NETWORK COMMUNICATION BY OPTICAL DIRECTIONAL LINK

Otakar WILFERT, Viera BIOLKOVÁ
Department of Radioelectronics
Technical University of Brno
Purkyňova 118, 612 00 Brno
Czech Republic

Abstract

In this article, infrared point-to-point technologies (optical directional links) are discussed which are designed for digital transmissions. Optical directional links (ODLs) are transparent for the SDH/ATM, FDDI-II, Ethernet, and Token Ring protocols. Depending on the type, ODL ranges are 300 m, 500 m, 1000 m and 2000 m. Steady and statistical models of ODL are presented as well as the measuring ODL arrangement and the graphs concerning the fluctuations of the received signal.

Keywords
fiberless optical communication, data transmission, optical directional links, atmospheric optical links

1. Introduction

Economic problems of network installations gave rise to growing interest in wireless network technologies. Wireless network technologies can be divided into: radio frequency, microwave, infrared diffuse, and infrared point-to-point technologies [1].

In the following, only infrared point-to-point technologies (optical directional links) are discussed which are designed for full duplex digital transmissions and work with a narrow beam in open space. Optical directional links (ODLs) have certain advantages over radio directional links, such as high directivity of the beam (elimination of the information dissipation in undesirable direction), high bit-rate (unattainable with radio or microwave wireless links), absence of legislative inconveniences (no licensing), smaller antenna size, lower weight and lower power.

A negative feature of ODL is the dependence of link quality on the weather. It was therefore suitable to focus research activity on the study of received signal fluctuations.

2. Network Communication by ODL

The basic arrangement of the ODL included in the computer network is shown in Fig. 1. The information is transmitted between two personal computers (PC), in which the network cards provide the interfaces. The heads (H_1, H_2) of the ODL are connected with the optotransceivers by optical fibres. The optical signal (as a full duplex) is carried between both heads through the atmospheric transmission medium.

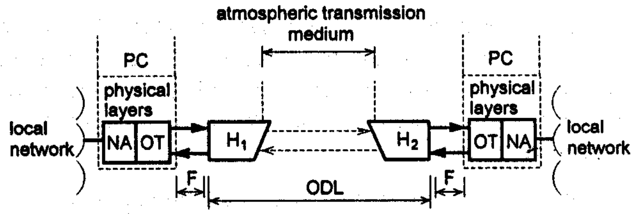

Fig.1 The basic network communication model with ODL (NA - network adapter; OT - optotransceiver; F - fibre; H_1, H_2 - ODL heads; PC - personal computer)

The ODLs were installed in several locations (universities, hospitals, observatory, etc.) in Brno [2]. An ODL connecting two hospitals is shown in Fig. 2. The significance of this ODL for the staff of the hospitals consists in the possibility of taking advantage of their own as well as international toxicological and pharmaceutical databases. A head of the ODL connecting two faculties is shown in Fig. 3.

The ODLs were designed at the Department of Radioelectronics of FEECS of TU Brno within the following research projects supported by the Ministry of Education:

- The Connection of Selected Dislocated Parts of Universities in Brno to the Metropolitan Academic Computer Network by Atmospheric Optical Links. (No. 0726/1996)
- Two High-Speed Connections by Laser Directional Links for the Metropolitan Academic Computer Network in Brno. (No. 0244/1998)

3. Steady and Statistical Model of the ODL

ODL is a link that uses an optical carrier wave in the atmospheric transmission medium (referred to as atmospheric random channel). The steady power values (average values) are calculated by the steady model of ODL. The atmospheric random channel causes that the power received oscillates around its average value. The probability distribution of received power is calculated by the statistical model of ODL. [1]

