OPTICAL FREE-SPACE COMMUNICATION LINK (OFSCL)

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OUTLINE

- ✓OFSCL definition and main features
- ✓OFSCL models: stationary
  statistical
- ✓Long-term experiments
- ✓Conclusion

Optical free-space communication link (OFSCL) is a link that uses the narrow optical beam for the communication connection. OFSCL is an alternative to the fiber link.

The main advantages of the OFSCL:

- the high bit rates,
- no need to ask the telecommunication office ...,
- no need to lay optical fiber.

The disadvantages of the OFSCL:

- optical beam needs direct line of sight
- the quality of communication can depend on some weather or other conditions.

OFSCLs **are transparent for these protocols**:

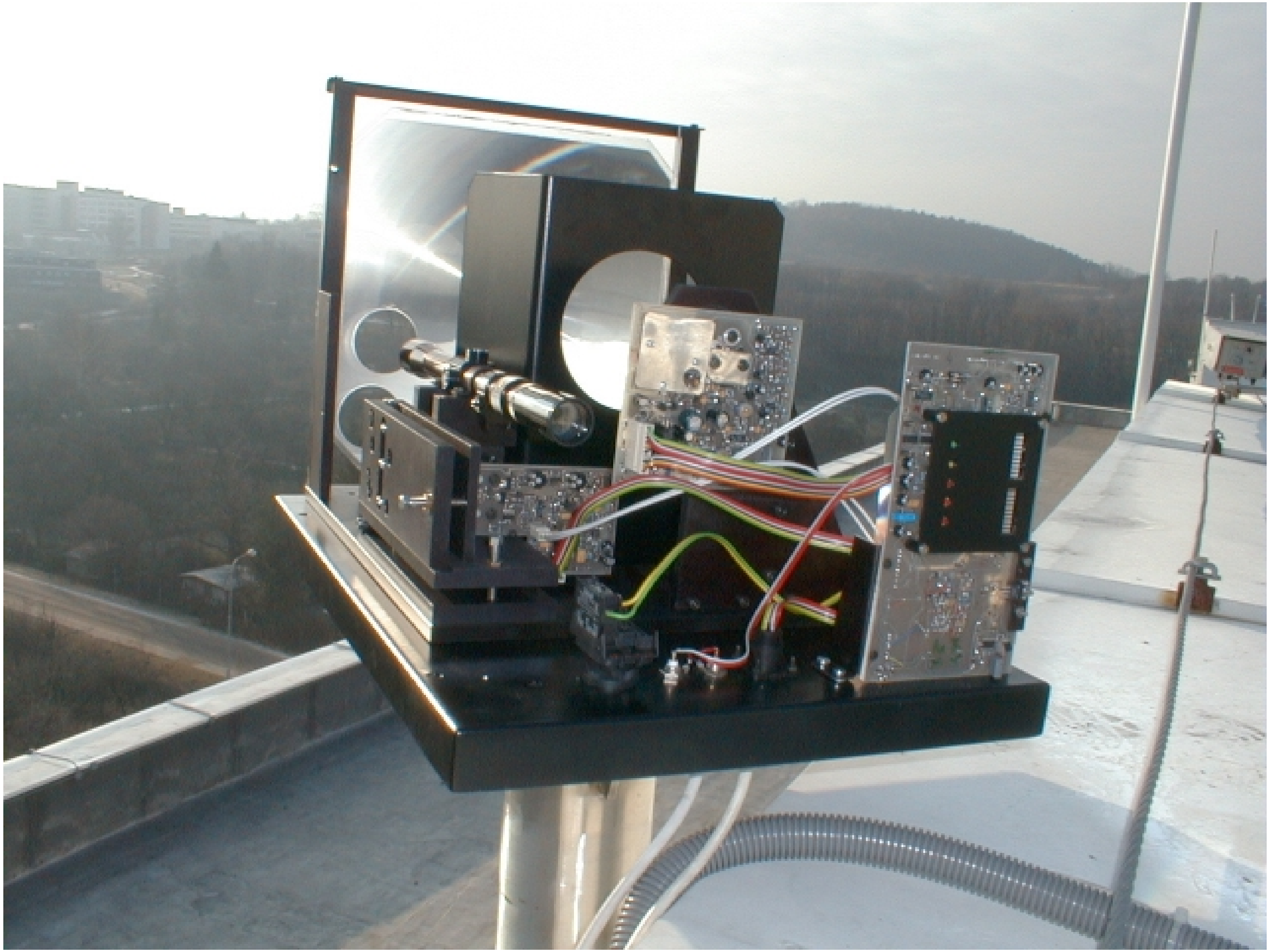
Ethernet, Token Ring, FDDI-II, ATM/SDH, etc. The corresponding transmission rates are 10 Mbit/s, 16 Mbit/s, 100 Mbit/s, 155 Mbit/s, 622 Mbit/s and 2.5 Gbit/s. Depending on the type, *OFSL* ranges are 300 m, 500 m and 1500 m (up to 8000 m are possible).

