Computer and Information Science
www.ccsenet.org/journal.html
Vol. 1, No. 1
February 2008

Mapping of Power Transmission Lines on Malaysian Highways Using UPM-APSB's AISA Airborne Hyperspectral Imaging System

Hj. Kamaruzaman Jusoff
Forest Geospatial Information & Survey Lab, Lebuh Silikon
Faculty of Forestry, Universiti Putra Malaysia
Serdang 43400 Selangor, Malaysia
Tel: +60-3-8946 7176 E-mail: kamaruz@aeroscan.biz
Norsuzila Ya'acob
Faculty of Electrical Engineering, Universiti Teknologi MARA
UiTM 40450 Shah Alam, Malaysia
Tel: +60-3-5544 2000 E-mail: norsuzilayaacob@yahoo.com

Abstract

Power transmission lines routes mapping is an important technique for locating power transmission line routes and towers on mountain/hilltops to assist viewing of their impacts on the environment, operations and allocation of public utilities. A study was therefore conducted to map the power transmission lines within Bukit Lanjan PLUS highway. The main objective of this study is to assess the capability of airborne hyperspectral sensing for mapping of power transmission. By using ENVI software, the airborne hyperspectral imaging data was enhanced using convolution filtering technique using band 3 which produced a gray scale image which appeared clearer and sharper. The spectral reflectance curves were acquired for each power line which showed the same spectrum characteristics in curve or the reflectance energy. This is because of the same power lines composition material for all power lines. Ground verification was done by comparing the UPM-APSB's AISA Global Positioning System (GPS) coordinates readings with ground GPS coordinates readings of the power transmission lines footings. The ground verification result from the two matching power transmission line footings showed that the accuracy of power lines identification was acceptable. This study implies that airborne hyperspectral imagers are powerful tools for mapping and spotting of suitable large transmission towers and lines.

Keywords: Power transmission lines, Airborne spectrometry, Spectral signature, Routing

1. Introduction

Power transmission lines are electrical lines that typically carry high voltage and have to traverse the length and breadth of the country, for evacuation of power from generating stations to load centers and beneficiary states, the topographical and geographical nature of the terrains play significant influence in the project cost and implementation time. Hence, it is important to determine power transmission lines routes spotting. Unmonitored power transmission lines such as when tree grow too close to power lines, it is potential threat to electrical system reliability and safety, resulting in unnecessary power outages and interruptions in electrical service to customers or may cause forest fires when the bamboo tops hit the wire lines. The potential environmental impacts from the construction and operation of transmission lines can be minimized once precise location of power transmission lines tower footings can be determined. Many of the issues relating to changes in land value resettlement and loss of productivity can be dealt with easily. For instance, sites with cultural or historical importance that might fall in the transmission line route or even the encroachment into precious ecological forested areas and valuable lands may be totally avoided (Kamaruzaman, 2004a).

Power transmission lines corridor are traverse along the linear length through physiographic features, land use pattern, types of habitation in and around the vicinity by supported of the transmission tower which is cover large distances. Due to the force of gravity, power lines tend to sag. This initial sag increases with line temperature because the conducting material, of which the line is made, expands, effectively lengthening the line. A small increase in line length produces a large, and potentially hazardous, increase in sag. Sagging power lines will contact vegetation and short circuit. This causes power interruptions and forest fires. On the other hand, the suitable sites for new transmission lines have been getting restricted, because of development of a rural areas and the growing concern over environmental issues. Power transmission lines should avoid the main settlements but there is a possibility that they pass over some houses scattered over the hill, grazing and pastureland and terrace farm this is cause by not well spotted during the planning stage. In lieu of the above problems, an urgent need for a remote sensing data is important to aid the spotting of power transmission footings on relatively high spots such as over the hills maintaining similar height. In Malaysia, the only alternative remote sensing data source is the UPM-APSB's AISA airborne hyperspectral imaging which carries an optical sensor and proven to be useful for different applications (Kamaruzaman, 2004b, 2004c; and Kamaruzaman, 2008).