Fig. 2. Digital atmospheric optical link (ODL) between two hospitals

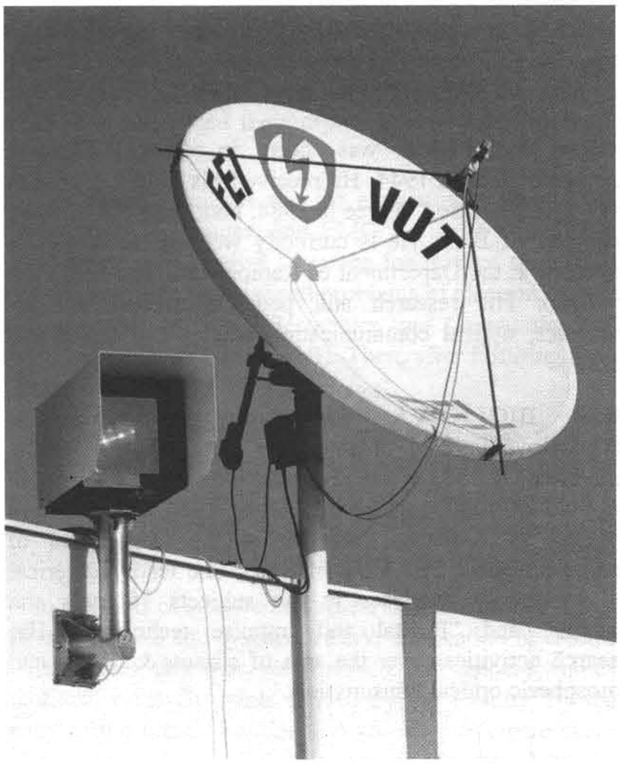

Fig. 3. A head of the ODL connecting two faculties

3.1 Steady Model of the ODL

The power balance according to the steady model of ODL can be expressed by the equation (average values in dB): the receiver sensitivity (P_0) equals the mean transmitted power (P_t) plus all gains (G), minus all average losses (L) and minus link and system margins (M)

$$P_0 = P_t + G - L - M\,. \tag{1}$$

Margins M is the difference between the expected (admissible) value of received power P_e and the receiver sensitivity P_0

$$M = P_e - P_0\,. \tag{2}$$

The noise level in the receiver and the desired bit-errorrate (BER) are respected when specifying the value of receiver sensitivity P_0.

A correct value of link margin (LM) will allow us to ensure a high-quality link transfer within the systems dynamic range, both in relatively good and in deteriorated weather conditions. The system margin (SM) must account for all of possible degradation of the system during its lifetime, as indicated in the CCITT recommendation for line systems. The power diagram of a typical ODL is given in Fig. 4. (It holds: $M = LM + SM$.)

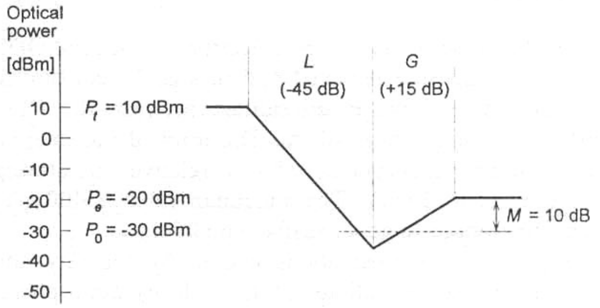

Fig.4 The power diagram of a typical ODL

3.2 Statistical Model of the ODL

It may happen that random losses in the atmospheric channel will exceed the value of 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

$$PBE = \int_M^{\infty} f(l)\,dl\,, \tag{3}$$

where $l = \sum_i l_i$ is the sum of random losses and $f(l)$ is the probability density function of all random losses

$$f(l) = \left(\prod_i * \right) f_i(l_i). \tag{4}$$

$\left(\prod_i * \right)$ denotes the consecutive convolution of the probability density functions f_i of random losses l_i. These losses are due to the beam wander, the angle-of-arrival fluctuations and the power scintillation. An illustration of the *PBE* calculation is presented in Fig. 5.

