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DIVERGENCE OF TRANSMITTED LASER BEAM IN RADAR OPERATION

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INTRODUCTIONS

In bad weather conditions, the RVR (Runway Visual Range) measured at ground level does not correspond to the slant visual range viewed from a cockpit of an airplane on the glide path. It is because the weather conditions of near ground and those of above sky are different especially at serious weather conditions. Therefore the slant visual range should be measured directly along the glide path for safe landing of airplanes.

In this study, a measurement system of the slant visual range has been developed for test purpose. As a result of measurements under various weather conditions, the measured data in bad weather conditions were found to not correspond to the general formula of the current laser radar equation (1),

$$Pr = C\,exp(-2\sigma R)\,/R^2 \quad \text{----------(1)}$$

where Pr is a received signal power, C is a constant determined by transmitted power, σ is the atmospheric extinction coefficient and R is the distance from the system to the target. The reason is that the transmitted beam diverges gradually as it propagates through the atmosphere of low visibility due to light scattering by haze, fog, rain, snow or other aerosol in the air to the extent over the receiving area of the receiving telescope as shown in Fig. 1.

The current laser radar equation, however, has been constructed under the assumption that the transmitted light would propagate as parallel beam and the scattered light should come back according to inverse square law.

Then considering the beam spread of the transmitted beam, a new laser radar equation should be expressed as follows,

$$Pr = C\,exp(-2\sigma R)\,/R^n \qquad n = 2+\alpha;\ \ 0 \le \alpha \le 2 \quad \text{----------(2)}$$

where α is an index expressing the divergence of the transmitted beam. This index equals to zero under clear weather condition, and gradually approaches two as visibility becomes lower.

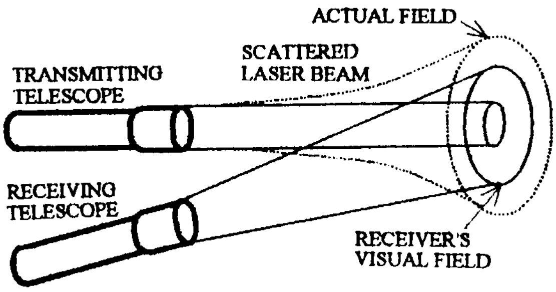

Fig. 1. Divergence of the transmitted beam

EXAMPLE OF OBSERVED DATA BY LASER RADAR

An example of measured data is shown in Fig. 2. This is the case of foggy condition. The power n and the extinction coefficient σ are chosen so as to minimize the mean error by least square method.

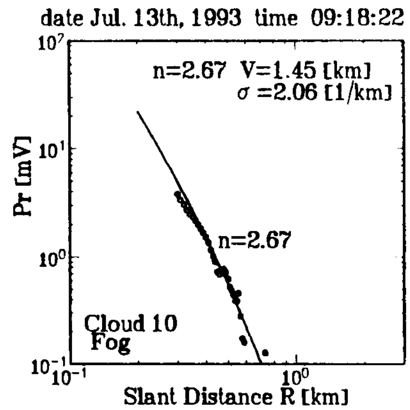

Fig. 2. An example of the observed data by laser radar

The slant visual range estimated under $n \neq 2$ corresponds well to the result estimated by slant transmittance. the slant visual ranges estimated under n =2 are lower than the actual ones. The reason is that the regression line is drawn by σ only, and the σ is higher than the real σ.

EXPERIMENT IN THE FOG ROOM

To confirm the properness of the new laser radar equation, the divergence of the transmitted beam is examined in the room filled with fog. Experimental system is shown in Fig. 3. The collimated He-Ne laser beam is swigged down, and the beam patterns are detected by a photomultiplier, which can move back and forth through fog's strata. Fog is generated by heating the water in the buckets. In practice, it is possible to lower the transmittance to the extent below 5% of the output beam at the last position of the photomultiplier. And the difference of the fog density in the whole room also lowers below 5%.

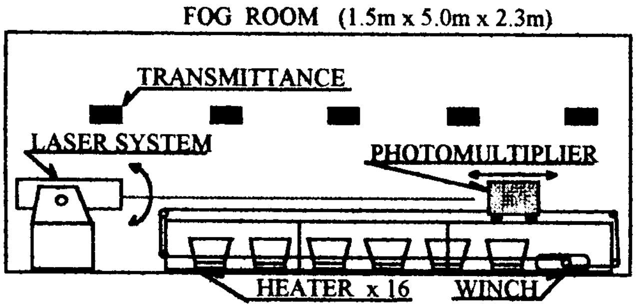

Fig. 3. Total set up of the fog room

EXAMPLES OF MEASURED DATA IN THE FOG ROOM

Examples of measured data are shown in Fig. 4 and Fig. 5. In this figure, the ordinate is a distance from the laser system to the detector, and the abscissa is a diameter of the integrated laser beam intensity. The calculated values show 50% of the integrated intensity of laser beam in Fig. 4, and 10% of that in Fig. 5. It is found that the hem of the beam pattern spreads more wide than the neck of that.

The current laser radar equation has been constructed under the assumption that the cross section of the transmitted beam is the section occupied by the half value of the power density, and that the multiple scattering of the transmitted beam has not been considered. The transmitted beam, however, spreads significantly. Because of spread of the transmitted beam, the measured intensities of backscattered light are lower than the predicted intensities of that. Therefore the current laser radar equation does not correspond to the measured data. In the practical measurement by using the laser radar system, the divergence of the transmitted beam is occurred in various weather conditions. In this study, it has been confirmed that the effect becomes large in the order of rain, fog, drizzle to snow.

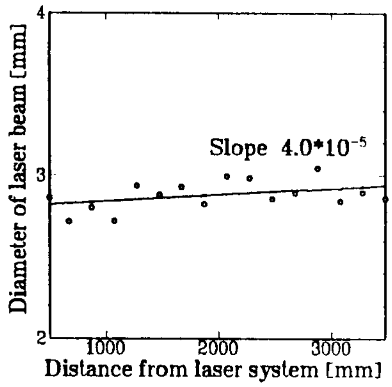

Fig. 4. 50% of the integrated intensity of laser beam

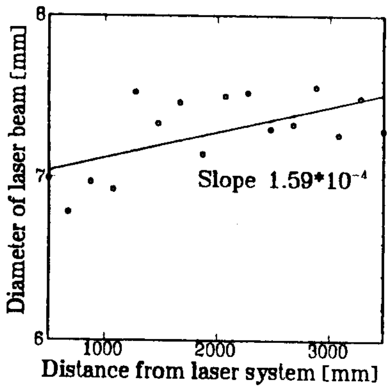

Fig. 5. 10% of the integrated intensity of laser beam

CONCLUSIONS

Proposed laser radar equation corresponds well to the measured data. And the properness of the proposed laser radar equation is confirmed by the fact that the transmitted beam spreads in foggy condition.

Now, the theoretical analysis of the relation between the scattering of the transmitted beam and the fog density is trying to be examined, and the computer simulation is under development.