OFSCLs **are produced by several companies**:

Canon, Sony, Nakayo (Japan), ATS (Canada), AirOptics (USA), CBL, GoC, Optel (Germany), Crown Tech (Hungary), ITC (Russia), Lucent Technologies & Bell Laboratories, etc.

OFSCLs **were also developed in the Czech Republic** by the Department of Radioelectronics, Brno University of Technology, in the cooperation with ATMOCOM LTD. in Brno.

Radius	2000 m
Transmission type	Full duplex with digital modulation BER < 10^{-9}
Transmitter	Laser diode
Laser features	Wave length: 830 nm Average power: 15 mW Laser of IIIb class
Beam parameters	Type of beam: elliptic Beam diameter on the output lens: 19 mm Divergence: 2,5 mrad
Receiver parameters	Diameter of lens: 260 mm Photodiode: PIN Visual angle: 2 mrad
Interface	Optotransceiver: multimode or single-mode Connector: ST Wave length: 1300 nm (or 850 nm)
Signaling on the head	Switch-on the head and laser, levels of received signals on the local and distant heads, presence of entering and transmitted data.
Operating temperature	from -20°C to +45°C
Size (one head)	(height $\times$ width $\times$ length): 400 $\times$ 400 $\times$ 700 (in mm)
Weight (one head)	7,0 kg
Cover	IP65