The general objective of this study is to assess the capability of airborne hyperspectral sensing for TNB power transmission lines mapping and spotting in Bukit Lanjan, Selangor. Meanwhile, the specific objective is to precisely locate and map the power transmission line route over the thick dense forested hills mountains and highway.

2. Methods and materials

2.1 Description of study area

The study was conducted in Bukit Lanjan (Figure 1), situated in the state of Selangor and approximately 47 km from Kuala Lumpur's capital city. It lies roughly between latitudes 3º10'40'' and 3º11'02'' North and longitudes 101º35'50'' and 101º36'26'' East. Bukit Lanjan is almost in the midst of affluence Petaling Jaya, is the highest lone peak in the Klang Valley. There is a small patch of pristine tropical forest at the peak. The road in Bukit Lanjan is currently under the maintenance of The North South Expressway (PLUS).

2.2 Equipment and software

2.2.1 Description of UPM-APSB's AISA Sensor

UPM-APSB's AISA is a solid-state, commercially produced inexpensive hyper spectral push-broom imaging instrument to recording remote sensing images over a large spectrum wavelengths from the visible (VIS) to near infrared (NIR) which is 400-1000 nm. Images have a ground pixel size of 1 m x 1 m with a flight altitude of 1,000 m a.s.l and a constant flight speed of 120 knots (Kamaruzaman, 2004a). It is designed to provide a near real-time, frequent, repetitive, accurate and reliable push-broom instrument that acquire images in 288 registered, contiguous narrow spectral band passes such that for each element it is possible to derive a complete reflectance spectrum. The UPM-APSB's AISA hyperspectral imager is a complete system that consists of a compact hyperspectral imager head, miniature Global Positioning System (GPS)/Integrated Navigation System (INS) sensor for precise positioning, data acquisition unit and CaliGeo pre-processing software. This small portable instrument, with a total weight of only 15 kg was mounted on an aluminium metal plate that is compatible with a standard aerial camera mount, available in any fixed wing aircrafts such as that of a Pan Malaysia Air Transport (PMAT) Short SkyVan SC7, a Sabah Air GAF Nomad N22B or a RMAF C402B. Swath width is 360 pixels and field of view (FOV) in cross track direction 20° which makes ground resolution from 1 km altitude approximately 1 m at a flight speed 120 knots (60 m/s).

The versatile graphical user interface (GUI) provides flexible, easy-to-use instrument with several efficient operating modes and features that may be changed during flight within seconds. The data is stored as a default to a large capacity hard disk, which is providing higher frame rates compared to traditional tape storage based systems. The refractive properties of the two opposing prisms allow for a linear projection of light onto the charged coupled device (CCD) array. The two-dimensional array consists of a spatial axis of 364 detectors, and a spectral axis of 286 detectors. The UPM-APSB's AISA sensor system with 20 pixels per swath for downwelling irradiance system was acquired via a fiber optic irradiance sensor (FODIS) on the N22B aircraft. The FODIS allows for the concurrent measurement of downwelling and upwelling radiance by the UPM-APSB's AISA sensor head. The calibration of the FODIS coupled with the UPM-APSB's AISA sensor allows for the calculation of apparent at-platform reflectance. Normally, downwelling irradiance system is needed so that the upwelling and downwelling measurements can be compared directly (Figure 1).

UPM-APSB's AISA is capable of collecting data within a spectral range of 430 to 900 nm. Although UPM-APSB's AISA is capable of collecting up to 286 spectral channels within this range, the data rate associated with the short integration times (sampling rates) required of the sensor in most operational/flight modes, limits the number of channels. Spectral resolution is important for detecting fine spectral features that can identify specific materials. The full spectral mode, however, is useful for acquiring 286 band spectral signatures of specific targets that can be used to generate pure end members as well as for band selection purposes. Current operational collection configurations range from 10 to 70 spectral bands depending on the aircraft speed, altitude and mission goals**.** Table 1 shows the spectral and spatial resolutions achievable when holding ground speed constant, in this case 120 Knots (*Table* 1).

