A NOVEL EMPIRICAL MODEL OF THE K-FACTOR FOR RADIOWAVE PROPAGATION IN SOUTHERN AFRICA FOR COMMUNICATION PLANNING APPLICATIONS

by

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Dedicated to the individuals
and organisations who have
supported this research.

ABSTRACT

The objective of this study was to provide an adequate model of the k-factor for scientific radio planning in South Africa for terrestrial propagation. An extensive literature survey played an essential role in the research and provided verification and confirmation for the novelty of the research on historical grounds.

The approach of the research was initially structured around theoretical analysis of existing data, which resulted from the work of J. W. Nel. The search for analytical models was extended further to empirical studies of primary data obtained from the South African Weather Service.

The methodology of the research was based on software technology, which provided new tools and opportunities to process data effectively and to visualise the results in an innovative manner by a means of digital terrain maps (DTMs) and spreadsheet graphics. MINITAB © software was used for regression analysis of the data, in addition to the neural network algorithm. The comparative studies and evaluation of the research were done by comparing predictions with existing data and primary data of groundbased meteorological observations obtained from the South African Weather Service.

A key finding of the study were that the expression for the cumulative distribution of the k-factor as a percentage of time for events could be represented by a truncated normal or gaussian function. The existing data were recreated according to the basic model. This model was extended further in terms of a dual cumulative distribution taking into account what appeared to be seasonal effects by using “dry” and “wet” terms. The results were validated successfully by comparison between observed and predicted data. The extended cumulative distribution model was in turn used with a DTM to generate height dependent contours of k-factor values for South Africa for different values of time availability. Use was also made of a point form of the refractivity gradient and ground based meteorological data obtained from the South African Weather Service, to predict the long-term average of the k-factor for South Africa. A contour map to illustrate the results was generated using the DTM. It has thus been possible to extrapolate values of the k-factor observed at a limited number of sites to cover the whole country using the algorithms developed and the DTM for the country. A number of new analytical models were proposed and evaluated.

Recommendations include that current research should continue in order to explain an apparent anomaly in the observed data around Alexander Bay. The vertical gradient of temperature will require further work to redefine its characteristics under different climatic and geographic conditions. Kriging, as a technique similar to the Neural Network approach, could be investigated further for applications using great circle distances between observation sites. The proposed model should be investigated further to determine whether it has potential global applications. A search for a generally applicable global representation of the k-factor should continue using the results of the work reported here.

KEYWORDS

The k-factor, effective earth radius, radio-wave propagation, refractivity gradient, vertical model of the troposphere, digital terrain model (DTM), neural network algorithm, multiple regression – MINITAB.

OPSOMMING

Die doel van hierdie studie was om 'n geskikte model te skep van die sogenaamde k-faktor vir die wetenskaplike beplanning van aardgebonde radiokommunikasiestelsels in Suid Afrika. 'n Breedvoerige oorsig van die literatuur het 'n noodsaaklike rol gespeel in die verifikasie en bevestiging van die oorspronklikheid van die werk op historiese gronde.

Die benadering tot die navorsing was aanvanklik gebaseer op ‘n teoretise analise van bestaande data, wat gevolg het uit die werk van J. W. Nel. Die soeke na analitiese modelle was verder uitgebrei tot empiriese studies van primêre data wat van die Suid Afrikaanse Weerdiens verkry is.

Die navorsingsmetodiek was gestruktureer rondom die tegnologie van programmering, wat nuwe metodes en geleenthede geskep het om data effektief te prossesseer, en om die resultate grafies voor te stel op ‘n innoverende wyse met digitale terreinkaarte (DTKe) en spreibladgrafika. MINITAB © programmatuur was gebruik vir regressie-analise van die data, tesame met neurale network algoritmes. Die vergelykende studies en evaluasie van die navorsing is gedoen deur bestaande data en primêre data vanaf die Suid Arikaanse Weerdiens met voorspellings te vergelyk.

'n Sleutelbevinding van die werk was dat die uitdrukking vir die kumulatiewe verspreiding van die k-faktor as 'n persentasie van die tydbeskikbaarheid van gevalle in terme van 'n getrunkeerde normaal Gauss-verspreiding voorgestel kon word. Vergelykende data was opgewek volgens die basiese model. Die model was verder uitgebrei in terme van 'n dubbele kumulatiewe verspreiding wat effekte wat gelyk het asof hulle seisoengebonde was, in ag te neem deur die insluiting van "droë" en "nat" terme.

Die resultate was suksesvol ge-evalueer deur middel van vergelyking tussen waargeneemde en voorspelde waardes. Die verbeterde model vir kumulatiewe verspreiding was verder gebruik tesame met 'n DTK om hoogte gebonde kontoerwaardes van die k-faktor vir Suid Afrika op te wek vir verskillende waardes van tydbeskikbaarheid.

Daar is ook gebruik gemaak van 'n puntvorm van die gradient van die brekingsindeks en oppervlakte waardes van meteorologiese data, wat van die Suid Afrikaanse Weerdiens verkry is, om die langtermyn waarde van die k-faktor vir Suid Afrika te voorspel. 'n Kontoerkaart om die resultate te illustreer, is met behulp van 'n DTK opgewek. Dit was dus moontlik om die k-faktor oor die hele land met 'n DTK te ekstrapoleer vanaf waardes wat by 'n aantal beperkte liggings geneem is deur gebruik te maak van die algoritmes wat ontwikkel is. 'n Aantal analitiese modelle is voorgestel en ge-evalueer.

Aanbevelings sluit in dat die huidige navorsing voortgesit moet word, om 'n oënskynlike anomalie in die waargenome data by Alexanderbaai te verduidelik. Verdere werk word benodig om die gedrag van die temperatuurgradiënt onder verskillende klimaat en geografiese kondisies te bepaal. Sogenaamde Krige-metodes, soortgelyk aan metodes wat met neurale netwerke gebruik word, kan verder ondersoek word vir interpolasie tussen wydverspreide waarnemingstasies. Die voorgestelde model behoort verder ook ondersoek te word, om te bepaal of dit potensiële wêreldwye toepassings het.

SLEUTELWOORDE

Die k-faktor, effektiewe aardradius, radiogolfvoortplanting, gradient van die brekingsindeks, vertikale model van die troposfeer, digitale terrainkaart (DTK), neurale network algoritmes, multi-regressie – MINITAB.

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Table of Contents