

Uncover Fully Ignored Vital Bathymetric Data Mysteriously Hidden in Digital Elevation Model Combining with Remote Sensing Imagery (Part 1: Methodology and Theoretical Interpretation)

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Abstract This is an interdisciplinary research to uncover a miss-observed and very important phenomenon in remote sensing. The high valuable bathymetric data hidden in digital elevation models have completely been ignored by scientists and researchers including main organizations in the world for a long time. The contents have been classified into two parts to demonstrate them. In the part 1, the focus is on introducing a special technique of discovering bathymetric data of lakes and rivers by means of remote sensing Image processing and the fact of water depths found in seeking for a resolution to water pollution for a large scale inland lake. The further performance is in analysing causes starting from radar interferometry. The more attentions are paid to how the microwave emitted and received by antennas of synthetic aperture radar installed in satellites during its propagation and scattering back interacts with molecules of chemical compounds in water body using spectral analysis in spectroscopy such as Raman scattering, nuclear magnetic resonance combining with knowledge of quantum mechanics and physical chemistry. The causes of losing those data have been found from phase shifting interferometry during phase detection and terrain mapping. The outcomes of this research have proved a fact that the capacity of microwave detecting depths of water relies on molecular structure, communication and strength of external electromagnetic fields and bathymetric data could also exist near sea coast. Research not only offered difference between optical imaging and radar imaging but also established correlation of effectively using individual data.

Keywords Bathymetric modelling, Chemical analysis, Chemical compounds, Digital elevation models, Electromagnetic fields, extinction coefficients, Image processing, Lakes, Microwave propagation, Microwave antennas, Microwave imaging, Microwave technology, Molecular communication, Molecular structure, Nuclear magnetic resonance, Optical imaging, Phase detection, Phase shifting interferometry, Physical chemistry, Quantum mechanics, Radar imaging, Radar interferometry, Radar remote sensing, Raman scattering, Remote sensing, Rivers, Satellites, Sea coast, Spectroscopy, Spectral analysis, Synthetic aperture radar, Terrain mapping, Water pollution

1. Introduction

1.1. A Very Crucial and Intricate Doubt Raised from One Bathymetric Modelling

There is a very important phenomenon in remote sensing, thus a long-term explored and highly desired bathymetric data secretly hidden in DEM (digital elevation models), which has rarely been mentioned or even fully ignored by researchers and scientists in the world for several decades.

Author accidentally discovered the phenomenon when modelled depths of water body in a fully polluted large-scale

inland lake making use of a unique technique created by author for other purposes initially [1].

Because the discoveries are full of not only crucial and practical significances but also mysterious doubts, it is quite necessary to review this special case again before explaining the phenomenon from the view of diverse theories.

This large scale inland lake is located at the following geographical location and named Dian Chi in China.

24°58'10" N	102°34'45" W
24°39'45" S	102°47'45" E

The pranchromatic sharpened remote sensing imagery and the corresponding DEM is represented in Fig. 1 and Fig. 2 respectively. Applying author's technique into dealing with this lake by means of integrating DEM with the remote

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sensing imagery of the lake, the technique is to be introduced in the subsections later, the outcome is much surprised. The elevations of water body can be completely obtained and even displayed by setting the bottom of lake water body up (see Fig. 3). Of course, it is impossible to carry out such behaviour in reality. In order to conveniently measure the absolute depths of water body, the same data of water body are set face and bottom up in two separate figures respectively, accordingly it is a special mathematic treatment for handling the elevation-based bathymetric data. The detailed explanations of this procedure are also supplied in author's research paper [1].

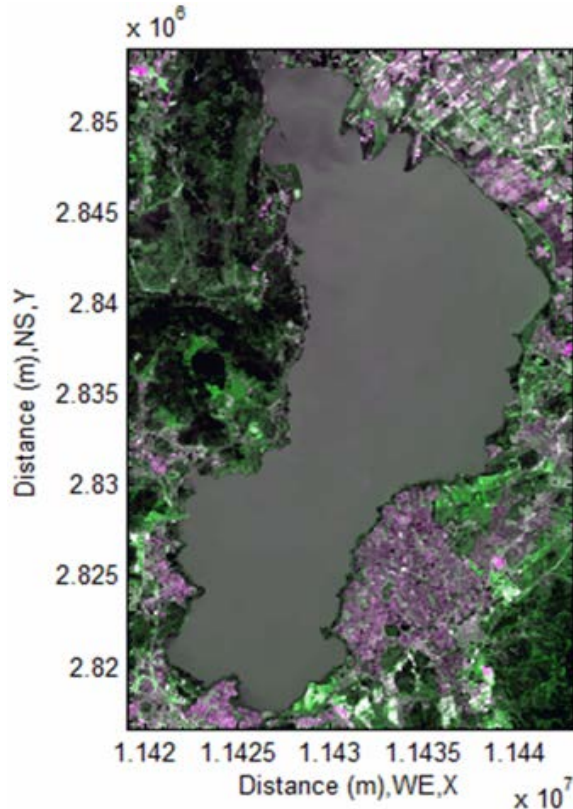


Figure 1. A fully polluted large scale inland lake (1249×805)