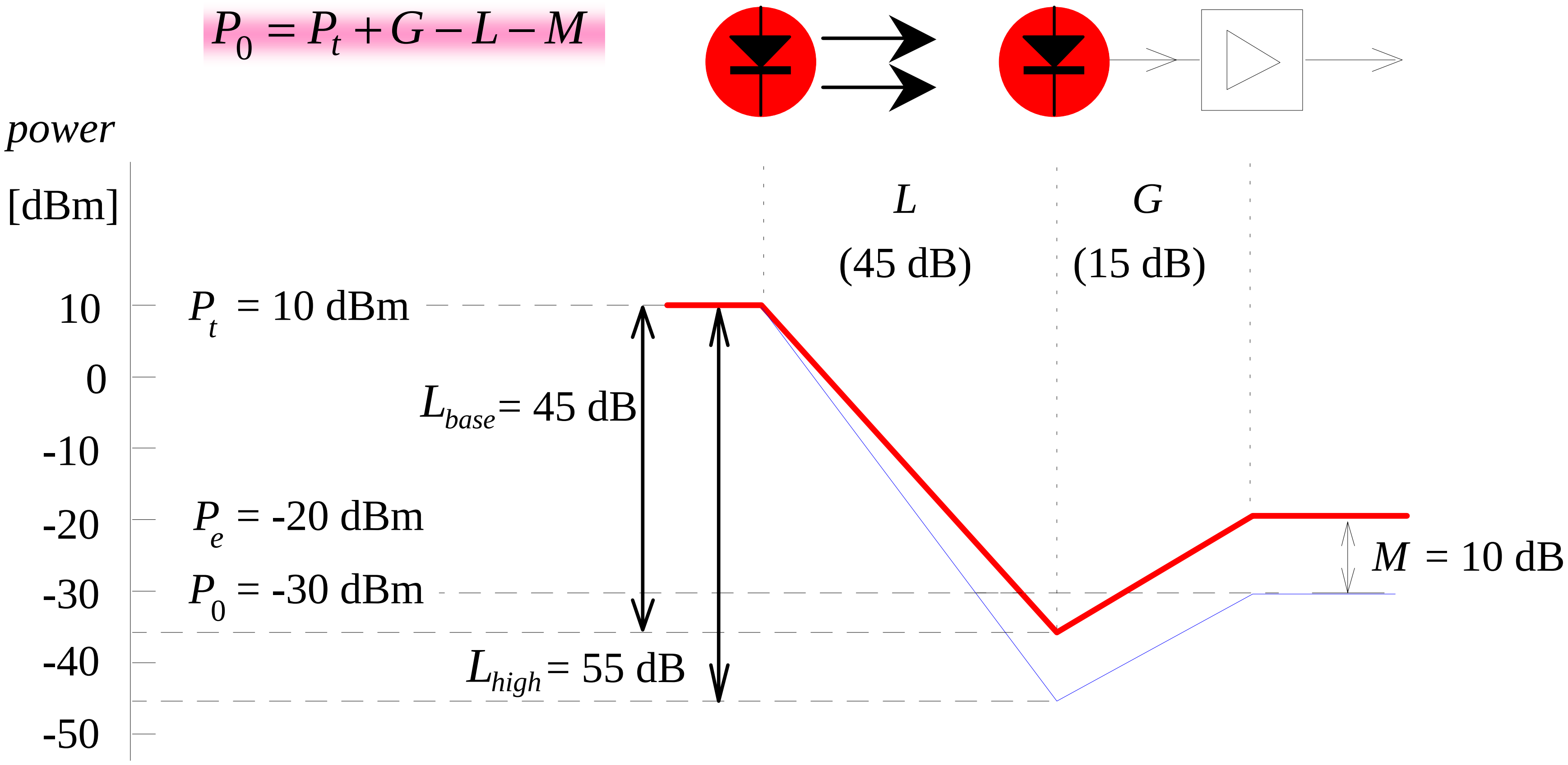


Stationary model of the OFSCL

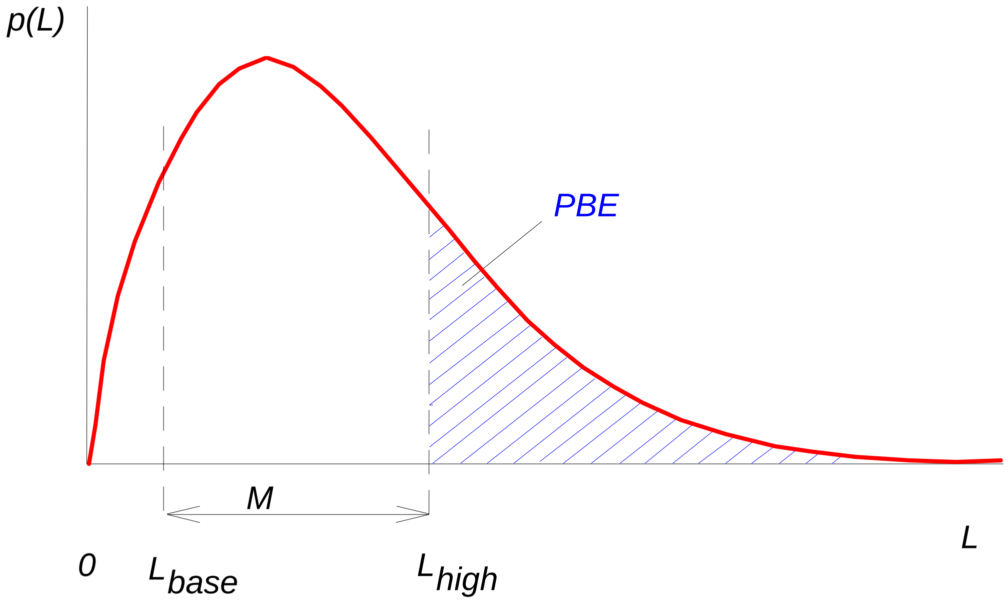
The power balance (average values in dB):