2.2.2 Softwares: The Caligeo and ENVI Version 4.0

CaliGeo is a software package designed to process raw UPM-APSB's AISA sensor data quickly and accurately to a format that can be read using a data analysis package and analyzed using the latest data processing and analysis methods into the final data products. The process follows few simple steps that included radiometric correction, geometric correction, rectification and geo-referencing. After these steps were completed, the data were visualized on a user-friendly interface that runs interactively. This means that the data can be viewed without a need to transfer data and large files from one program to another reducing the amount of inconvenience for the user. Most of the processing is relatively straightforward and automatic, and the graphical user interface (GUI) makes it easy for any one to learn and to use. After CaliGeo processing the data was then analyzed using ENVI.

ENVI software version 4.0 which is a unique approach and user friendly to search for images spectral signatures, in addition to the geospatial capabilities, which result in an effective identification, visualization, spatial and spectral data reduction and management tool with integrated decision-making capabilities. ENVI is used to find hidden targets (including sub-pixel targets), identify terrain features, visualize 3D terrain, and perform line-of-sight analysis. ENVI is also the undisputed leader in hyperspectral image analysis, providing the only environment capable of fully utilizing the feature identification power of hyperspectral data. Easily ingest panchromatic, multispectral, hyperspectral, radar, elevation images, or vector GIS data.

2.3 Airborne data acquisition and data pre-processing

The calibration flight by UPM's FGISL/Aeroscan Precision (M) Sdn.Bhd. took place on 19 February 2004 in Bukit Lanjan using a SC-7 aircraft with flight altitude of 1,000 m a.s.l and 1m x 1m ground spatial resolution. Mission profiles were planned using high-resolution digital maps of the operating area. The flight path lines (FPL) were identified using a specialized GPS software and 20 operational bands ranging between 438.8 nm to 894.1 nm wavelengths including visible light (red, green, blue) and near infrared were selected and configured. Data delivery over some the selected Area of Interest (AOI's) i.e Bukit Lanjan was accomplished within 24 hours of completion of data acquisition.

The UPM-APSB's AISA imaging spectrometer was configured to measure 20 spectral bands. The data was first pre-processed using a CaliGeo software (a plug in of the latest ENVI version 4.0) for a calibrated and provides for the automatic geometric and radiometric correction, rectification, mosaicking, and calculation of radiance or apparent at-platform reflectance (FODIS ratio). The program uses the GPS and attitude information from the INS to perform the geometric, geo-referencing and mosaicking operations. Automated batch processing provides for rapid turnaround times for data delivery.

Geometric correction is an error on its image between the actual image coordinates and the ideal image coordinates. The distortions are in form of internal distortion resulting from the geometry of the sensor and external distortion due to the altitude of the sensor or the shape of the object. Meanwhile, radiometric correction is to correct for the varying factors such as scene illumination, atmospheric conditions, viewing geometry and instrument response. Radiometric correction also detects and measures the radiant energy, either as separate wavelengths or integrated over a broad wavelength band, and the interaction of radiation with matter in such ways as absorption, reflectance and emission. All the three types of radiometric correction i.e., radiometric correction due to sensor sensitivity, sun angle and topography, atmospheric correction due to absorption and scattering were corrected on-board the aircraft during image pre-processing using the Caligeo software.

Rectification is the process by which the geometry of an image is made planimetric using GCP's to transform the geometry of an image, so that each pixel corresponds to a position in a real world coordinate system. However, UPM-APSB's AISA sensor is unique in the sense that no GCP's were required with the available GPS/INS unit on-board the aircraft to automatically calculate the position of the aircraft.

2.4 Ground verification

Ground data verification was conducted to determine the mapping accuracy and exact location of the power transmission lines on the ground using a handheld differential GPS.