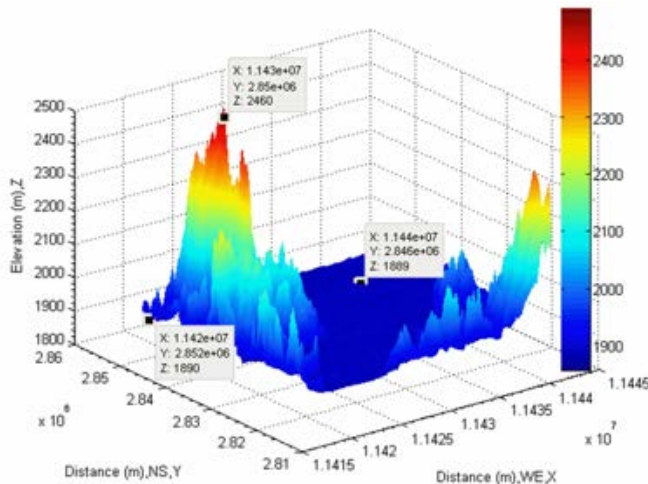


Figure 2. The corresponding DEM of a fully polluted large scale lake (1249×805)

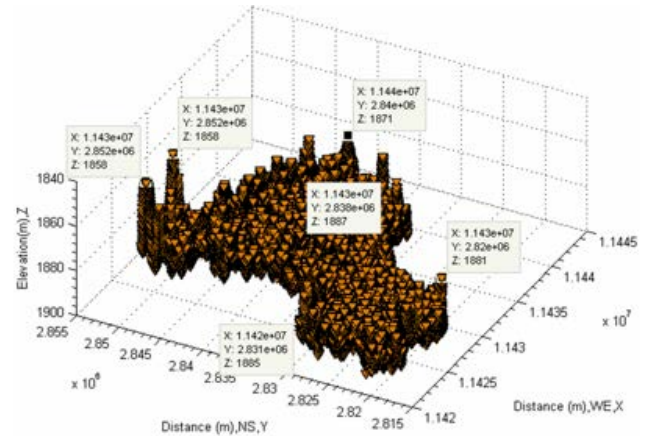


Figure 3. The elevations of water body are displayed by bottom-up

However, an extremely vital doubt is then raised from the data of water body hidden in DEM. How does DEM have such important data? Are they reliable? Do the bathymetric data hidden in DEM exist in other water bodies in other lakes, rivers and near coast? In order to seek for a solution to these arcane doubts, author did the massive literature reviews which are to be briefly introduced as follows.

1.2. Bathymetric Modelling Reviews

Although over thousands reports about bathymetric modelling exist in the world, all of these researches in the process of detecting depths of inland water body or seawater are based on the passive optical remote sensing imageries [2, 3]. However, those researchers may not fully understand the mechanism of how the intensity of incident solar radiation is affected by water body at ground level besides the atmospheric factors. In fact, the depths of water body obtained from this approach is not reliable.

The reasons are specified as follows.

1. The backscattered electromagnetic waves (or say signals in electronic engineering) from water body are seriously affected by water and other substances existing in the water body before they leave the water surface. Hence, the signals leaving the water surface are influenced by the water temperature, pressure and concentration of substances in water body. Those parameters can be finally expressed by the term: *attenuation coefficient* or say *extinction coefficient*. The water body can be considered as a system containing many diverse components (or say pollutants) with the varying temperature-dependent heat capacity at the constant pressure in terms of the thermodynamics. The varying temperature is a temperature gradient with respect to the variation of depths of water body in the vertical direction, which is caused by the heat adsorption of water body from incident solar radiation. Thus there must be a layer in lakes, rivers and sea or ocean due to different diffusion and conduction coefficients of components in water body according to theories of transport

phenomena [4].

2. The attenuation coefficient is unevenly distributed in the water body because the water mixture in rivers or lakes including seawater is a flowing fluid.
3. On the other hand, the signals are also affected by atmospheric layer before they are captured by sensors installed in satellites. The reflectance must be treated by atmospheric correction before it is used into the calculation. In order for users to conveniently use the products of reflectance, NASA MODIS provides several reflectance data without considering atmospheric correction [5, 6].
4. If both mean attenuation coefficient and individual reflectance are applied into a commonly used Beer-Lambert equation to seek for so-called depths of water body, on the basis of above factors, this approach is very unreliable. The obtained distances in such an approach are in nature the penetrations of solar light rather than the real depths of water body.

Furthermore, based on those concepts, other approaches in seeking for depths, geometric shape and the quantity of water body [7-11] are unreliable either. These researchers failed to tell the absolute depths of water body. So-called depths which they found and derived water storage of water body are usually based on the variation of seasonally measured water level sampled at banks of lakes or rivers. Thereby, the figures they obtained are not the absolute depths of water body at all.

1.3. Radar Backscattered Wave Modelling Reviews

Radar is a very powerful tool in detecting some unknown physical phenomena by means of emitting microwave within certain regions (bands) from about 1mm to 1.3 m [12]. The emitted microwave from the antenna of a radar installed in one high-speed flying platform in space is capable of transmitting through clouds at day and night [13]. Thus, it has weather-independent working functionalities. Accordingly, it is already widely used in the fields in detecting such as Crop [14], oceanic surface waves [15-17], tidal current [18], ice [19, 20], canopy [21], soil [22-24], cloud [25], desert surface [26], wind wave [27], fresh water [28, 29] and snowflake [30] and so on.

Nevertheless, in above mentioned reports, researchers hardly discussed the mechanisms of how the backscattered wave being formed and generated when the electromagnetic wave emitted by radar impacts upon the observed objects (scatters) at the *molecular* level. The reason could be that such a study at molecular level is already beyond the research scopes of their interests for radar engineering based researchers. Hence their focuses are only on either the effect of geometric shape and speed of observed objects on the physical properties of the backscattered wave or microwave being polarized near antenna and targets [31] rather than the physicochemical properties raised from the interaction between molecules consisting in the observed objects and electromagnetic wave. The latter belongs to the domain of

quantum chemistry (quantum mechanics), analytical chemistry or physical chemistry. Even if there was a report about microwave acting on substance issued by one former U.S.S.R. scientist in 1964, however, the focus was on how the atom of solid substance is ionized in the strong field of electromagnetic wave [32] other than liquid.