receiver sensitivity (P_0) equals the mean transmitted power (P_t) + all gains (G), minus all average losses (L) and minus link and system margin (M)

$$P_0 = P_t + G - L - M$$



Statistical Model of the Link



$$PBE = \int_{L_{base}+M}^{\infty} p(L)dL$$

It may happen that random losses in the atmospheric channel will exceed the value of link margin *M* at given time intervals and the received power will be below the receiver sensitivity. These intervals will result in the probability of burst error *PBE*.

$$L = \sum_i L_i \quad [dB]$$

is the sum of random independent losses,

$$p(L) = \left(\prod_i *\right) p_i(L_i)$$

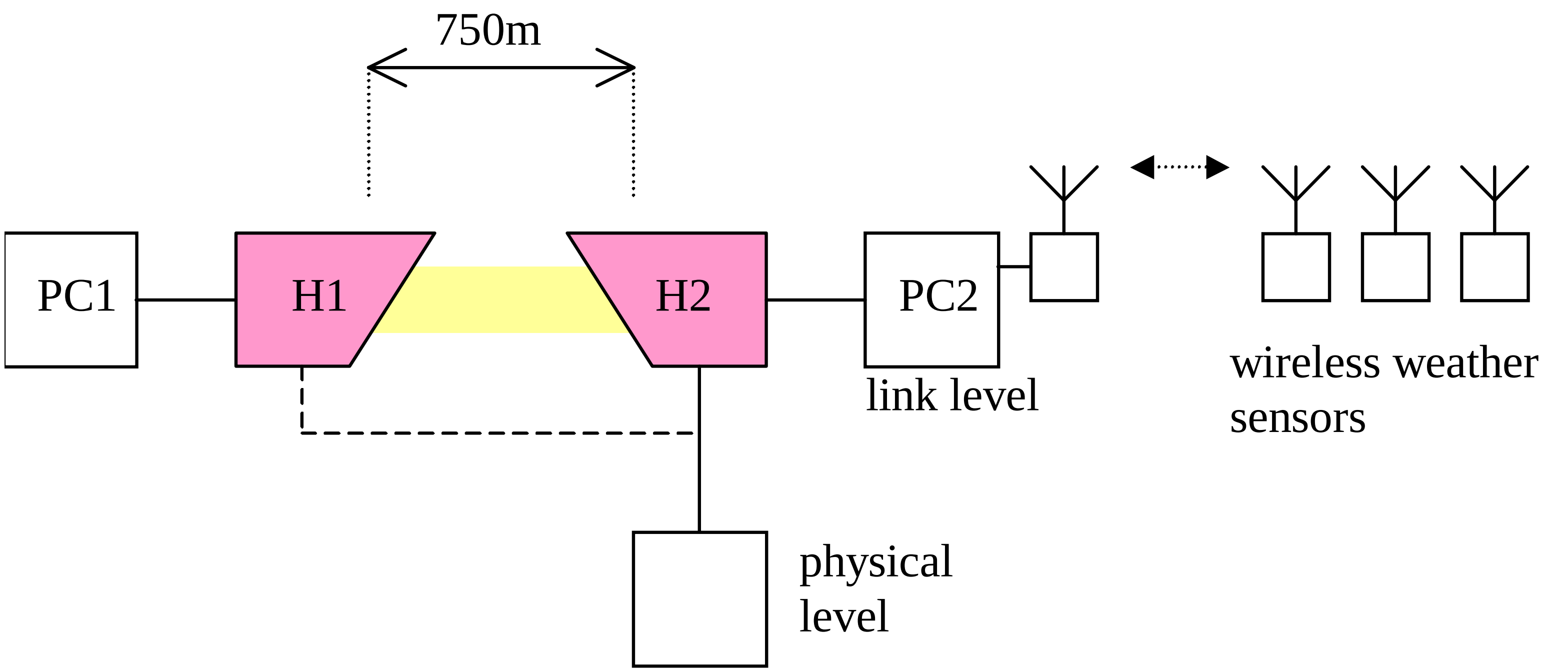
$\left(\prod_i *\right)$ denotes the consecutive convolution of the probability density functions p_i of random losses L_i.

