Application of Satellite Image Processing to Earth Resistivity Map

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Abstract: - This paper proposes a useful technique for generating an earth resistivity map. Earth resistance is one of essential factors in a broad range of power system analysis and design. Information of earth resistivity is helpful for practical power system engineers in order to establish power system grounding. In this paper, a LANSAT7 image of a tested area of 50 km^2 was used by ENVI program in associative with a set of resistivity data obtained from field measurement. By using the maximum likelihood for supervised classification of a mixed band 7, 5 and 3, highest value of 85.71% confidence was obtained.

Key-Words: - Earth resistivity, Wenner method, Satellite image technology, Power system grounding, Classification technique, Multispectral

1 Introduction

Satellite images have found their several applications [1-5] in fields of agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence, warfare, weather forecast, electric power system, etc. Images can be in visible colors and in other spectra. To interpret and analyze satellite images, some efficient software packages like ERDAS or ENVI are necessary. All satellite images produced by NASA are published by Earth Observatory and are freely available to the public. Several other countries, nowadays, have satellite imaging programs, and a collaborative European effort launched the ERS and Envisat satellites carrying various sensors. There are also private companies that provide commercial satellite imagery. In the early 21st century satellite imagery became widely available when affordable, easy to use software with access to satellite imagery databases became offered by several companies and organizations.

Satellite Image Technology or Remote Sensing has guided the way to the development of hyperspectral and multispectral sensors around the world as a useful tool that can be used to map specific materials by detecting specific chemical and material bonds from satellite and airborne sensors. Multispectral data obtained in space by those sensors have been exploited extensively for the past several years in a wide range of research projects such as land cover and topographic mapping, physical and biological oceanography, archaeology, etc. Research has expanded to include analysis of hyperspectral data. acquired simultaneously in tens to hundreds of narrow channels. New algorithms have been developed both to exploit the spectral information of these sensors and to better deal with the computational demands of these enormous data sets. It is an excellent tool for environmental assessments, mineral mapping and land cover mapping, wildlife habitat monitoring and general land management studies. Multispectral imaging often can include large data sets and require specialized processing methods. In this paper, satellite images have been brought to estimate earth resistivity that can be used extensively in applications of power system grounding. Hyperspectral data sets of satellite images are generally composed of about 100 to 200 spectral bands of relatively narrow bandwidths (5-10 nm), whereas, multispectral data sets are usually composed of about 5 to 10 bands of relatively large bandwidths (70-400 nm). Actual detection of materials is dependent on the spectral coverage, spectral resolution, and signal-to-noise of the spectrometer, the abundance of the material and the strength of absorption features for that material in the wavelength region. In remote sensing situations, the surface materials mapped must be exposed in the optical surface and the diagnostic absorption features must be in regions of the spectrum that are reasonably transparent to the atmosphere. With these assumptions, it is possible to employ satellite images in order to visualize earth resistivity of the earth surface.

This paper consists of five main sections. Section 2 gives explanation of earth resistivity and its measurement. Section 3 covers a brief of satellite image processing. Results and discussion are put in Section 4. Section 5 presents a conclusion remark and further work.

2 Earth Resistivity and Its Measurement

Electrical equipment at all voltage levels must be earthed i.e. connected directly to an electrode driven or buried in the ground [6,7]. The resistance between the earth electrode is critical to the safety of equipment and personnel. Usually it must be less than 100 Ω e.g. 10 Ω for an overhead line pylon. This is not always possible because of the high resistivity of some earthy materials. Earth resistivity depends on the nature of the ground, moisture content and can vary substantially. Table 1 gave information of resistivity of various soil types.

Table 1 Resistivity of some soil materials

Materials	Resistivity (Ω·m)
Ashes	3.5
Clay soil – 40% moisture	7.7
Clay soil – 20% moisture	33
Clay – London	4-20
Clay – very dry	50-150
Chalk	50-150
Coke	0.2-8
Consolidated Sedimentary rocks	10-500
Garden earth 50% moisture	14
Garden earth 20% moisture	48
Gravel - well graded	900-1000
Gravel - poorly graded	1000-2500
Gravel clay mixture	50-400
Peat	45-200
Sand - 90% moisture	130
Sand - normal moisture	300-800
Sand clay mixture	200-400
Surface Limestone	100-10,000