Similarly, such a topic is less mentioned or discussed in some remote sensing books [12, 33-38], specific reports and books [31, 39-44] and radar engineering books [45, 46].

In short, the topic of the electromagnetic wave acting on molecules consisting in the observed objects has almost ignored by scientists and researchers in the radar engineering or relevant fields due to the limitation of research scope.

1.4. Brief Summary of Literature Reviews for Radar Backscattered Wave

Strictly speaking, in terms of classification of research field, studying the physicochemical properties change of molecules raised from the interaction between molecules and electromagnetic wave belongs to the domain on which the chemists focus. However, it gives rise to a series of difficulties and problems in investigating phenomena generated by remote sensing technology.

Difficulties and Gap

1. Although chemists have specific knowledge to be capable of interpreting the phenomenon which is already ignored by both radar researchers and GIS (Geographic Information System) researchers, they are more interested in the laboratory-scale research than the large-scale one. Furthermore, chemists may not have much knowledge in GIS.
2. The radar researchers pay less attention to GIS and the interaction between molecules of observed substances and electromagnetic wave.
3. GIS researchers may not feel interested in molecular structure and radar engineering.
4. The further problem is that even if they know the concerned topics well, they may fail to provide engineers in other fields such as hydraulic engineering, environmental engineering and civil engineering with desired data and information extracted from remote sensing.

Such a gap amongst the research fields directly results in a fact that some important phenomena and hidden data have been fully ignored and "lost" due to the disconnection of interdisciplinary knowledge in the process of studying remote sensing.

1.5. Objectives of Research

As seen from above summary, this research is therefore to concentrate on trying to fill specific knowledge into the gap in this field, namely discovering and demonstrating the vital bathymetric data hidden in DEM by means of smoothly connecting interdisciplinary knowledge based on the existing fact and the technique of extracting the useful data

which can be further applied into diverse applications.

In order for ones to easily and systematically understand them, the contents of this research are grouped into two parts in this paper. The objectives to be performed in the part 1 are those

1. Showing a very important case which was discovered by bathymetrically modelling a fully polluted large-scale inland lake. This significant case gave rise to a very important doubt which is to be further explored and interpreted by the current research.
2. Introducing a specific technique which was created by author and used to discover some unknown facts. In this section, the fundamental principle and scope of the existing and potential applications to be briefly introduced.
3. Understanding how DEM is produced. Firstly, the basic principle of how the SAR (Synthetic Aperture Radar) works is to be presented starting from the basic concepts of electromagnetic wave. Secondly, the technique of InSAR (Interferometric Synthetic Aperture Radar), which generates DEM from two interferometric radar images is to be introduced afterwards.
4. Implementing a bridging introduction of interaction between electromagnetic wave and molecules in water body within a same geographic environment so as to easily connect two different disciplines.
5. Eventually the theoretical explanations for the existing phenomenon and its hidden data are to be performed by using the knowledge of physical chemistry containing some specific knowledge of quantum chemistry and analytical chemistry.
6. On the basis of the reasonable theoretical explanations, it can be concluded that such a phenomenon and its hidden bathymetric data exists in all lakes and rivers in the world. The further conclusion is that it can be also extended to the seawater near coast.
7. Furthermore, a comprehensive summary including difference between optical and radar imaging and further consideration topic are supplied in the conclusion respectively based on the theoretical exploration.

Once above objectives are achieved, the more evidences and further discussions and conclusions are to be provided and carried out respectively in the part 2 of this research.

2. Technique of Integrating Remote Sensing Imagery with DEM

In this section, the several basic concepts of the technique created by author is to be introduced as follows.

2.1. Interactive Data Transferred within Two Systems

In general, Fig. 4 offers several basic concepts of how to

build an algorithm to extract the information and data from two different systems (thus remote sensing imagery and DEM). And then, in terms of specific requirements to classify observed object in a given remote sensing imagery.

However, it may need more words to explain their correlation between two systems. At first, mathematically speaking, so-called system actually is a matrix. As well known, the remote sensing imagery is made by one platform (such as satellite). The signals reflected from the ground in the form of electromagnetic wave are captured by the sensor installed in the platform. The received electromagnetic wave is digitalized and signal is then stored into matrix-like cells according to the intensities of received photons under a certain voltage, hence in a matrix array of charge-coupled device (CCD) [13, 47]. Therefore a digital remote sensing imagery is formed when the platform flies over one geographic location within a time interval.

Although DEM made by InSAR installed in other platform which may be different from the optical imaging platform and the functionalities between digital imagery and DEM are completely different, for a digital remote sensing imagery and DEM, their correlations can be mathematically established by means of the following facts:

1. They have the same geographic location, the time may not be important for a general application.
2. They are all built on a matrix. The dimensions of matrix are adjustable under the condition of remaining the same geographic location. Geographically or physically speaking, such an approach does not affect the quality of any modelling because the real geographic location of observed objects such as terrain and lake are not changed in the process of adjusting dimensions of matrix. It is only a mathematical treatment at this stage. Such a mathematical treatment is very analogous to the case of mathematically assigning different geographic coordinate systems to the earth such as WGS 1984. But it is unnecessary to discuss such an issue, the reason is that the performance to be carried out in the research is based on the geographic coordinate system which was already chosen by DEM and remote sensing images designers and providers.

Once the correlation between two different systems is mathematically established, the functionalities in applications are more powerful than the ones generated by each individually. In other words, all functionalities owned by each can be not only fully utilised but also their seamless combination are able to produce many applications in many diverse fields. Author has successfully modelled a very complicated process of bushfire spread in landscape including the quantitative calculation of mass (pollutants) and heat (bushfire) emission ratio, smoke spatial dispersion [48]. The applications were already extended to accurately modelling floodplain [49] and bathymetrically modelling [1]. Unfortunately, most researchers in the world are still singly

using those data, waste too much.

