Technical Note 001

Insertion loss measurement

1. Purpose

The purpose of the insertion loss measurement, also abbreviated IL, is to determine the loss of optical power, also called attenuation, of a passive optical component.

2. References

The references for the insertion loss measurement are the following:

- Standard IEC 61300-3-4 'Basic test and measurement procedures - Examinations and measurements - Attenuation'
- Standard IEC 61300-3-34 'Basic test and measurement procedures - Examinations and measurements - Attenuation of random mated connectors'

3. Methods

The measurement of insertion loss is performed using a light source, LED or Laser, and a power meter. In the case of passive optical components terminated with connectors the preferred measurement methods are the method B and method C according to the standard IEC 61300-3-4 and explained at paragraph 3.1 respectively 3.2.

The insertion loss measurement is a measurement of a relative value which is expressed in deciBel (dB) and calculated with the following formula:

$$IL = -10 \cdot \log\left(\frac{P_{meas}}{P_{ref}}\right) \quad [dB] \qquad (1)$$

Where P_{ref} is the reference power level expressed in W and P_{meas} is the measured power level expressed in W with the passive optical component under test, also called DUT, Device Under Test.
In the fibre optic the power level can also be given in a logarithmic scale and expressed in dBm. The formula to transform the power level from mW to dBm is given below:

$$P_{dBm} = 10 \cdot \log\left(\frac{P}{P_0}\right) \quad [dBm] \qquad (2)$$

Where P_{dBm} is the power level expressed in dBm, P is the power level expressed in mW and P_0 is the reference power level corresponding to 1 mW.

And with some examples:

P		⇒	P_{dBm}	
1000	mW	⇒	30	dBm
100	mW	⇒	20	dBm
10	mW	⇒	10	dBm
1	mW	⇒	0	dBm
1	µW	⇒	–30	dBm
1	nW	⇒	–60	dBm

In this way the insertion loss given in (1) can be also expressed with the power level in dBm, as follow:

$$IL = P_{ref,dBm} - P_{meas,dBm} \quad [dB] \qquad (3)$$

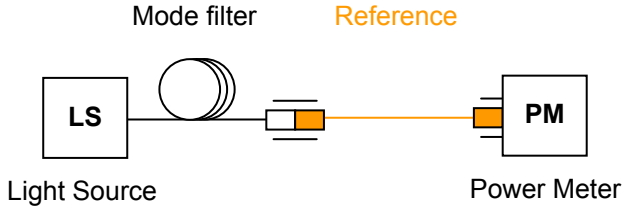
The insertion loss is generally referred to the loss of an optical connection between two mated connectors. The attenuation of the optical fibre itself, considered as length attenuation in dB/km, is negligible if considering patch cords with a length of 2-3 m.
A single mode fibre has a length attenuation of ca. 0.35 dB/km at 1310 nm and ca. 0.20 dB/km at 1550 nm, a graded index multi mode fibre has a length attenuation of ca. 3 dB/km at 850 nm and ca. 0.7 dB/km at 1300 nm.

3.1 Measurement method B

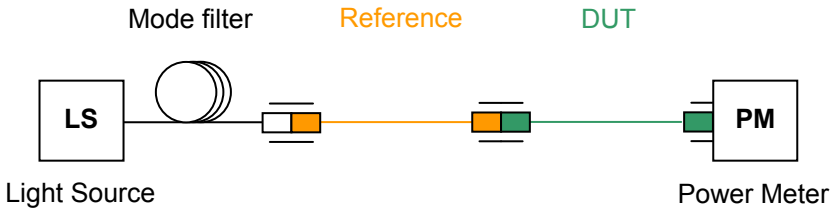
According to the standard IEC 61300-3-4 several measurement methods are available. For passive optical components terminated with connectors method B or C are applied.
Measurement method B consists in the measurement of the insertion loss of the optical component mated to a reference connector. The measurement is performed in two steps, the first step consists in the measurement of the reference power level P_{ref} at the reference output, the second step consists in the measurement of the power level with the mated DUT. The measurement setups are schematically represented below.

3.1.1 Measurement setup

a) Reference measurement (P_{ref})



b) DUT measurement (P_{meas})

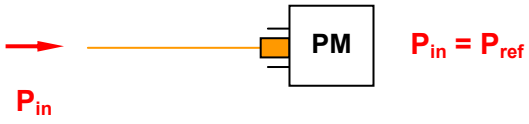


3.1.2 Measurement result

Performing insertion loss measurements with measurement method B following remarks have to be considered.

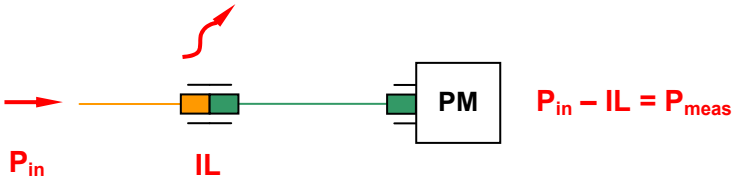
a) Reference measurement (P_{ref})

The measurement of the reference power level P_{ref} in dBm is performed using a reference connector, as represented in the following schema:



b) DUT measurement (P_{meas})

The measurement of the power level with the mated DUT against the reference connector P_{meas} in dBm is performed as represented in the following schema:



Where the difference between the reference power level P_{ref} and the power level with the mated DUT P_{meas} is:

$$IL = P_{ref} - P_{meas} \quad [dB] \qquad (4)$$

A correct insertion loss measurement according to method B needs same measurement conditions at the entrance of the Power Meter, and precisely same connector standard in order to avoid additional uncertainties due to different tolerances of the connector body or different ferrule diameter, same end face material and same end face angle in order to avoid different reflective phenomena.

