Concept of wind lidar system with the adaptive parameter tuning for various atmospheric conditions

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INTRODUCTION

Conventional wind lidar systems have an issue in the instability of performance, since signal-to-noise ratio (SNR) depends on the atmospheric condition the atmospheric conditions such as the aerosol density, turbulence, and so forth. For example, it is known that the measurable range fluctuates distinctly even in an hour. To overcome this issue, we invented the concept of the wind lidar system with the adaptive parameter tuning for various atmospheric conditions, which automatically realize the best performance under the given atmospheric condition. We had completed to file the patents of this concept, of the key components, and of the software algorithms related to this concept. Here, we introduce the above mentioned concept and the advantageous effects.

SYSTEM CONFIGURATION

System configuration is shown in Fig. 1. The new components (gray squares) are added for realizing our concept to the general fiber-based CDL system[1]. The other conventional components are described as follows. Transmitted laser is modulated to be pulsed by the acousto-optic modulator (AOM), and is amplified by the fiber amplifier. The pulsed laser is transmitted to the target through the telescope and the scanner. The received light is converted to electric signal by the balanced receiver. The received signal is processed in the signal processor, where spectral analysis and accumulation are executed. Finally, the wind velocity and spectral width of each range are calculated using the accumulated spectrum. In the previous lidar system, the constant parameters, for example, (1) laser pulse width, (2) focal range, (3) beam diameter, (4) number of accumulation, and (5) scanning speed (or method), are used for each observation. On the other hand, in this new system, the system controller calculates the best parameters of (1)-(4) automatically using obtained range profile of SNR, line-of-sight wind velocity, spectral shape, and user's request. The dashed lines in Fig.1 indicate the signals to control the above parameters.

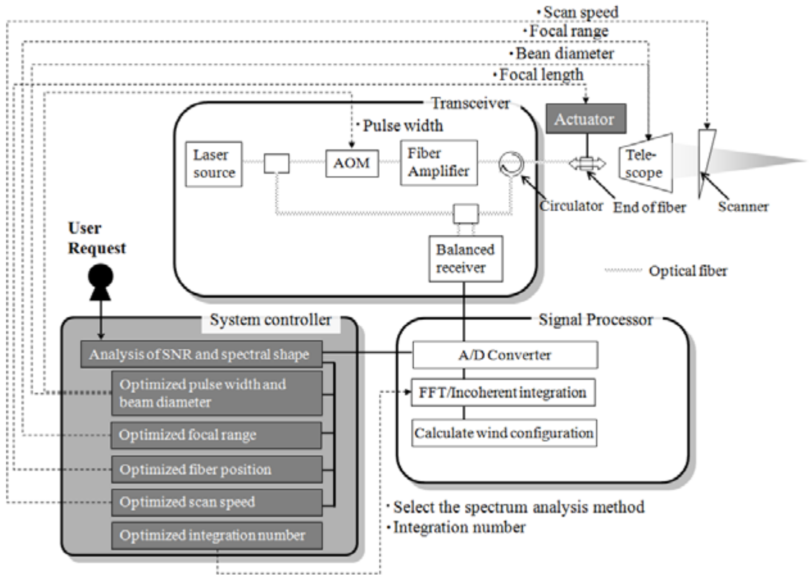

Fig. 1. System configuration.

ADVANTAGEOUS EFFECT OF ADAPTIVE PARAMETER TUNING

The “Analysis of SNR and spectral shape” in Fig.1 derives the best measurement parameters which fit best to the user’s needs depend on the atmospheric conditions. In this section, some examples of advantageous effects for parameter tuning are shown as follows.

Optimization of focal range

Figure 2 indicates the case of decreasing SNR related to the measureable range depending on the atmospheric condition. The chain line, dashed line, and solid line correspond to the cases of (i) infinity focal range under high aerosol density condition, (ii) infinity focal range under low aerosol density condition, and (iii) focal range of L1 under low aerosol density condition, respectively. The dot line indicates the SNR threshold for correct signal detection. It is shown that when the aerosol density becomes low, there are no available data for all ranges if the focal range is set at infinity. However, this lidar recognizes this situation automatically by the analysis of SNR, and changes the focal range to the point for realizing the best performance, which is the longest measurable range in many cases.

Optimization of beam diameter / pulse width

The relation of SNR, beam diameter, pulse width, and focal range are indicated as follows[1].

$$SNR \propto \frac{\Delta R \cdot D^2}{1+\left(1-\frac{L}{F}\right)^2\left[\frac{\pi D^2}{4\lambda L}\right]^2} \qquad (1)$$

where L, F, λ, D, and ΔR indicate range, focal range, wavelength, beam diameter, and range resolution derived from pulse width, respectively. The larger beam diameter increases SNR at the far-field (L=F), but decreases it in the near-field (L<<F). On the other hand, the small beam diameter decreases SNR at the far-field but increases it in the near-field. In this concept, the beam diameter is optimized using equation (1). The effect of this beam diameter tuning is shown schematically in Fig. 3. The pulse width is also tuned by the analysis of SNR and spectral shape (i.e. coherence time of the received signal). Setting wider pulse width is suitable for longer range measurement if the spectral broadening is small and low range resolution is permitted. When the aerosol density is enough high, the pulse width can be set shorter for better range resolution.

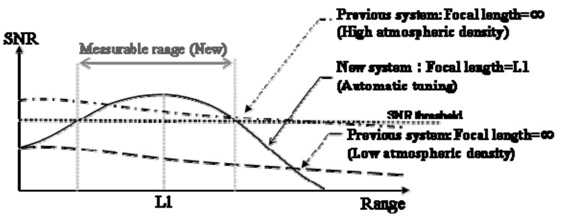

Fig. 2. Schematic explanation for the effect of the focal range tuning.

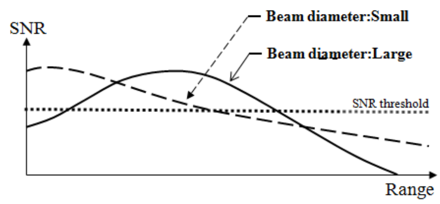

Fig. 3. Schematic explanation for the effect of the beam diameter tuning.

Optimization of signal processing parameter

In this concept, accumulation number is automatically tuned. For example, when SNR becomes lower than the threshold in a specific range, this situation is recognized in the SNR analysis, and the spectral accumulation continues until enough SNR can be confirmed. This processing can be done for each range independently.

SUMMARY

We introduced a new concept of wind lidar system with adaptive parameter tuning (filed patent). This concept provides the lidar performance which fits best to the user’s needs under various atmospheric conditions..

REFERENCES

1. S. Kameyama T. Ando, K. Asaka, Y. Hirano, and S. Wadaka,”Compact all-fiber pulsed coherent Doppler lidar system for wind sensing,” Applied optics, **46**, No.11, pp.1953-1962, 2007.