2.2. Interactive Data Transferred within Diverse Systems and Applications

Although Fig. 4 precisely demonstrate some basic concepts of integrating two different systems. In fact, those concepts can be further developed by using more interdisciplinary knowledge and the skills which were already discovered and utilised in the previous practices.

Based on the same mathematical principle of treating data, the different data supplied by more than two platforms can be combined together. For instance, physical parameter: *reflectance* can be added into the dual system of remote sensing imagery and DEM to model and investigate the

degree of water being polluted [1].

Based on the mechanisms of how the devices installed in the platforms works, some unknown matters are able to be discovered in diverse researches. Fig. 5 provides more approaches and procedures of how to discover fully ignored data hidden in DEM in terms of Fig. 4. There must be more applications in other fields to be produced. However, in this research, the focus is only on discussing how the bathymetric data hidden in DEM are formed and found.

Furthermore, one very important issue which must be taken care of in the process of performing such an approach is that make sure the dimensions of the individual matrix generated from the different systems always remain the same. Otherwise, treating diverse data is impossible to be handled.

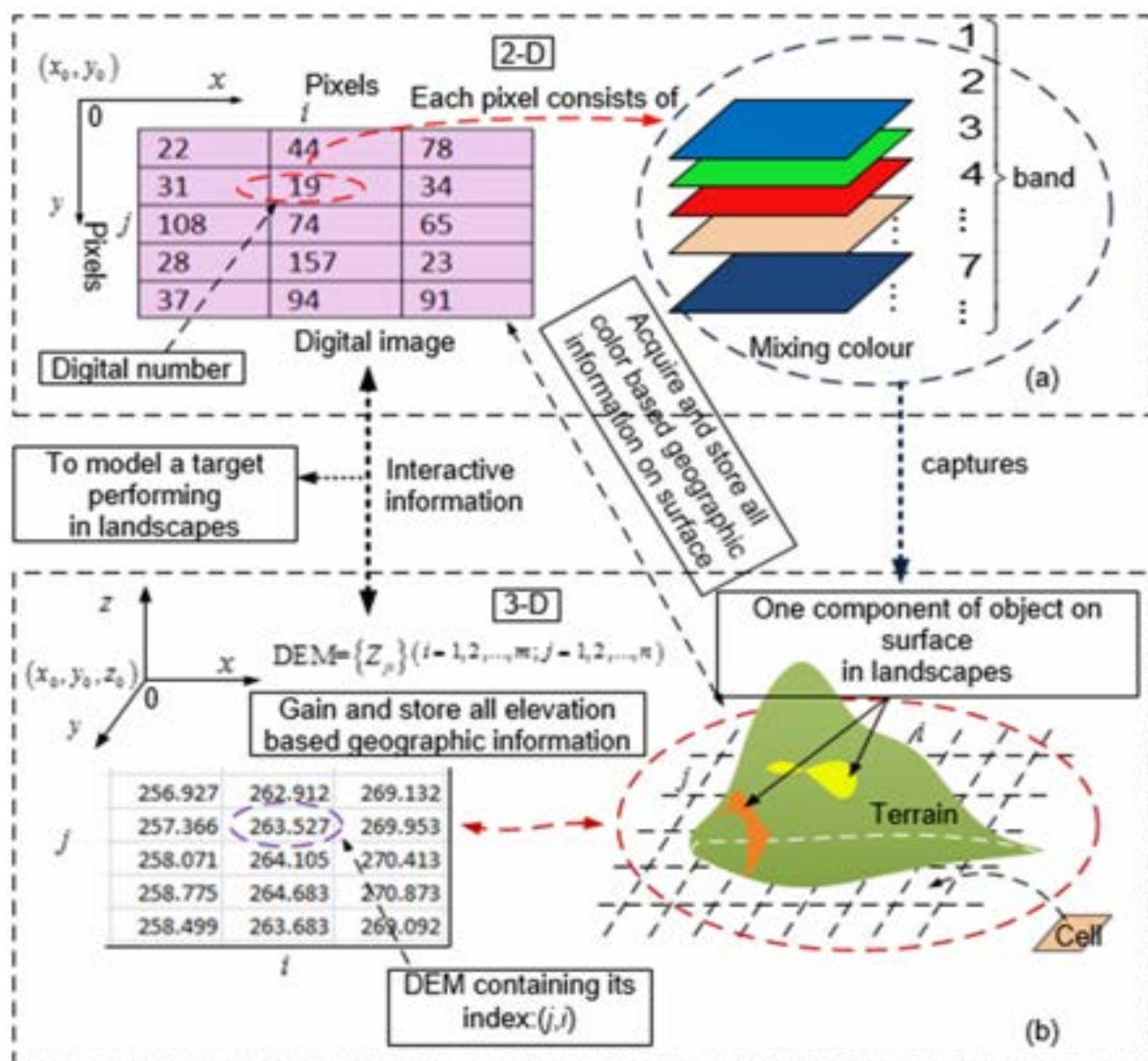
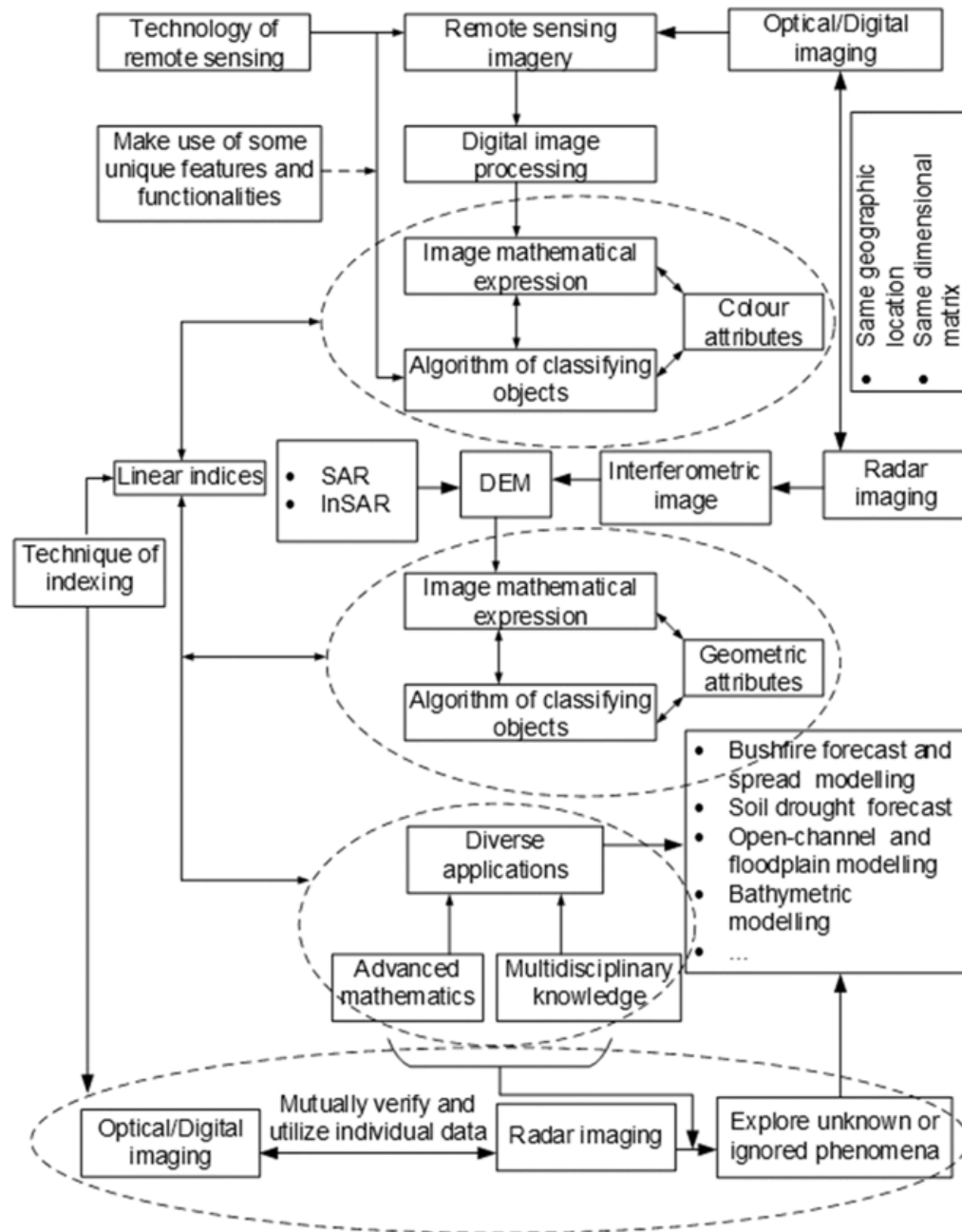


