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Modeling and Observations of Anomalous Propagation Effects in Weather Radar Systems

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Refraction is described as the change in the direction of electromagnetic wave propagation due to transmission medium’s refractive properties. This phenomenon occurs when an oblique incident electromagnetic wave propagates through media with different refractive indices. Refractivity indices of air layers in the troposphere are affected by the changes of temperature, relative humidity and pressures because of meteorological influences. Therefore, electromagnetic energy radiated from weather radar systems may follow unusual paths during its propagation depending on the difference of refractivity indices in the tropospheric layers. This mentioned unusual propagation paths are defined as anomalous propagation.

Anomalous propagation effects in troposphere are classified as subrefraction, superrefraction and ducting. Mentioned anomalous effects can be modelled with ray tracing technique which is based on high frequency approximation of Maxwell Equations. This approximation is valid for microwave frequency bands where weather radar systems operate. We implemented a MATLAB based code for ray tracing model in order to visualize the anomalous propagation effects in different duct types: Evaporation duct, surface duct and elevated duct types are studied with the implemented ray tracing model. The model includes a module which computes the refractivity indices of horizontal tropospheric layers from radiosonde measurements (temperature, relative humidity and pressure). The module is based on ITU recommendation ITU-R P.453-11, "The radio refractive index: its formula and refractivity data". Real life radiosonde measurement data are used to compute the refractivity indices according to this recommendation. Module computed refractive indices are used in ray tracing model to predict the propagation paths of electromagnetic energy which is radiated from a given weather radar system antenna. Finally, visualized outputs of ray tracing model and real life observations of weather radar systems are also compared in our current study.