2.5 Image processing and final output

The UPM-APSB's AISA data were processed digitally using a user friendly ENVI version 4.0 to develop the image spectral signatures in addition to the geospatial capabilities, which result in an effective identification, visualization, spatial and spectral data reduction and management tool with integrated decision-making capabilities. The data were subjected to the minimum noise fraction transformation, pixel purity index, n-dimension visualizer, identification; spectral angle mapper and mixture tuned matched filtering processing. The final output is the AeroMAP^{TM} product that shows the location and routing of power transmission lines tower footings which is useful for developing a systematic management of the distribution and position of power transmission lines.

3. Results and discussion

3.1 Band Combination without Image Enhancement

Generally, there are 20 different bands in UPM-APSB's AISA data that can be combined to produce false color composite images. Figure 2 shows the pre-processed image of power transmission lines using band combination 19-11-2 (RGB) without enhancement. From the raw image, there is no indication that the power transmission lines are detected.

There are three sets of false color composites selected consisting of band combinations 3-3-3, 8-8-8 and 9-9-9. Contrast Stretching and Quick Filter with band combinations was applied to adjust the color or gray scale range of a selected image. By applying this technique, the computer display's dynamic range can be filled and the selected contrast of the image can be improved as shown in Figure 3. There are several default stretching options consisting of Linear 0–255, Linear 2%, Gaussian, Equalization, and Square Root. The image showing the power transmission lines routings and footings in the gray scale appear sharper and clearer compared to the other band combinations.

3.2 Spectral library profiles

By using the ENVI software, the image spectral reflectance curves for each power transmission lines were acquired (Figure 4). From the spectral library profiles, the spectral reflectance of each power lines shows a relatively high spectral signature profile which is between the frequency ranges of 450-900 nm. This is due to the aluminium material used by the power transmission lines which has a shiny surface that reflects every visible and near infrared wavelength range (Baskar, 2000). (Figure 2, Figure 3, Figure 4).

3.3 Ground truth/verification

The ground verification was done by comparing the UPM-APSB's AISA Differential GPS coordinates readings with the handheld ground DGPS coordinates of power transmission lines footings. From the airborne hyperspectral data, the locations of power transmission lines footings lies between latitudes 3º 10' 57'' and 3º 10' 58'' North and longitudes 101º 36' 4'' and 101º 36'5'' East. Meanwhile, the ground GPS readings for No. 1 footing is latitude 3º 10' 57.4'' North and longitude 101º 36' 04.9'' East, No. 2 footing is latitude 3º 10' 57.3'' North and longitude 101º 36' 04.3'' East (Figure 5). The ground verification result from both power transmission lines footings show that the accuracy is acceptable and was used to support the capability of airborne hyperspectral data in mapping power transmission lines routing (Figure 5)

4. Conclusions and recommendation

From the study carried out on mapping of power transmission lines routing and spotting using UPM-APSB's AISA sensor in Bukit Lanjan PLUS highway, the following conclusions can be derived from this study, namely (i) airborne hyperspectral imaging can locate and map the power transmission lines, and (ii) Image enhancement filtering using convolution technique with band 3 produced gray scale image was found to be the best technique for power transmission lines mapping. UPM-APSB's AISA hyperspectral imagery should be used for power transmission lines mapping over thick dense forested hills and highway.

References

Bhaskar, S.D. (2000). *Sub-pixel analysis of urban surface material: A case study of Perth, Western Australia.* (Student Prize Competition) 24rth-29th July, 2000 IEEE/IGARSS, Honolulu, USA.

Kamaruzaman Jusoff, (2004a). AISA Airborne Hyperspectral Imaging for Highway Transportation Planning and Management. Poster paper presented at *International Seminar Geospatial* 2004, Istana Hotel, Kuala Lumpur. 8p.

Kamaruzaman Jusoff, (2004b). The Potential of Utilizing Hyperspectral Remotely Sensed Data Integrated Coastal Management with Special Emphasis on Airborne Imaging Spectrometry. Invited paper presented *the KUSTEM 3rd Annual on Science, Sustainability & Management*, 4-5 May, 2004, Primula Beach Resort, Kuala Terengganu. 6p.