Figure 4. The principle of integrating remote sensing imagery with the corresponding DEM



2.3. Detect Water Body in one Remote Sensing Imagery and Display Detected Data into DEM

In above sections, the main principle of how to extensively use remote sensing imagery and DEM is already introduced.

In this section, the procedure of how to deal with dual system is depicted as follows.

1. At first, one remote sensing imagery and the corresponding DEM is chosen. Applying one designed algorithm into the remote sensing imagery. In this case, the remote sensing imagery containing a fully polluted lake (see Fig. 1) is selected. The detected lake coloured by red is shown in Fig. 6.
2. The detected lake have to be inserted in the

corresponding DEM (see Fig. 2). In order to clearly visualize, the detected data of lake are added 120 meters into them before they are transferred into DEM. Finally, DEM containing transferred data of detected lake is represented in Fig. 7. At this stage, the visualized data not only contain information owned by the remote sensing imagery but also have the intrinsic properties owned by DEM (see Fig. 5). These individual properties can be further developed on demand. However, individual data and information can be accurately transferred and displayed mutually as did above. The reason why the performance is so accurate is the linear indices play a crucial role in this process. The definition of linear

index can be found in the user's manual of MATLAB®.

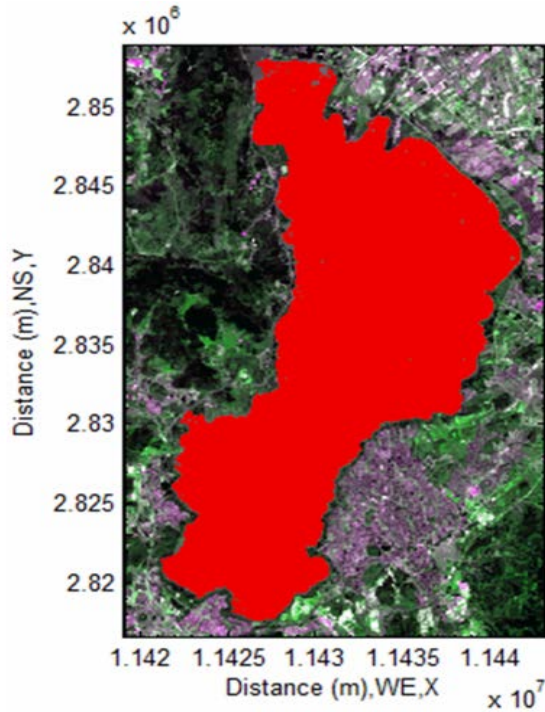


Figure 6. The detected water body of a fully polluted lake (1249×805)

