Ionosphere Equivalent Conversion Methods from Oblique to Vertical using Oblique Measurement Data

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Korean Space Weather Center (KSWC) of Radio Research Agency (RRA) has function to forecast the space weather like space weather indicators in radio range.

KSWC is performing routine observation of ionosphere using 2 digisonde systems deployed at Jeju site & Ichon site.
- Delivers daily ionosphere status information through homepage, e-mail, etc. to users.

As a part of KSWC’s plan, ionosphere measuring and analysis project was started since January 2013.
- to checkup and verify oblique sound measuring function between two digisondes
- to make conversion technology from oblique ionogram data to converted vertical parameters at mid point of between two digisondes
The project was performed by ETRI funded by KSWC for Developing Ionosphere Measuring and Analysis Technology

- The purposes of this project were as follows;
  - to re-check & verify oblique function of existing Digisonde systems
  - to develop SW for extracting ionogram data from raw data (RSF file)
  - to develop algorithm for extracting ionogram trace data from ionogram data
  - to develop algorithm for converting ionogram trace data from Oblique to Vertical
  - to develop algorithm for extracting ionospheric N-profile & parameters from converted vertical ionogram trace data
  - to implement SW
• Ionosonde deployed at KSWC in Korea
  – Fully digital ionosonde made by LDI, model DPS-4D
    * LDI : Lowell Digisonde International

• Ionosonde sites in Korea
  – North site at Icheon (37.1°N, 127.5°E)
  – South site at Jeju (33.4°N, 126.3°E)
    ※ distance between two site : 480Km

• Oblique sounding in Korea
  – Frequency range 1MHz ~ 16MHz
  – Frequency step 25kHz
  – Sounding interval 30 minute
• Measurement schedule
  – Vertical sounding measurement: 8 minutes interval
  – Oblique sounding measurement: 30 minutes interval
• Total 4 oblique ionogram are produced every hour
• ETRI divided this project into 5 tasks as follows;

- Generation oblique ionogram data from RSF data file of Digisonde  
  ※ RSF : Routine Scientific Format  
- Oblique trace data extraction from the oblique sounding ionogram  
- Trace conversion from oblique to vertical  
- Get electron density profile from the converted vertical ionogram  
- Extraction ionospheric parameters from electron density

• This project was performed by ETRI with IPS & LDI and SELab support
Concept of O2V Ionogram Conversion Procedure

Oblique Ionogram (measured) → Trace extraction → Extract Oblique Ionogram Trace → O to V conversion → Vertical Ionogram Trace (converted) → N-profile & Parameter extraction → Ionospheric N-profile & parameter
Trace Extraction (1/2)

- **Vector tracking algorithm**
  - is for trace extraction from the scattered data in the ionogram
  - calculate 8 direction amplitude sum of echo signal up to 4 echoes in each direction (T1)
  - Move trace coordination to direction of maximum amplitude sum (T2, T3, T4)

- **3 steps of trace extraction**
  - Find maximum amplitude echo signal in the ionogram, that will be T1
  - Trace extraction of right part of ionogram from the maximum amplitude point by the vector tracking algorithm (T2, T3)
  - Trace extraction of left part of ionogram from the maximum amplitude point by the vector tracking algorithm (T4)
Trace Extraction (2/2)

- Validation Process of trace extraction
  - 3 steps development were performed
    - Algorithm verify using Excel ➔ Algorithm verify using Matlab ➔ S/W program

- Trend of extraction trace is seemed to be similar to oblique ionogram
• Equivalent conversion theory was applied to trace conversion from O to V

• The vertical frequency \( f_v \) and virtual height \( h'_v \) can be derived from the oblique frequency \( f_{ob} \) and virtual path \( P'_{ob} \)

\[
\begin{align*}
    f_v &= \frac{f_{ob}}{1.002} \cos\left(\sin^{-1}\left(\frac{428.8748}{P'_{ob}}\right)\right) \\
    h'_v &= -3.6097 + \frac{214.4374}{\tan\left(\sin^{-1}\left(\frac{428.8748}{P_{ob}}\right)\right)}
\end{align*}
\]

• Validation of Trace Conversion
  – Compare vertical ionogram between measured and converted was impossible because there was no digisonde at mid point and there was not available vertical measured ionogram
  – Alternative validation method was considered that is compare converted vertical ionogram to measured vertical ionogram before and after oblique sounding measurement
    • Converted vertical ionogram at midpoint can be compared with measured vertical ionograms at TX and RX station for the validation
    • If converted vertical ionogram at midpoint is located between the vertical ionograms of TX and RX station, conversion algorithm seems to be validated

breit-tuve [1926], martyn’s equivalent path theorem [1935]  
Ionogram Trace Conversion verification

- O to V conversion verification method
  - Compare converted vertical ionogram to measured vertical ionogram of Jeju and Ichon site digisonde (450Km apart between 2 sites)

- O to V conversion verification (using 13 ionograms @Ichon site, 2013.05.27)
Electron Density & Parameter Extraction

- POLAN algorithm has adopted to extract electron density and ionospheric parameters
- Validation of POLAN algorithm
  - By comparing with ARTIST of Digisonde for same measured vertical ionogram data

Measured at Jeju (2013.09.10 00:07:30 UT)
Summary

• This project had been completed end of 2013
  – Oblique sounding measurement data between Jeju and Icheon stations was used
  – To build sw program on server in KSWC was completed
    • Trace extraction from the oblique measured ionogram data
    • Conversion from oblique to vertical ionogram trace
    • Extraction of electron density & ionospheric parameters from converted vertical ionogram data

• Future Works
  – KSWC has a plan to perform 2\textsuperscript{nd} phase of ionosphere measuring and analysis project from this year with domestic institute and company
    • to upgrade the O2V conversion SW algorithm developed in 2013 and the SW to be user friendly more
    • to perform long distance (around 1,000Km) O2V conversion algorithm development to measure ionosphere status information above sea between NICT and KSWC
    • to install new ionosonde receiving system only for receiving the signal from NICT’s new ionosonde
Thank you!