse widths showed differences of $> 5\text{dB}$.

Figure 3 shows the results obtained using the variable return loss system for the same OTDR as used in Figure 1a. It can be seen that the OTDR in this case measures return losses accurately up to $\sim 70\text{dB}$.

Discussion

The OTDR calculates the return loss from the amplitude of the end reflection and the pulse width used in the measurement (1). If either of these are incorrect then the wrong return loss will result. Checks showed that the pulse widths were correct and that the OTDR was correctly measuring the height of the reflection peak above the backscatter trace for the end reflection type artifacts. However, there are also a number of assumptions that relate the measured reflection to the return loss and these tend to become less accurate at shorter pulse widths and especially at high return losses (3). Software has been developed which appears to overcome the problem (3) but to implement it requires transferring the OTDR trace to a computer with the required software, not a practical proposition for most OTDR users. It is possible that future OTDRs will come with the necessary software installed but this seems unlikely in the near future. A more practical approach would be to improve the accuracy of the artifacts with return losses of $> 50\text{dB}$ and to use these to calibrate the OTDR for return loss. When the reflection occurs at 'low loss' joint between two fibres then accurate OTDR return loss measurements up to at least 70dB appear possible.

Conclusions

OTDRs appear capable of measuring 'end reflection' type return losses in the range 30 to 50dB to better than 1dB . If the measurement is carried out for a number of pulse widths and the lowest value of return loss taken as the correct one then the error is likely to be $< 0.5\text{dB}$. For return losses above 50dB , and especially 60dB , then errors of several dB can easily occur. The artifacts described will allow calibration of OTDRs to keep these errors below 1.5dB . We expect to be able to reduce these uncertainties to less than 0.5dB in the near future.