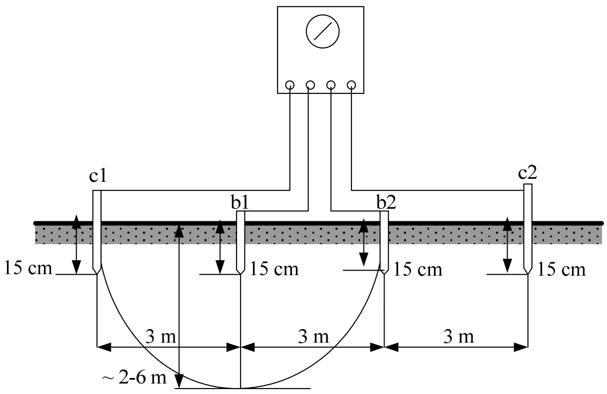

Fig. 1 Measurement of the four point method

Several methods exist to measure the earth resistance and impedance, earth resistivity and potential gradients from ground current. It is recommended that were possible the four point method (Wenner method) be used. When carrying out measurements it should be remembered that earth resistivity varies with salt contents, moisture content and temperature. Care should be taken when carrying out earth measurements as large potentials can exist between the station earth tests and remote earth's if a power system fault occurs. Four electrodes are spaced apart as shown in Fig. 1 (equally spaced or Wenner arrangement). A disadvantage of the Wenner method is the rapid decrease in potential when the spacing is increased to large values. Often commercial instruments are inadequate at measuring such low values.

3 Satellite Imaging Techniques

As mentioned previously, this paper was based on aerial picture analysis. The source of these pictures came from two main sources: i) satellite images from LANDSAT and topographic map based on topographical surveys.

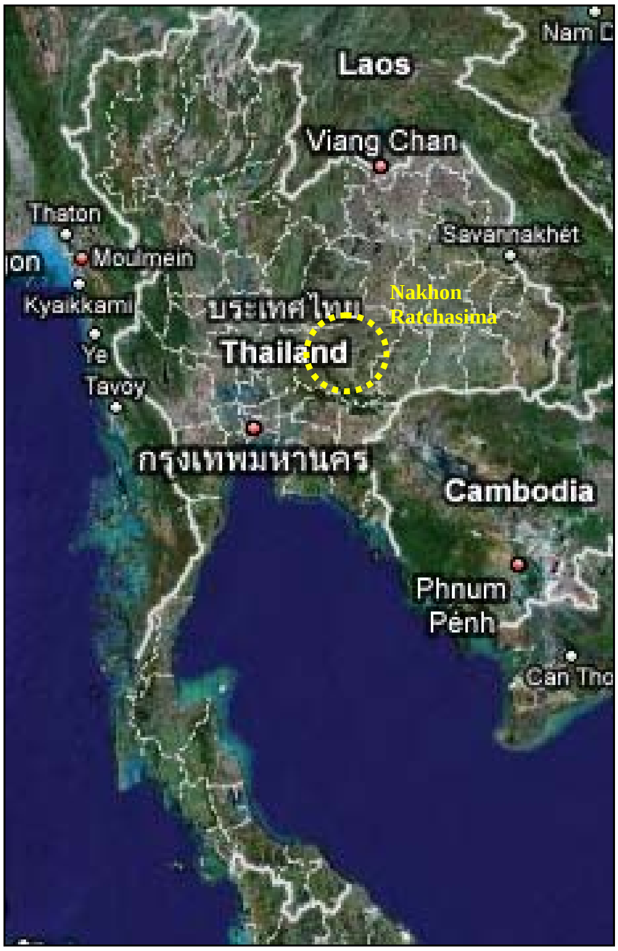

Fig. 2 Satellite image covering Thailand [8]

3.1 LANDSAT Imaging

A latest LANDSAT, LANDSAT 7, was launched in April 1999 [10]. It has a unique and essential role in the realm of earth observing satellites in orbit. The earth observing sensors on LANDSAT 7, the enhanced thematic mapper plus (ETM+), replicates the capabilities of the thematic mapper instrument on LANDSAT 4 and 5. The ETM+ also includes new features that make it a more versatile and efficient instrument for global change studies, land cover monitoring and assessment and large area mapping. The primary new features on Landsat 7 are: i) a panchromatic band with 15m spatial resolution, ii) on board, full aperture, 5% absolute radiometric calibration and iii) a thermal IR channel with 60m spatial resolution. Fig. 2 showed a satellite image covering Thailand [8]. As mentioned earlier the dot circle is the area of study in this paper. Fig. 3 gave a close view inside the circle of Fig. 2. It revealed city of Nakhon Ratchasima from the space.

