Modelling the ionospheric electron density profile using neural networks

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Introduction

This paper discusses the application of the technique of neural networks (NNs) to modelling the electron density profile in the lower and bottomside ionospheres. Two distinct applications are presented; the LAM model, which was developed to provide a prediction tool for the electron density profile over the South African region, and the IMAZ model, which was developed to provide an electron density model for the ionospheric D and E regions over the auroral zone.

The LAM Model

At URSI 2002, a single station version of the LAM model was presented. Data is being continually archived from 3 stations within South Africa, namely Grahamstown (33.3S, 26.5E), Madimbo (22.4S, 30.9E) and Louisvale (28.5S, 21.2E), and this model has now been updated to include data from all 3 stations. Grahamstown is the longest running ionosonde with 31 years of hourly vertical incidence ionospheric characteristics and 8 years of profile measurements, while Louisvale and Madimbo only have 4 years of profile measurements each. For the LAM model, NNs are used to predict the parameters needed to construct an electron density profile for the given inputs. These parameters include the coefficients of a Chebyshev polynomial. The inputs to this NN based model are geographical latitude and longitude, year, day number, and hour. The year input may be substituted for a measure of solar activity and a measure of magnetic activity. From these given inputs the NN input space is determined and the NNs are interrogated for the parameters required to construct the profile that corresponds to the given inputs. For the solar activity input a running mean of the sunspot number is used and for the magnetic activity input a running mean of the magnetic a_k index is used. The optimum time length of the running mean depends on the output parameter of the NN being interrogated. A powerful feature of the LAM model includes its ability to predict the probability of existence of an F1 layer and apply corrective measures to ensure a realistic result.

IMAZ

Recently, the NN based model IMAZ (Ionospheric Model for the Auroral Zone) was developed in a joint South African-Austrian effort to provide a reliable prediction tool for the electron density profile at the altitudes below 150 km and at high latitudes. A combination of data obtained from the European Incoherent Scatter Radar (EISCAT) and measurements from rocketborne wave propagation experiments provided enough high latitude data to cover one solar cycle. The inputs to this model are local magnetic time, total absorption, local magnetic activity, solar zenith angle, and the F10.7 cm solar flux value. The pressure surface, which combines the effects of the seasonal variation (day number) and the altitude, is also included as an input parameter. The output is the electron density at the given input pressure (i.e. altitude).

Results and Conclusion

Both models provide realistic electron density profiles within the boundaries laid down by the data with which the NNs were trained and the purposes for which the models were developed. Predicted profiles from each model are compared with other similar existing models, which indicates that the technique of NNs provides a more successful approach to electron density profiling than analytical techniques.