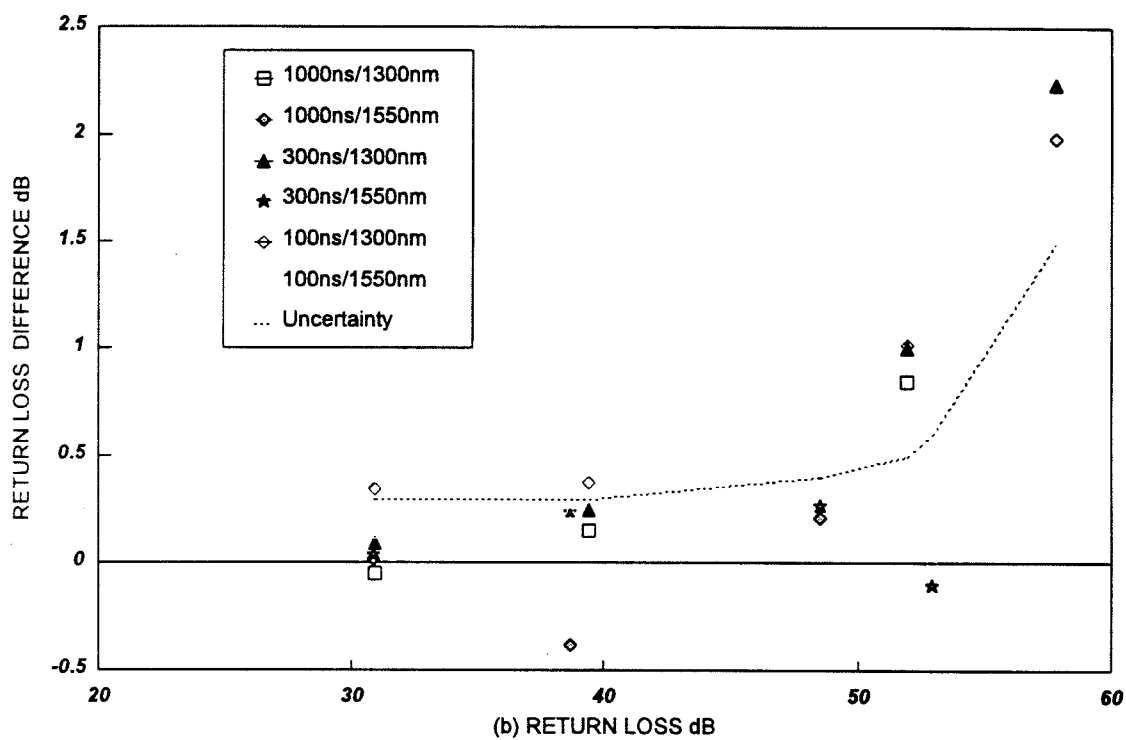
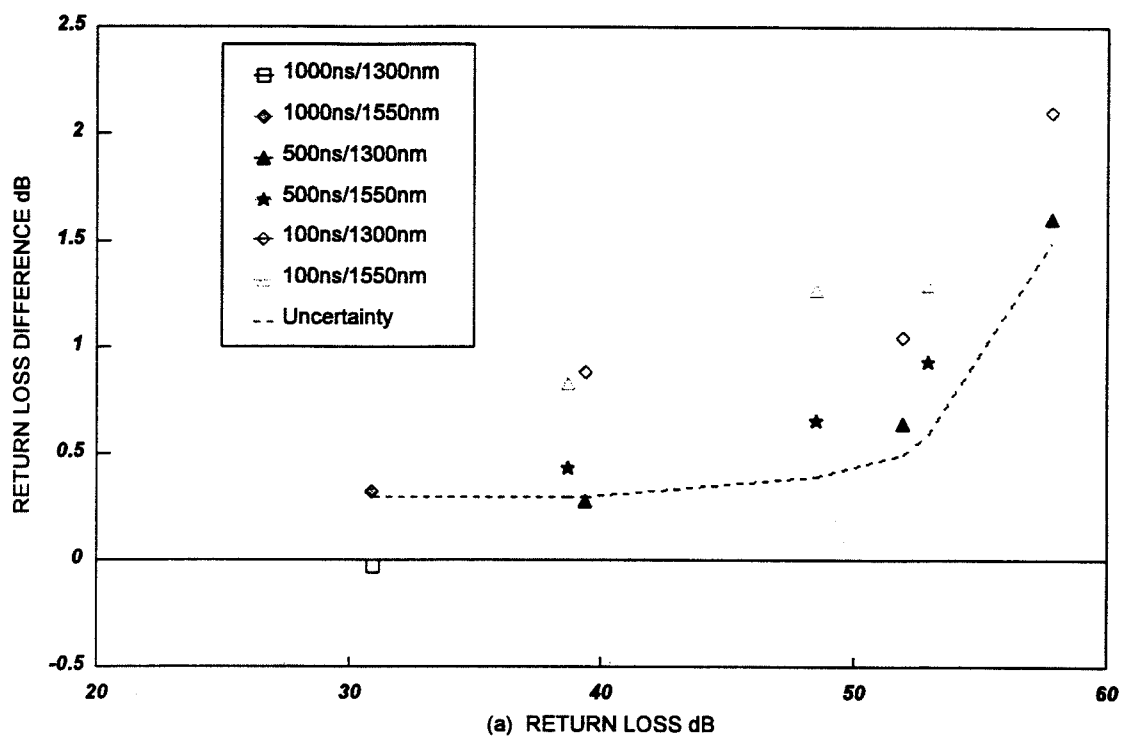
When the reflection occurs at 'low loss' joint between two fibres then accurate OTDR return loss measurements up to at least 70dB appear possible.

Acknowledgement

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Figures 1a and 1b. Difference between OTDR and calibration artifact return loss values for two OTDRs at 1300 and 1550nm and various pulse widths.

