Atmospheric Laser Comm. Links Appear Feasible in Saudi Arabia

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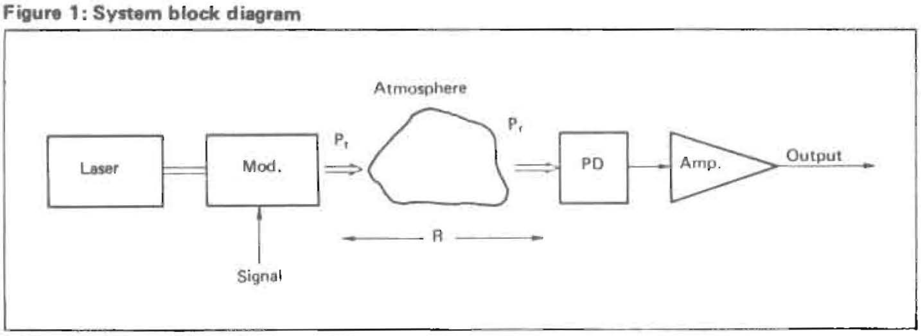
The reliability of an atmospheric optical communications link in Riyad has been predicted based on the pertinent weather data. The dependence of the reception quality on the communication range and the atmospheric propagation conditions has been estimated. Based on these results, it appears that short-range atmospheric laser communications links would be very satisfactory in Saudi Arabia.

A short-range laser communications link through the atmosphere might be a promising competitor to conventional high-capacity communications links in Saudi Arabia. An He-Ne laser link utilizing intensity modulation and a direct-detection receiver, as shown in Fig. 1, provides an attractive wide-bandwidth system (1, 2). Such a system might be preferred when simplicity and easier alignment are desired (3). The reliability of an atmospheric optical communication link in Riyad, discussed below, was predicted based on the pertinent weather data. The dependence of the reception quality on the communications range was estimated for a probability of link failure of less than 1% throughout a year.

Figure 1: System block diagram



System design considerations

Two basic effects of atmospheric turbulence should be taken into consideration in the design of a direct-detection atmospheric optical communication link (4, 5).

First, scintillation must be minimized by using a receiving-aperture with a diameter (d_r) much larger than the log amplitude correlation length:

$$d_r \geq 2\sqrt{\lambda R}$$

where λ is the wavelength, and R is the communications range.

Second, beam steering should be compensated either by using a tracking system (6), or by proper choice of the laser beam size to limit the variation in the received intensity level (7).

Repeater spacing should be selected to achieve the desired signal-to-noise ratio (SNR) corresponding to the allowable bit error rate.

When a silicon avalanche photodiode, of low dark-current, is used with an optimum avalanche current gain (G), the SNR may be related to other system parameters by (8):

$$\mathrm{SNR} = \frac{n\, t\, Pt\, f\, d^2 t\, d^2 t \exp(-\alpha R)}{8hC\,\lambda\, G^{1/2}\, BR^2}$$

where n is the quantum efficiency, t is the product of the transmitter and receiver transmissivities, Pt is the transmitter power, f is the reduction penalty due to beam steering, dt is the transmitter beam diameter, α is the atmospheric attenuation coefficient, h is Planck's constant, C is the velocity of light, and B is the amplifier bandwidth.

When the SNR decreases below the design value, the reception quality is degraded, and the communications system is considered to be interrupted.

System reliability

The pertinent weather data (average numbers of days per month of different visibilities) for Riyad are presented in Table I.

Table I shows that there may be 10 days of poor visibility (less than 1 km) per year.

The atmospheric attenuation (dB/km) for an He-Ne laser link ($\lambda = 0.63\mu m$) and a CO_2 laser link ($\lambda = 10.6\mu m$) can be calculated for different weather conditions, assuming that the predominant attenuation is due to Mie scattering using the empirical relation (8):

$$\alpha = \frac{3.91}{v}\left(\frac{\lambda}{0.55}\right)^{-0.58v^{1/3}}$$

where v is the visual range in km.