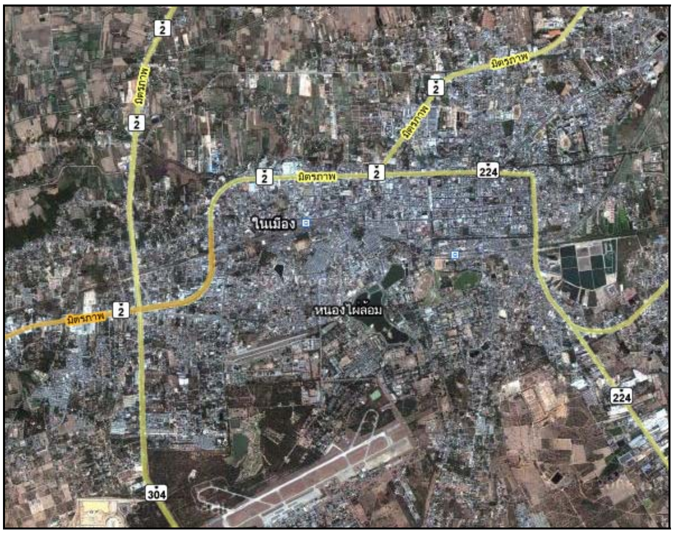

Fig. 3 Satellite image of City of Nakhon Ratchasima [8]

3.2 Classification Techniques

In order to obtained information of earth resistivity from the satellite image, two methods of classification are commonly used: unsupervised and supervised classifications [9]. In unsupervised classification any individual pixel is compared to each discrete cluster to see which one it is closest to. A map of all pixels in the image, classified as to which cluster each pixel is most likely to belong, is produced (in black and white or more commonly in colors assigned to each cluster). In a supervised classification the interpreter knows beforehand what classes, etc. are present and where each is in one to perhaps many locations within the scene. These are located on the image, areas containing examples of the class are circumscribed (making them training sites), and the statistical analysis is performed on the multiband data for each such class. All pixels in the image lying outside training sites are then compared with the class discriminants derived from the training sites, with each being assigned to the class it is closest to - this makes a map of established classes (with a few pixels usually remaining unknown) which can be reasonably accurate (but some classes present may not have been set up; or some pixels are misclassified.

4 Results and Discussion

This research was conducted by using ENVI software as an image processing tool for extracting earth resistivity from the satellite data. A LANSAT 7 image of a tested area of 50 km^2 as shown in Fig. 4 was used for test.

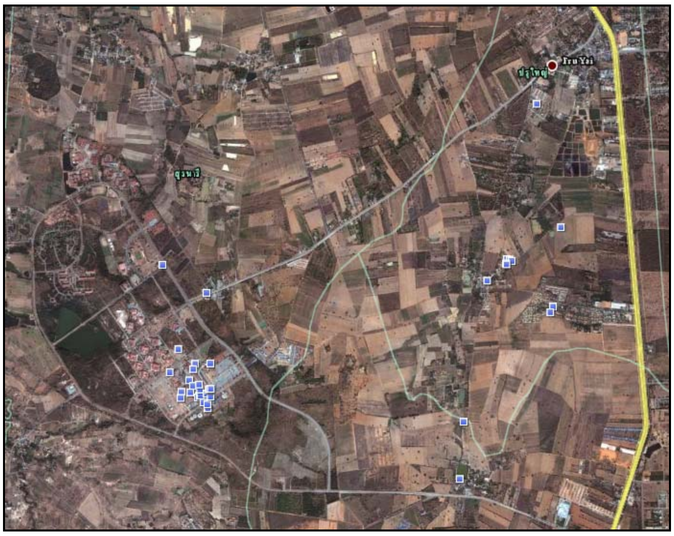

Fig. 4 Satellite image of the test area

A satellite image acquired from LANSAT 7 consists of eight spectral bands with spatial resolutions ranging from 15 – 60 meters. To create earth resistivity map, five mixed bands were prepared for supervised classification as follows.

1. Bands 4-3-2
2. Bands 4-5-3
3. Bands 4-5-7
4. Bands 7-4-3
5. Bands 7-5-3

Table 2 Result of confidence level

Mixed bands	Confidence level (%)
4-3-2	64.29
4-5-3	57.14
4-5-7	71.43
7-4-3	71.43
7-5-3	85.71

50 test locations were selected and then measured for earth resistivity. 36 of all were used as input of supervised training process, while 14 left were used for verifying the effectiveness of the earth resistivity classification. Figs 5 – 9 showed visualization of five respective mixed bands as described earlier. Fig. 10 presented the earth resistivity map of the test area. This picture was selected from the mixed bands that gave the best estimation of the earth resistivity result. Table 2

gave results of evaluation of confidence level from the supervised classification. The results showed that the mixed bands of 7-5-3 gave the best of 85.71% confidence. The mix of bands 4-5-3 was the worst result of 57.14% confidence.

