

Learning-Based Radar Detection Range Prediction Using Parabolic Equation Method

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Accurate prediction of radar detection range is a critical aspect of radar system design and operation. In real-world operational environments, electromagnetic (EM) wave propagation is significantly influenced by atmospheric refraction, Earth's curvature, and complex terrain features. The traditional parabolic equation (PE) method effectively accounts for these factors, demonstrating strong capabilities in analyzing wave propagation within non-uniform media. However, the PE method is computationally intensive and time-consuming, limiting its practicality for rapid processing applications. Additionally, prior studies have shown that radar detection ranges can vary significantly under the same terrain conditions due to changes in atmospheric refractivity, highlighting the need for predictive models that can swiftly adapt to varying meteorological conditions.

This study introduces a novel radar detection range prediction model that integrates the PE method with learning techniques. By leveraging multi-year high-altitude meteorological observation data and actual terrain data, radar detection range maps under various meteorological conditions are generated and utilized as training data for the learning model. The PE method's ability to incorporate Earth's curvature, atmospheric refractivity, and terrain allows it to effectively capture propagation characteristics in non-uniform media. Through this data integration, the learning model learns the complex relationships between meteorological information and terrain features, enabling rapid detection range predictions under specific operational scenarios.

The proposed learning-based model demonstrates superior performance compared to traditional PE methods in prediction speed. Notably, the model effectively reflects variations in radar detection range due to changes in atmospheric refractivity even within the same terrain environment, making it highly suitable for operations requiring swift responsiveness. By utilizing only meteorological data for a specific date, the model can swiftly derive radar detection ranges without the need for the computationally demanding PE calculations. This approach ensures reliable radar performance predictions across diverse and complex environmental conditions, offering significant improvements in the efficiency and operational readiness of radar systems. Furthermore, the integration of actual terrain data and three-dimensional atmospheric refractivity profiles enhances the model's ability to generalize across different scenarios, providing robust detection range estimations. The methodology presents a promising advancement for optimizing radar operations, with potential applications that require immediate or near-immediate responsiveness in dynamic environments, thereby contributing to more efficient and reliable radar system deployments.

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