These losses are mainly due to

- the beam wander,
- the angle-of-arrival fluctuations and
- the power scintillation.

Testing OFSCL

- to study the influence of atmospheric phenomena upon the OFSCL



Full duplex digital OFSCL whose heads are connected to the ATM/SDH metropolitan academic computer network (155 Mbit/s). Bit error maximum under good weather conditions, residual bit error, maximum atmospheric attenuation (without signal interruption) and the probability of link interruption due to atmospheric effects are tested.

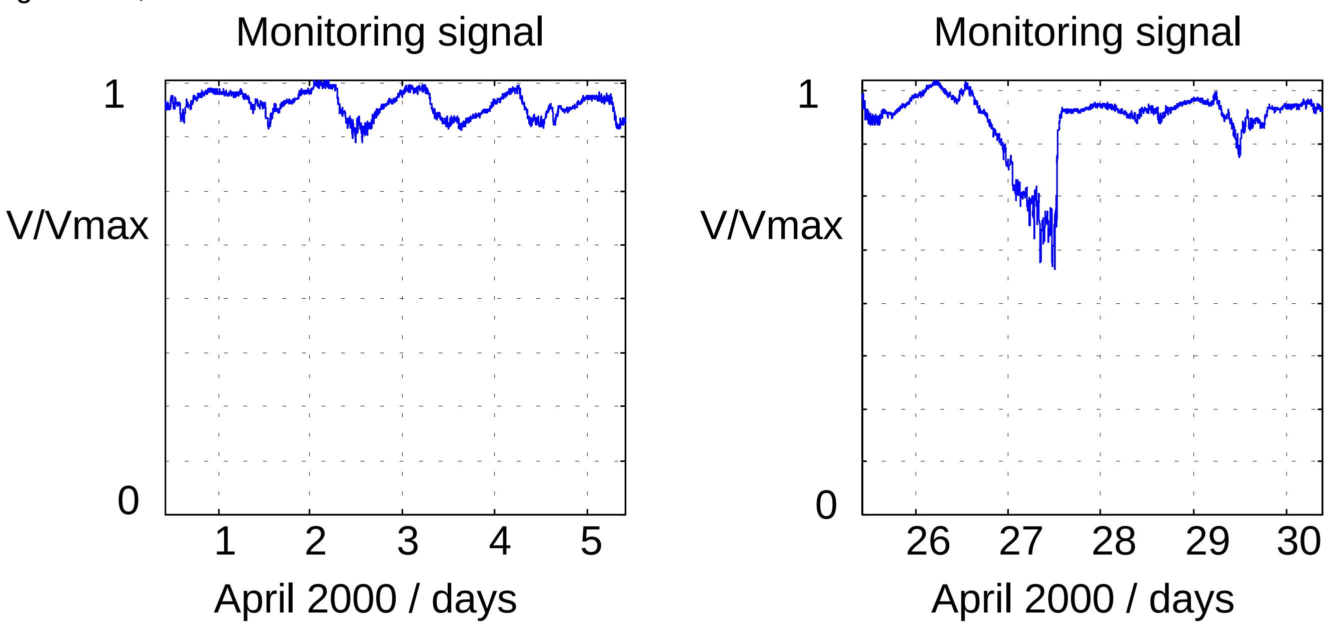
The distance between heads of the link is 750 m. The level of the internal receiver noise corresponds with a relative monitoring signal quantity of 20 mV. The maximum value is 400 mV, which corresponds to good weather conditions.

The build-up area is below the optical beam. It is a source of disturbances, especially in the form of thermal radiation and some other operations that produce typical aerosols into the atmosphere.