3.1.3 Applications

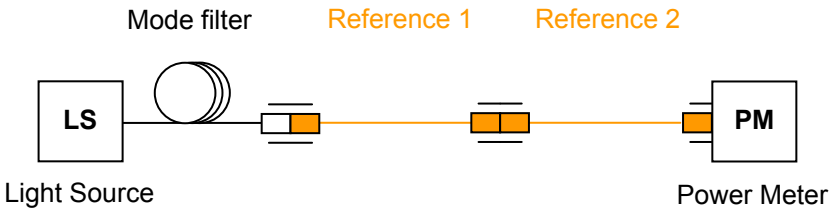
Measurement method B is generally used to measure the insertion loss of a pigtail, of a single connection and of a patch cord attenuator.

3.2 Measurement method C

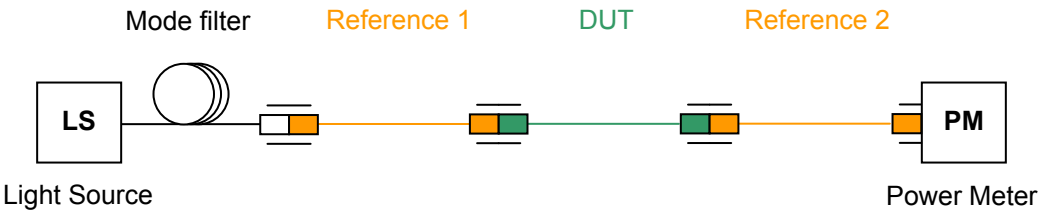
According to the standard IEC 61300-3-4 measurement method C consists in the measurement of the insertion loss of the optical component mated between reference connectors. The measurement is performed in two steps, the first step consists in the measurement of the reference power level P_{ref} of the reference connection, the second step consists in the measurement of the power level with the mated DUT between the two reference connections. The measurement setups are schematically represented below.

3.2.1 Measurement setup

a) Reference measurement (P_{ref})



b) DUT measurement (P_{meas})

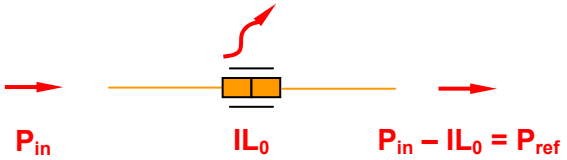


3.2.2 Measurement result

Performing insertion loss measurements with measurement method C following remarks have to be considered.

a) Reference measurement (P_{ref})

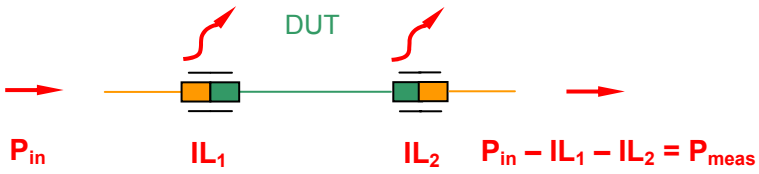
The measurement of the reference power level P_{ref} in dBm is performed using a reference connection with a given insertion loss IL_0, as represented in the following schema:



The measured reference power level P_{ref} is given by subtracting the insertion loss of the reference connection IL_0 from the input power level P_{in}.

b) DUT measurement (P_{meas})

The measurement of the power level with the mated DUT between the two reference connections P_{meas} in dBm is performed using the reference connection with the given insertion loss IL_0, as represented in the following schema:



Where the difference between the reference power level P_{ref} and the power level with the mated DUT P_{meas} is:

$$IL = P_{ref} - P_{meas} \quad [dB] \tag{5}$$

With the substitution of the measured values the resulting insertion loss is:

$$IL = (P_{in} - IL_0) - (P_{in} - IL_1 - IL_2) = IL_1 + IL_2 - IL_0 \quad [dB] \tag{6}$$

According to the result the insertion loss of a DUT measured with method C is given by the insertion loss IL_1 of the first connection with the reference connector of Reference 1, the insertion loss IL_2 of the second connection with the reference connector of Reference 2 and the insertion loss IL_0 of the reference connection.
If the insertion loss IL_0 of the reference connection is not previously measured with method B, the insertion loss IL of a DUT with method C will contain the unknown value IL_0. Furthermore, the single insertion loss values IL_1 respectively IL_2 of both connections with the reference connectors are not further distinguishable.

3.2.3 Applications

Measurement method C is generally used to measure the insertion loss of a patch cord, of a patch cord attenuator or a passive component such as an in-line attenuator or a coupler.