Kamaruzaman Jusoff, (2004c). AISA Airborne Hyperspectral Imaging for Precision Agriculture and Forestry. An oral paper presented at *4th KUSTEM Annual Seminar Sustainability Science and Management Meeting Challenges in Sustainability Agrotechnology*, 2-3 May, 2004, Primula Beach Resort, Kuala Terengganu. 6p.

Kamaruzaman Jusoff, (2008). Search and Rescue (SAR) Operations for the Missing Bell 206 Long Ranger. Helicopter in Sarawak, Malaysia Using UPM-APSB's AISA Airborne Hyperspectral Imaging Data. *An Int. J. Disaster Prevention & Management* (In Press).

Table 1. Spectral and spatial resolutions with ground speed of 120 knots

Altitude	Spatial Resolution	Numbers of spectral bands
1,000 m (3,280 ft)	1.0 m	20
1,500 m (4,920 ft)	1.5 m	26
2,000 m (6,560 ft)	2.0 m	34
2,500 m (8,200 ft)	2.5 m	55
3,000 m (9,840 ft)	3.0 m	58
4,000 m (13,120 ft)	4.0 m	70

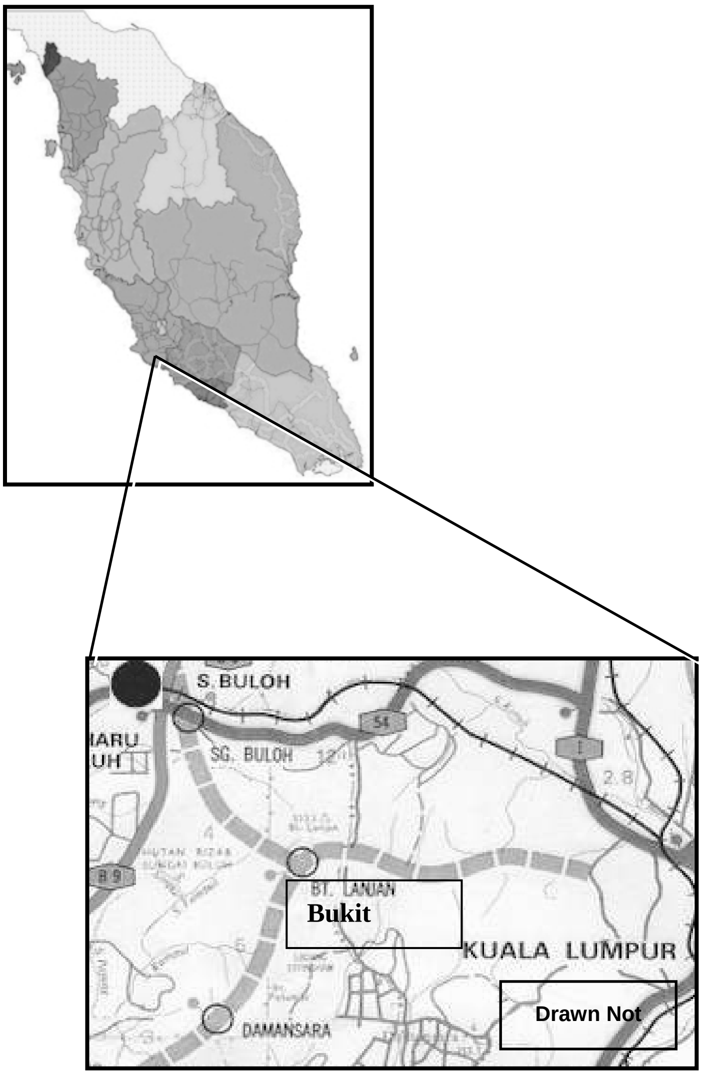

Figure 1. A map of Peninsular Malaysia showing the location of the study site