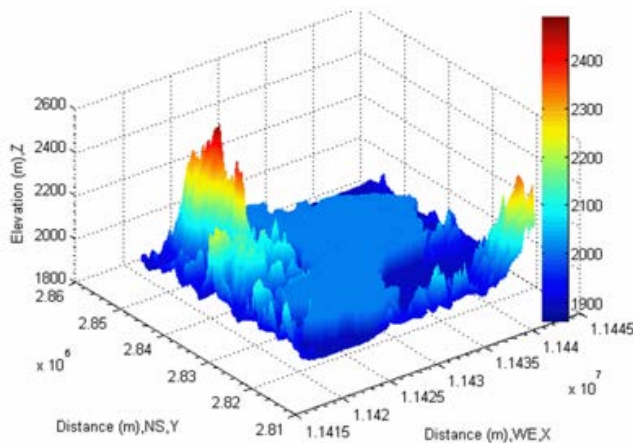


Figure 7. Display detected water body into the corresponding DEM (1249×805)

In this case, of importance is that the figure shown in Fig. 7 contains the bathymetric data hidden in DEM which is expressed by elevation and to be uncovered in the following subsections.

Up to this point, main necessary information for explaining this hardly discovered phenomenon are already offered. In the following two sections, the focus is to be located on explanation from the angle of traditional physics and physical chemistry. The basic theories of electromagnetic wave can be obtained from some text books of traditional physics [50]. As to physical chemistry, for ones who never learned it, it may be difficult to understand some

relevant contents. Physical chemistry is a very important subject rather than physics plus chemistry, which studies chemical phenomena by means of physical manners and contains too many diverse theoretical contents ranging from macro-behaviours to micro-structures of molecules and atoms. The most popular and useful text books [47, 51] can be referred if necessary before reading some high-level contents in the later subsections, because the relevant contents to be briefly mentioned is used to quickly explain above phenomenon on the basis of the well-known and approved diverse theories and facts.

3. Generation of DEM Using InSAR

3.1. Basic Concepts of Electromagnetic Wave and Spectra

Electromagnetic Wave

The electromagnetic wave (or say electromagnetic radiation) may be a well-known term in traditional physics. The light is one form of electromagnetic wave travelling in free space at the speed of 2.998×10^8 m/s. The electromagnetic wave is already and massively involved in the applications of interdisciplinary researches.

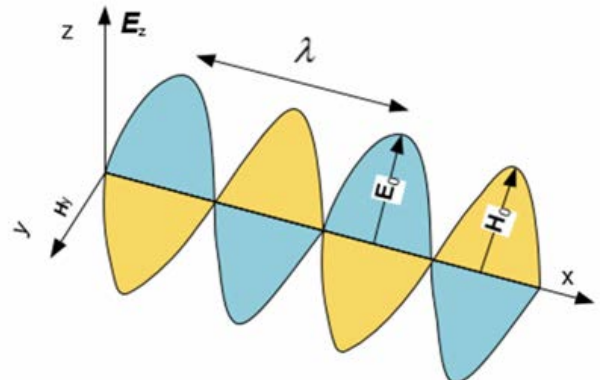


Figure 8. Electromagnetic wave

The electromagnetic wave consists of an oscillating electric field E and an oscillating magnetic field H (see Fig. 8). These oscillating fields are vectors and in phase at right angle (90°) to each other. They can be expressed by the following correlation [50].

$$\begin{cases} E_z = E_0 \sin(\omega t - \phi_e) \\ H_y = H_0 \sin(\omega t - \phi_h) \end{cases} \quad (1)$$

Where t (s) is the transmitting time of phase change, E_0 and H_0 are the amplitudes of the fields, ϕ_e and ϕ_h are their phase angles. The subscript e and h denotes electric field and magnetic field respectively, ω (rad/s) is the radian frequency, which can be expressed by the following relationship using parameters: measured frequency f (Hz), the duration of one period of its oscillation T (s) and wave length λ (m) and the velocity of light c .

$$\begin{cases} \omega = 2\pi f \\ f = \frac{1}{T} \\ f = \frac{c}{\lambda} \end{cases} \quad (2)$$

Spectra Required by Devices Designers

The electromagnetic wave is capable of being produced by specific devices such as laser and radar. However, sensor is designed to receive electromagnetic wave. Those physical devices are designed according to their individual applied purposes. Because of the difference of application purposes, the following fundamental factors must be taken into account before engineers and scientists start to design specific physical devices.

1. Which the region (band) of electromagnetic wave is able to detect observed objects and obtain the desired physical properties reflected from the scatters?
2. How to design the device to produce or receive such band of electromagnetic wave and so on.

In fact, to gain solution to above factors, it requires a spectra to obey and then perform detailed sub-tasks. The spectra shown by Fig. 9 is adopted from textbook of physical chemistry [47] and modified in terms of the text book of molecular spectroscopy [52] by adding molecular behaviours under laboratorial conditions at the bottom line of the spectra.

Based on this spectra a series of satellites and radars with different functionalities have been designed and produced in the world.

Spectra Required by Users

The remote sensing imageries and DEM are products produced by satellites and radars respectively and distributed by official organizations such as NASA and USGS for international users. Therefore, users have to know spectra too before learning how to their products. However, the spectra are employed by massive knowledge, which are to be seen later.