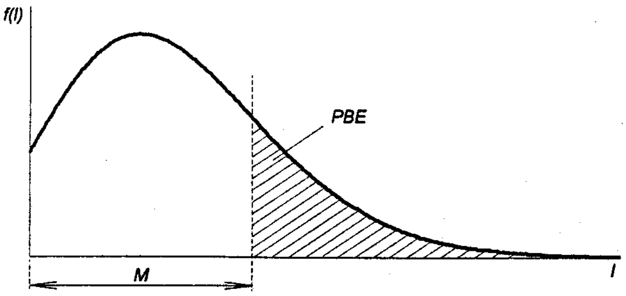

Fig.5 Illustration of the *PBE* calculation

4. ODL for measuring received signal fluctuation

At the Department of Radioelectronics a special ODL was built to measure received optical signal fluctuations. The monitoring signal is transmitted between the ODL heads over a distance of 700 m. The level of the internal receiver noise corresponds with a relative monitoring signal quanity of 20 mV. The maximum value is 400 mV, which corresponds to good weather conditions.

Fig. 6a shows fluctuations caused by the day and night temperature variations of the (clean) atmosphere. Fig. 6b shows the influence of heavy rain.

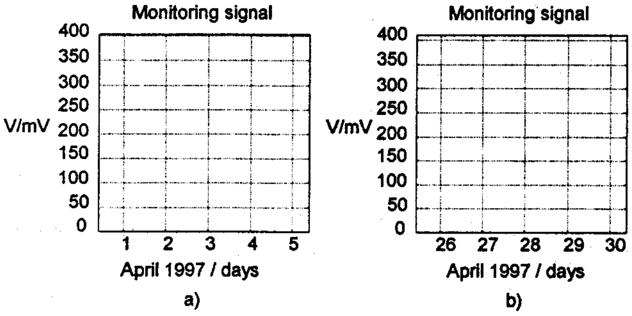

Fig.6 Monitoring signals received over different weather conditions (a – influence of the atmosphere temperature variations, b – influence of the rain)

The measuring chain is able to measure the temperature around the ODL head as well as the wind velocity, atmospheric pressure, humidity, and precipitation.

All signals are analysed and evaluated by the Matlab program. The results are applied to determine the link margin (*LM*).

The measuring ODL will allow us to determine the percentage of the time for which the ODL is available. A good-quality ODL should operate for at least 98% of the time in a month, demonstrating a high-degree of availability ($BER = 10^{-6}$).

5. Conclusion

The ODL was designed with good computer network applications. The ODL is designed for optical connection where fiber is impossible to use because of the legislative inconveniences or some technical problems. The ODL can be regarded as network technology devices and can be used as a complementary, reverse, or route link with the possibility of changing (optimize) the network topology.

An ODL was set up to measure received optical signal fluctuations. The characteristics of the signal are processed by the Matlab program. The results of long-term measurements are applied to the determination of link margin, which is the basic and key concept in ODL engineering.

References

[1] SANTAMARIA,A. - LOPEZ-HERNANDEZ,F.J.: Wireless LAN Systems. Artech House, London 1994.

[2] WILFERT,O.-KOLOUCH,J.: Adaptive Digital Atmospheric Optical Link. In: *Proceedings of the 40th International Scientific Colloquium*, Part 1, Ilmenau, 1995, pp. 262-267.

About the authors...

Otakar WILFERT was born in Česká Třebová, Czechoslovakia in 1944. He received his „Ing." degree in 1971 and the „CSc." degree in 1984, both from the Military Academy of Brno. He is currently working as Associate Professor at the Department of Radioelectronics, FEI VUT of Brno. His research and pedagogical interests are photonics, optical communication and optical directional links.

Viera BIOLKOVÁ was born in Partizánske, Czechoslovakia. She obtained her „Ing." degree (MSc. equivalent) in 1983 at the Technical University of Brno, in the field of Radioengineering. Since 1986 she has been working as Assistant Professor at the Department of Radioelectronics, FEI VUT of Brno. She leads numerical and laboratory exercises in the subjects "Signals and systems" and "Digital and impulse technique". Her research activities cover the area of circuits & signals and atmospheric optical transmission.