Figure 2. Pre-processed image band combination 19-11-2 (RGB) without enhancement

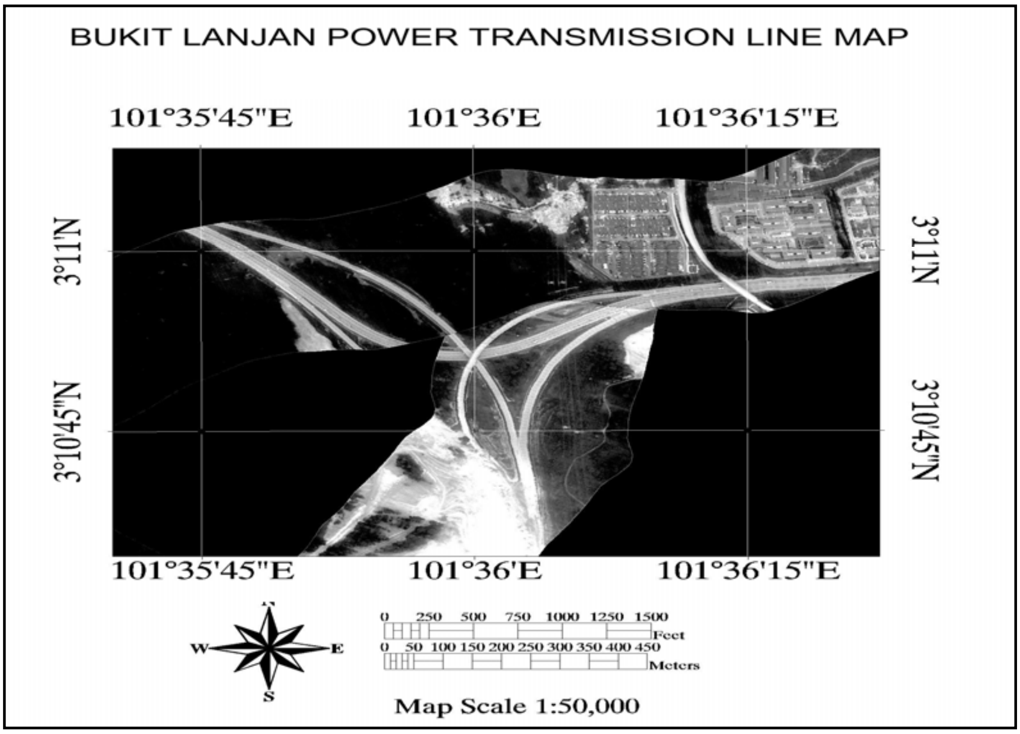

Figure 3. Image enhancement and filtering using convolution technique

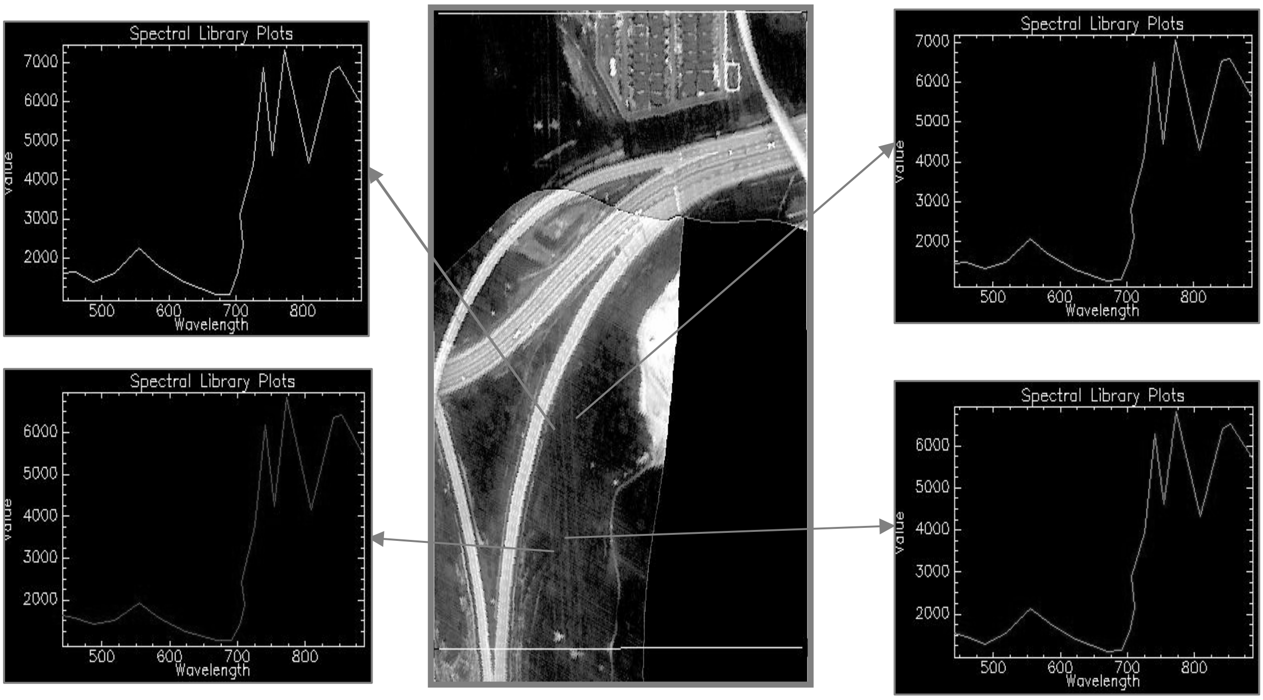

Figure 4. Image Spectral Signatures Developed and Defined
for Power Transmission lines Features in Bukit Lanjan PLUS Highway

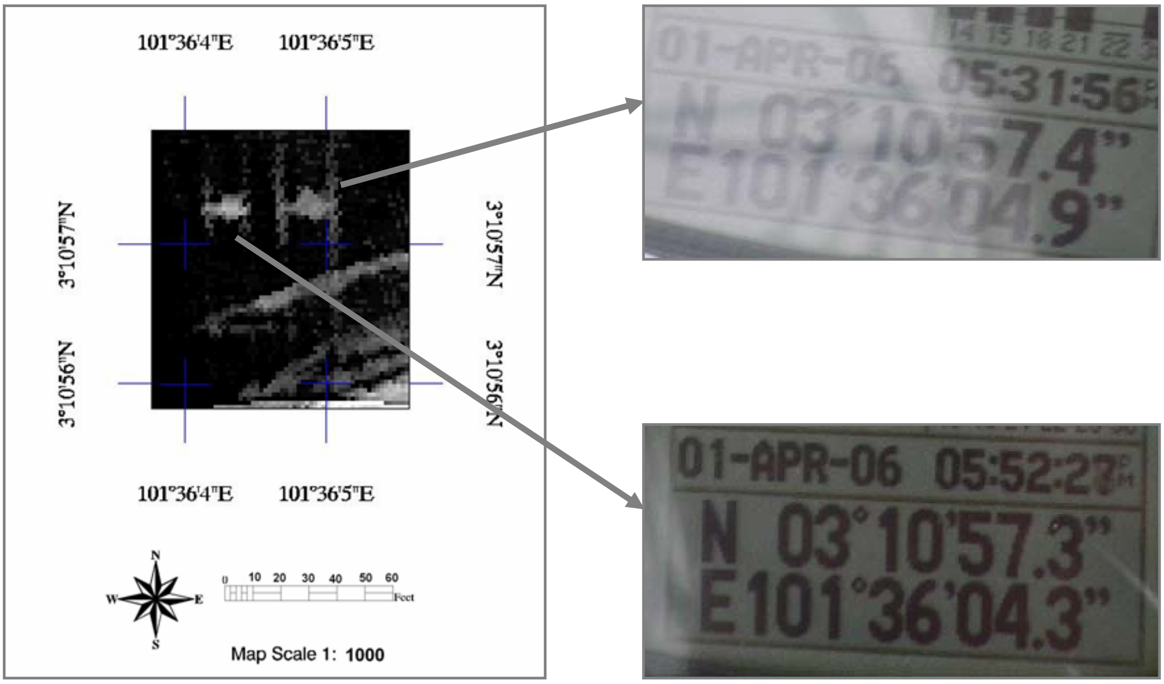

Figure 5. Field DGPS Readings of Power Transmission Lines Footings