

氏名	劉 薇
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学位論文題目	Practical Research on Portable Instruments for Wind Characteristics Investigation using a Mini Doppler SODAR –Investigation of High Altitude Wind Characteristics at Hojyo Sand Dune– (ミニドップラーソーダによる移動式風況精査の実用化研究 –北条砂丘における高高度風況精査–)
学位論文審査委員	(主査) 林 農 (副査) 大西善元 原 豊

## 学位論文の内容の要旨

This study proposes and considers the practicality of a new multi-point mobile observation method using a Mini Doppler SODAR for the purpose of a wind characteristics investigation, which is the feasibility study of electricity generation from wind power for commercial realization. Furthermore, this study shows feasible conditions for wind power generation at Hojyo Sand Dune of San-in coast, which site can expect moderate breeze.

The height of a conventional observation tower is lower than 30m for wind characteristics investigations. This conventional observation tower cannot therefore directly measure the wind speed at heights of 70m to 100m, which the hubs of many modern high-power wind turbines are located at. In such case, the wind speed at higher than 40m is usually extrapolated by using the power law of a wind profile. However, the power law is effective only if the geographical feature is simple. It overlooks many factors caused by the complexity of the terrains, which is usual in most parts of Japan. Therefore, the pinpoint determination of a wind power optimum site by multi-point mobile observation is desired, instead of a fixed-point observation, using an observation tower.

Recently, Mini Doppler SODAR (sonic detection and ranging) has been developed for the observation of atmospheric boundary layers. It is a kind of acoustic remote sensor and can be used to measure the wind velocity and direction at various heights up to several hundred meters. It is portable and may be used in complex terrains. The ultimate goal of the present work is to use a Mini Doppler SODAR, not only in place of observation towers, but also as a portable instrument to investigate the wind characteristics of the entire site planned for the construction of a wind farm. As a first step, this research project looked into the feasibility of using a Mini Doppler

SODAR as an instrument for the investigation of wind characteristics.

Hojyo Sand Dune, facing the Sea of Japan, was selected for the study site. The site has the characteristics of moderate breeze and relatively flat terrain; however, there are windbreaks of pine groves. On the south side of the windbreaks, a wind characteristics investigation was performed by a 70m tower corresponding to the hub height of a large-scale wind turbine, and a feasibility study of wind power electricity generation was implemented. And a phased-array type Mini Doppler SODAR (KPA-100C made by Kaijo Corp.) was set at about 40m south of the pine groves and at 80m west of the observation tower, and the Mini Doppler SODAR examination was carried out. The wind data obtained by the Mini Doppler SODAR were compared with those from the 70m-observation tower in this study.

From the results obtained by the 70m-observation tower, sea and land breeze circulations were observed in the early summer. It was found that the extrapolation by the power law produced a large error under the influence of the windbreaks. The capacity factor  $c$  ( $c = P / P_r$ ,  $P$  is the mean power which the wind turbine yields within a calendar year, and  $P_r$  is the rated power) exceeded 20% for the large-sized turbine with hub heights of 80m to 100m. This means that Hojyo Sand Dune is a promising place for wind generation. In this research, in order to raise the accuracy of data, only the received acoustic signal which had the signal to noise ratio of the 9dB or more was considered as effective. And the averaged data, which had the rate of data acquisition of 75% or more for 10 minutes were used for evaluation of the wind characteristics. Good correlation of wind speed was observed between the tower data and the Mini Doppler SODAR data. The correlation coefficient of wind speed ranged from 0.86 to 0.91. The Mini Doppler SODAR tended to underestimate wind speed compared with the tower. However, it can be corrected mathematically with a suitable regression line. The statistical characteristics of the wind direction obtained by the Mini Doppler SODAR and the tower were very similar. The wind profiles measured by both methods agreed well in the land breeze period, because the stable stratified boundary layer was formed at night. On the other hand, the wind profile of the sea breeze could not be obtained accurately using the Mini Doppler SODAR. This was caused by the sound noise from the adjacent highway, the turbulence from the pine groves and the large unstable convection in the daytime. As mentioned above, this study shows that Hojyo Sand Dune is a promising place for wind generation, if a large-sized wind turbines with a hub height greater than 70m (e.g. 80m to 100m) is used. Wind characteristics investigation at multiple points was proposed with a portable Mini Doppler SODAR, and a Mini Doppler SODAR could be a useful and reliable instrument for the investigation of wind characteristics by use of correction with a suitable regression line. In conclusion, the Mini Doppler SODAR could be a good substitute for an observation in the future.

## 論文審査の結果の要旨

本論文は、事業への取り組みが本格化してきた風力発電の可能性調査に用いられる風況精査に、小型で可搬式のドップラーソーダを採用した移動式風況精査の実用化を検討し提案するものである。さらに、強風地域と言えるほどでもない山陰海岸の北条砂丘で、風力発電事業を可能にするための方策を探って実用可能な条件を提示したものである。

通常行われる NEDO 仕様の風況精査は 30m と 20m の高さに風速計と風向計を取付けた観測鉄塔により行われているが、現在の大型風車はハブ高さが 70m~100m に達しており、受風面に対応していない。また、複雑地形の多いわが国の風力発電最適地点においては、ベキ法則を適用して観測結果をハブ高さまで外推する方法は誤差を生じやすい。風力最適サイトのピンポイント決定が望まれるが、現在の鉄塔を使用した定点観測に代わって移動観測による広範囲な領域の観測が望まれている。

北条砂丘の防風林南側において、大型風車のハブ高さに相当する 70m 鉄塔による風況精査と、ミニドップラーソーダによる風況精査を同時に行い、風力発電事業化可能性調査とドップラーソーダの検定試験を実施した。70m 鉄塔観測では、初夏は海陸風循環が支配的であること、地上高 20m、30m のデータを用いたベキ乗則による高い高度の風況推定は防風林の影響により大きな誤差を生むこと、高度 70m での実測値からは北条砂丘はハブ高さ 80m~100m の大型風車を設置すれば設備利用率 20% を超える風力発電に有望な場所であることを明らかにした。ミニドップラーソーダの鉄塔風況観測値を用いた検定では、高い高度における測定精度を高めるため受波信号のパワースペクトルの SN 比が 9dB 以上のみを有効データとして 10 分間のデータ取得率が 75% 以上の場合のみを取り扱い補正すれば、ミニドップラーソーダは風況精査に有効であることを明らかにした。

以上のように、本論文は北条砂丘にハブ高さ 80m~100m の大型風車を設置すれば風力発電事業化に適した地点であること、ミニドップラーソーダを利用すれば移動式風況精査の実用化が可能なことを提案したものと高く評価できる。よって本論文は、博士(工学)の学位論文に値すると認める。