As indicated above somewhat, under the analytical conditions, some ranges of spectrum could vary slightly from the ones under static conditions. Although measuring samples in the analytical devices is a small-scale dynamic process, it is much closed to the large-scale topic which is concerned in this research and to be introduced in the last part of this paper in detail.

In this research, the spectra is often referred and used to understand not only how the electromagnetic wave (microwave) emitted by the antenna installed in platform imposes on the observed objects but also how the molecules consisting in the observed substances (scatters) are influenced by the external microwave and then emit their electromagnetic wave having different frequencies within a chemical environment. Therefore, it is very useful and extremely important in practice.

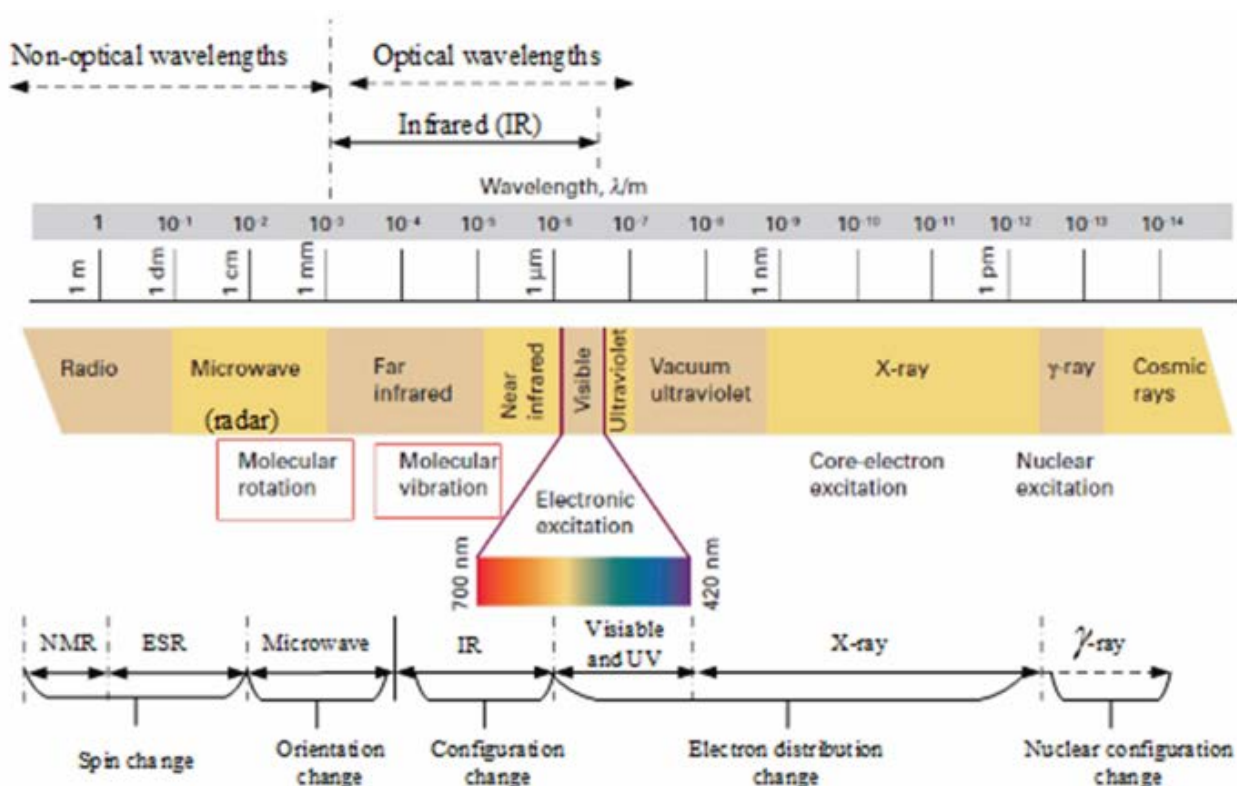


Figure 9. Electromagnetic spectra

3.2. Fundamentals of SAR

Flying Trajectory of Platform

Before introducing how DEM is finally made, it is necessary to know how SAR works when it performs radar imaging. The SAR is installed in a platform flying along one specific orbit in space. A series of electromagnetic waves are emitted by the antenna installed in the platform in the form of pulse (see Fig. 10). The receiver of signal can be in the same antenna or other antenna. Thus, the receiver or transmitter can be installed at the same antenna or different antennas [40, 53].

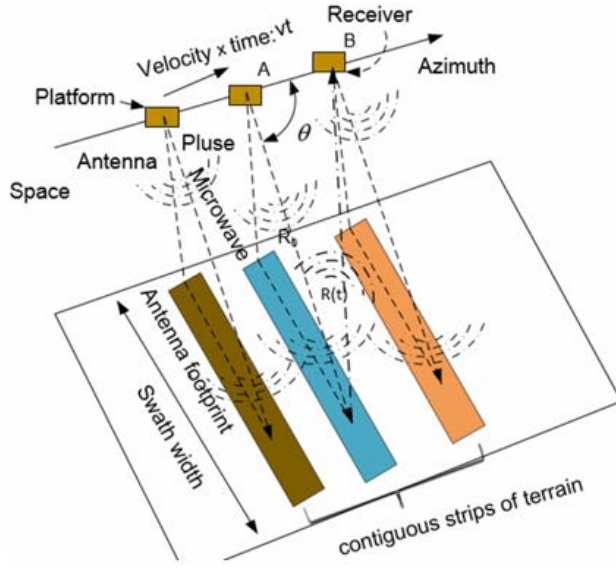


Figure 10. The working principle of SAR (Synthetic Aperture Radar) to build interferometric radar imagery

During the period of platform flying over one region along a given azimuth, the terrain is scanned strip by strip. Each contiguous strip have a constant swath width formed by the antenna footprint (see Fig. 10).