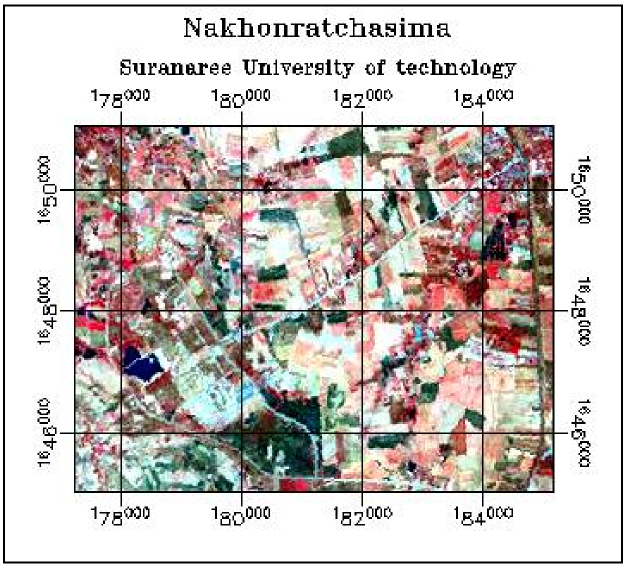

Fig. 5 Color rendering of the mixed bands 4-3-2

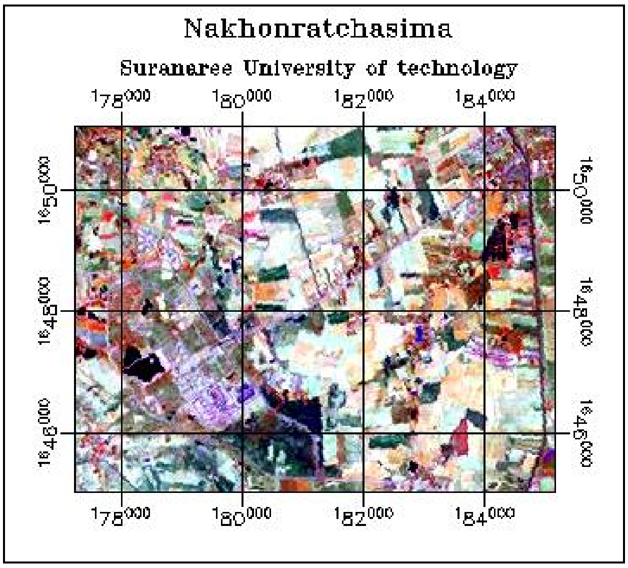

Fig. 6 Color rendering of the mixed bands 4-5-3

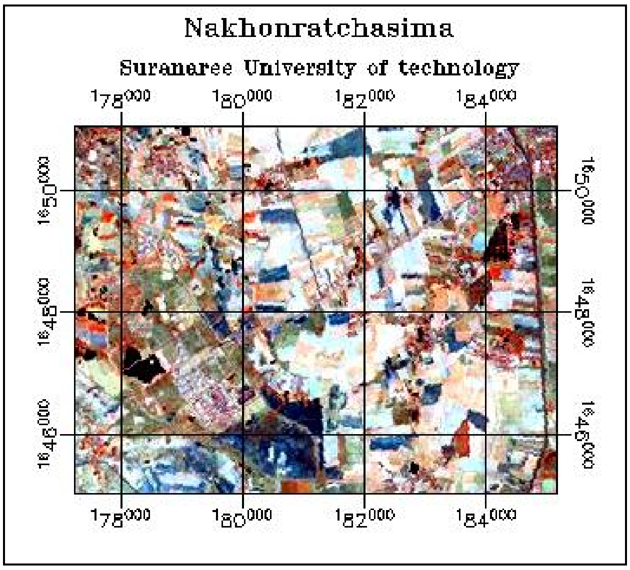

Fig. 7 Color rendering of the mixed bands 4-5-7

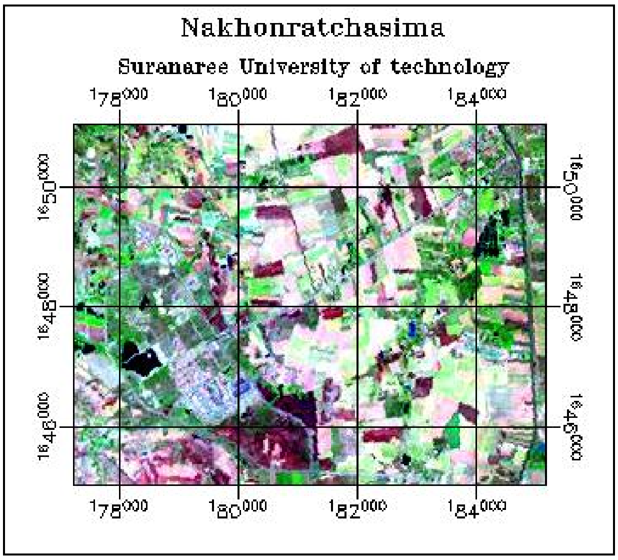

Fig. 8 Color rendering of the mixed bands 7-4-3

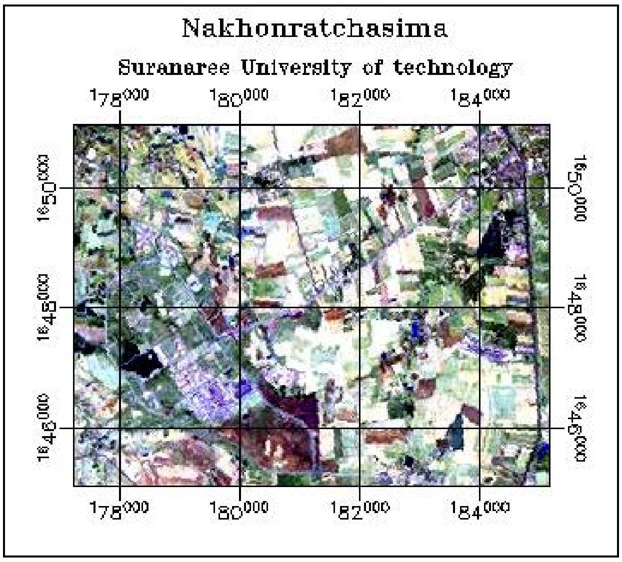

Fig. 9 Color rendering of the mixed bands 7-5-3

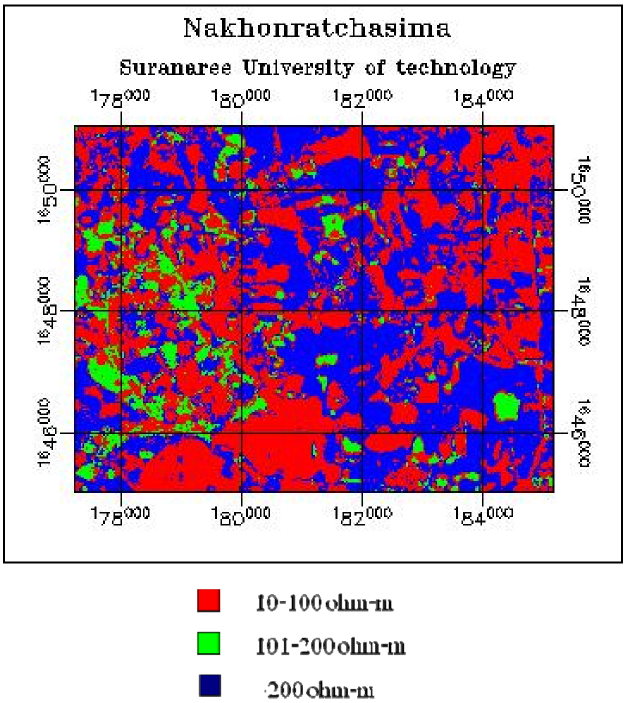

Fig. 10 Earth resistivity map of the mixed bands 7-5-3

5 Conclusion

This paper presented a satellite imaging technique of estimating earth resistivity. A 50-km^2 satellite image acquired by LANSAT 7 of the test area was used by ENVI program in associative with a set of resistivity data obtained from field measurement in order to evaluate the proposed scheme. By using the maximum likelihood for supervised classification of a mixed band 7, 5 and 3, highest value of 85.71% confidence was obtained. The earth resistivity can be exploited in various fields, for example, power system grounding, lightning, ground fault protection, etc, in both transmission and distribution levels.

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