Continuous measurement of:

bit error of the link in both directions, level of the received signal in both heads, illumination of the heads by the Sun, and the basic parameters of the atmosphere inclusive of wind velocity and rain intensity.

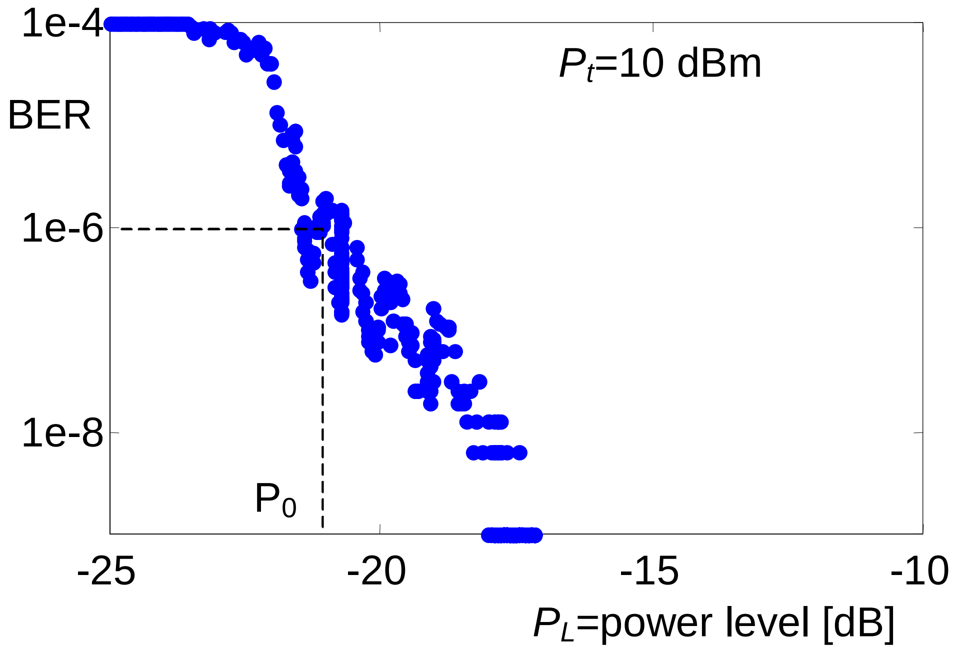
Long-term observations (even a couple of years) of the link parameters and weather conditions and perform computer processing of the recorded results.