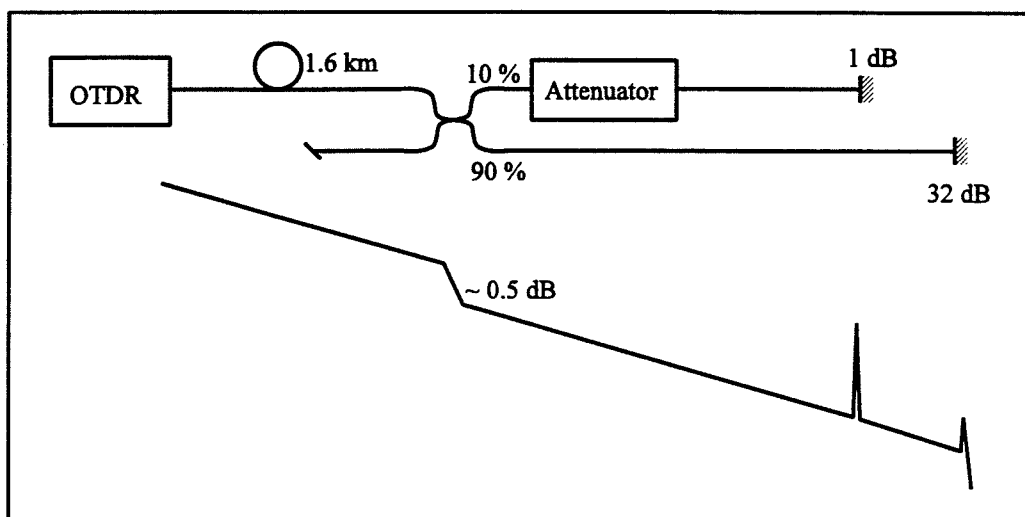


Figure 2. Variable return loss calibration set up

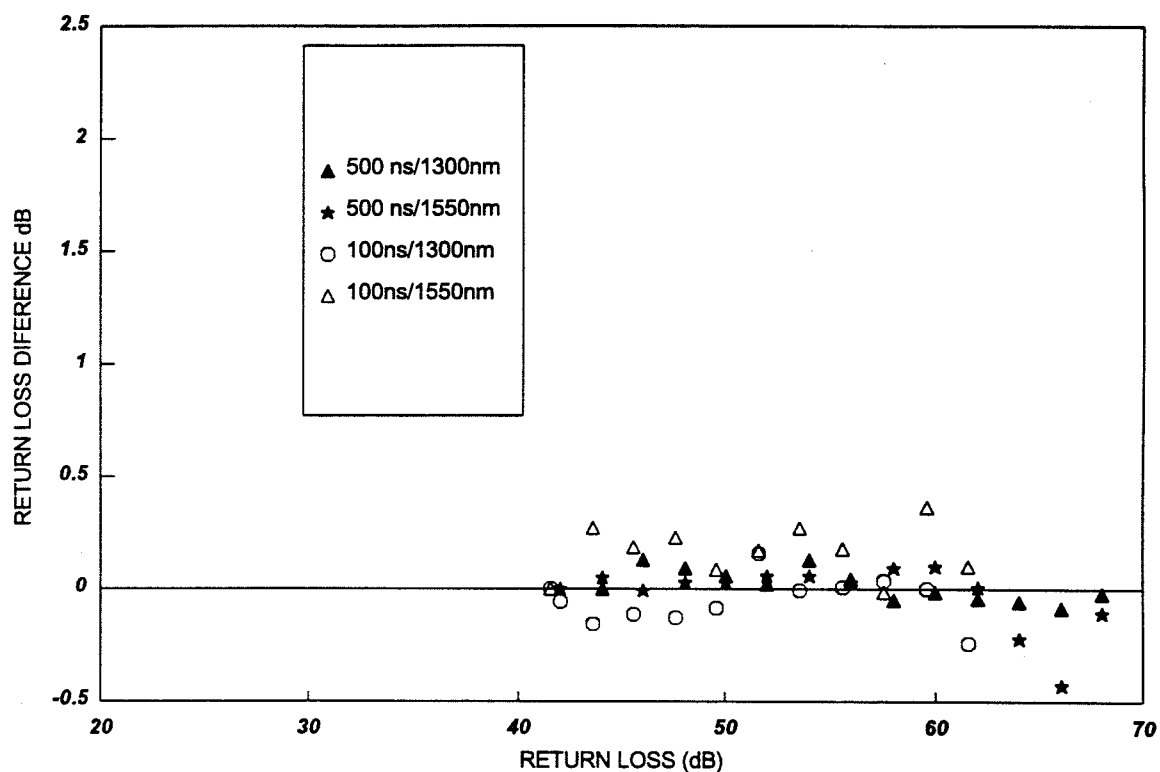


Figure 3. Difference between OTDR and variable return loss artifact for the OTDR of figure 1(a) at 1300 and 1550 nm and two pulse widths.