The cumulative probability distribution of attenuation of light in Riyad is shown in Fig. 2. It can be a useful guide for estimating the mean time for atmospheric propagation loss. Figure 2 shows that the probability of link interruption in Riyad due to weather conditions

Table 1

Meteorological observations for the number of days of different visibilities in Riyad.

Month	less than 1 km	1–3 km	3–5 km
January	2	7	14
February	–	2	7
March	3	2	8
April	1	6	7
May	1	8	10
June	1	5	10
July	2	7	15
August	–	2	8
September	–	3	6
October	–	5	11
November	–	–	4
December	–	4	6
Total %	2.7	14	29

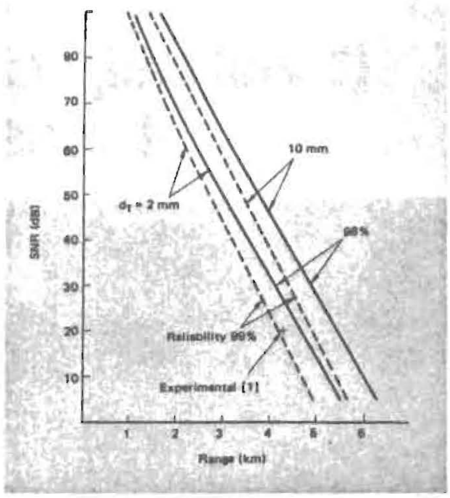


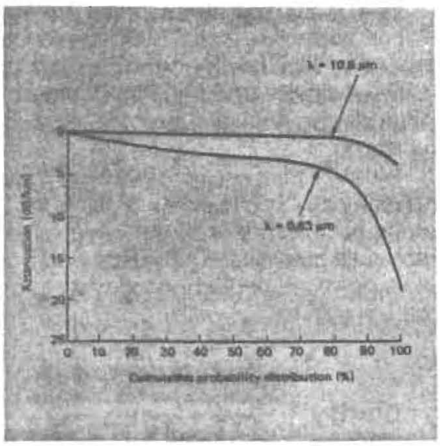
Figure 3: Dependence of reception quality on communications range (P_t = 100mW, λ = 0.63μm, d_r = 15cm and B = 100Mb/s).

can be kept to less than 2% throughout a year, if a propagation loss of 16 dB/km is allocated for the He-Ne laser link and a loss of 3 dB/km, for a CO_2 laser link. These values compare favorably with the allowable loss in atmospheric communications links in Japan (1).

Numerical results

An atmospheric link for digital transmission at a communication rate of 100 Mb/s was considered. An He-Ne laser ($\lambda = 0.63\mu m$) with output power of 10mw and a silicon APD receiver of n = 0.7 and G = 100 were considered, as discussed next.

Figure 2: Cumulative probability distribution of attenuation of light (in Riyad).



A receiving antenna diameter of 15 cm was chosen to provide adequate aperture averaging of scintillation for a short-range link. A 6-dB loss in the transmitting and receiving optical systems was assumed, so t = 0.25. No beam tracking was used, and a reduction penalty of 4.3 dB was considered to account for beam steering (7).

Two values of the transmitter beam diameter of 2 mm and 1 cm appear to be more appropriate when there are random beam deviations of ±50 cm and ±10 cm respectively in a propagation length of 4 km.

Atmospheric attenuations of 16 dB/km and 18 dB/km are considered to correspond to a probability of link interruption, due to weather conditions in Riyad, of 2% and 1% throughout the year respectively.

Figure 3 shows the dependence of the reception quality on the communication range and the atmospheric propagation conditions.

A minimum allowable SNR of 20dB, corresponding to a maximum allowable bit error rate of 10^{-6}, may be considered to be the limit of the service.

Figure 3 shows that the reliability of this system would reach about 99% in a year for a communications range less than 4 km.

Thus atmospheric laser communications links would be very satisfactory for short-range applications in Saudi Arabia.

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