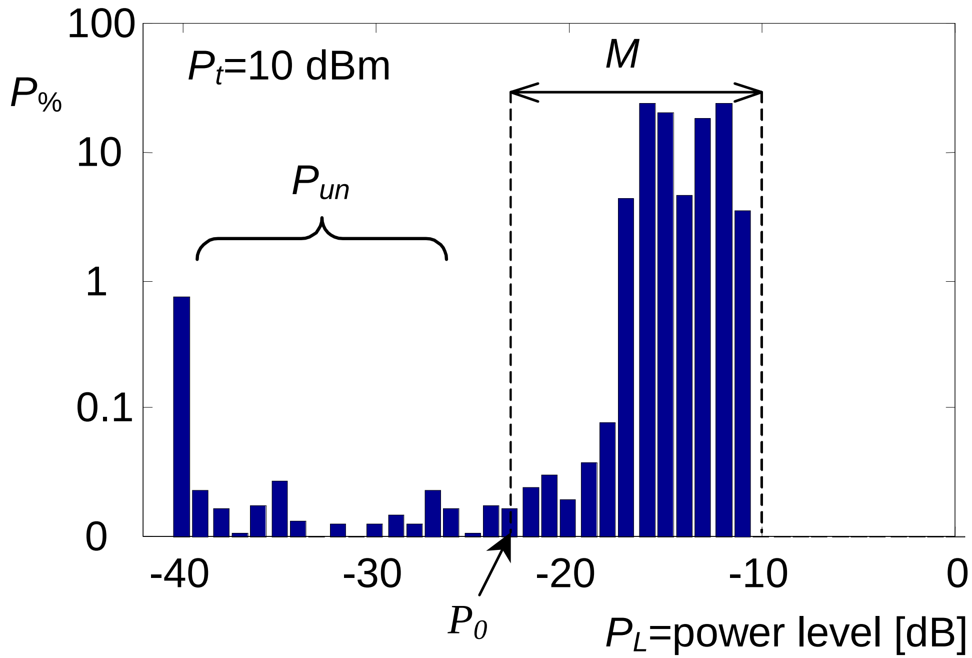


a) *console twisting due to heating*

b) *effect of rain*

All **recorded signals** are analyzed and evaluated by the Matlab and the results are applied to determine the link margin. The testing OFSCL will allow us to determine the percentage of the time for which the OFSCL is available.

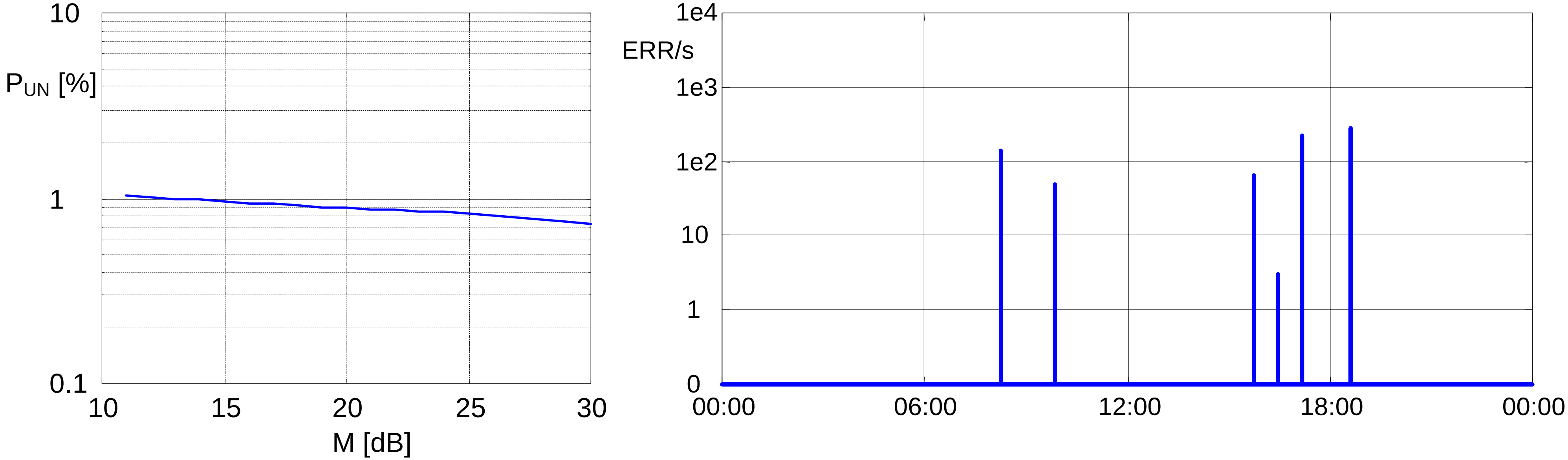




Probability of the situation when the link is unavailable:

$$P_{UN} = \int_{-\infty}^{P_0} P_\% dP_L$$

The test link is set so that M = 11dB and P_{UN} = 1%. The maximum value of M is constrained by dynamic range of the receiver.



Significant decreasing of P_{UN} is expensive, because it requires increasing M of tens of dB.

Even during a good weather the link exhibits some background BER. Detailed measurements and analysis revealed that this is due to drops in received power for tens of milliseconds caused by birds, insect and bigger objects flying through the beam near the transmitter.

Conclusion

A sufficient power reserve, wide dynamic range and a special adaptability of the system guarantee a good quality of the system, even in bad weather conditions.

OFSCLs were installed in several locations (universities, hospitals, observatory, etc.). An OFSCL connecting two hospitals is shown in Figure.