Spatial Geometrical Calculation

The spatial geometrical calculation of flying trajectory between the positions in space and the ones at ground is performed as follows.

Assume that the platform flies along one direction of AB at the velocity v , in the time t later, the distance R between the antenna (or platform) and the scatters can be estimated by

$$R(t) = \sqrt{R_0^2 + (vt)^2 - 2R_0vt \cos \theta} \quad (3)$$

$$\approx R_0 - vt \cos \theta + \frac{(vt \sin \theta)^2}{2R_0}$$

Where R_0 is the initial distance between the antenna and the targets to which the radar signal is emitted at the ground, θ is an angle between the direction of flying platform and the one of the radar signal against the targets at ground.

The distance change of radar signal travelling along the

dual distance (thus, the electromagnetic wave travels forward and backward between the antenna and the scatters) within a time interval t can be written as

$$\Delta R = 2[R_0 - R(t)]$$

$$\approx 2vt \cos \theta - \frac{(vt \sin \theta)^2}{R_0} \quad (4)$$

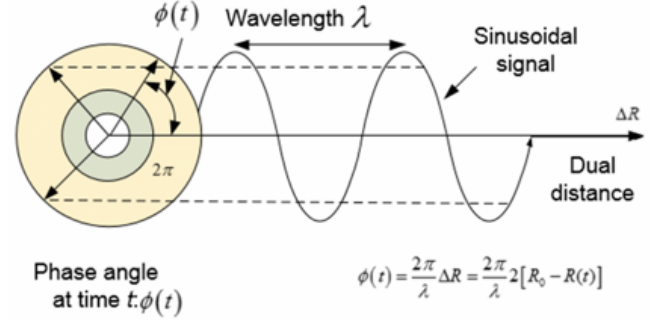


Figure 11. The Output phase of received signals

Phase Output and Doppler Shift

The distance change ΔR is then converted to the output of phase in the receiver with respect to the time t : $\phi(t)$ (see Fig. 11) and shown as follows.

$$\phi(t) = \frac{2\pi}{\lambda} \Delta R$$

$$\approx \frac{2\pi}{\lambda} \left(2vt \cos \theta - \frac{(vt \sin \theta)^2}{R_0} \right) \quad (5)$$

The variation of the output phase $\phi(t)$ is then able to be expressed by the frequency f_d of the received signal as follows.

$$f_d(t) = \frac{1}{2\pi} \frac{d\phi(t)}{dt}$$

$$= \frac{2v}{\lambda} \cos \theta - \frac{2v^2 t}{\lambda R_0} \sin^2 \theta \quad (6)$$

In which, the second term at the right hand of (6) indicates that there is a *Doppler shift* caused by the relative motion between the antenna and the scatters with respect to the elapsed time t . The subscript d denotes Doppler shift happening in this process. The first term can be considered as the constant frequency of the emitted signal from the antenna, which is independent of the time on which the platform spends when travelling in space over one section of terrain on the earth.

Within the time interval t , many pulses are emitted by antenna. Each of them forms a strip or a scanned line in the radar imagery (see Fig. 10). A series of strips then form continuous flatten terrain in an interferometric radar imagery.

3.3. Backscattered Wave from Radar Scattering and Polarized Substances

As indicated in literature reviews for radar backscattered wave previously, the radar scattering is one of hot topics which are massively discussed by researchers regarding how the electromagnetic wave emitted by the antenna from the platform works. Unfortunately, the discussions are mainly confined to the topics such as how the radar scattering is influenced by geometric properties, such as shape and surface roughness and moisture content including the wavelength of wave and so on. The less discussions are carried out on the issues of how the scatters are polarized.

There are several “superficial” models and relevant assumptions made for explaining and calculating the radar scattering in almost relevant books and reports [31, 34, 41, 43, 46, 54]. The so-called superficial models built by the interest of individual researches actually are ideal models, thus the media in air are treated as rigid and inertial particles within assumed layers between air and surfaces of scatters.

The corresponding calculation of the scattering is then performed by a series of matrices in such a designed homogeneous or an inhomogeneous system and specifying several parameters of coordinates for a system combining with the physical parameters owned by the electromagnetic wave. In other words, the reports regarding the interaction happening between the intrinsic properties of the electromagnetic wave such as the strength of electric and magnetic field, the intensity of photons and the molecules of (liquid) scatters in the field of remote sensing or radar engineering are hardly found in the world. The possible reasons are already mentioned previously.

3.4. A Fully Ignored Vital Fact at SAR Scanning

At this point, except for the interest in radar engineering mentioned above, there is a very important fact on which must be emphasized. In terms of the interest of this research, the preceding described process can be interpreted as the one of that electromagnetic fields emitted by the antenna impose on the substances like water mixture (thus water is mixed by other substances) in lake or river for several times. In other words, the molecules consisting in substances or aqueous mixtures are influenced by external electromagnetic fields for several times within a very short period (taking about 1 ns to transmit each pulse).

In fact, the strengths of instantaneous external electromagnetic fields are large enough to affect the molecules of water body in lakes or rivers including seawater, which is to be calculated and discussed in subsections later.

However, above fact is always ignored because at this stage

1. The platform flies over lake or river at a very high speed (about 7km/s) in space. Thereby, such a phenomenon is immeasurable at ground level.
2. No specific physical devices are able to distinguish the signals emitted by molecules and atoms in water body from others scattered back from terrains.

3. It is in excess of the scope of research in radar engineering.

This important fact is then secretly hidden into DEM at the first step of scanning using SAR. Unfortunately, this secret is still not found at the following step of producing DEM using InSAR.

3.5. Procedures of Producing DEM Using in SAR

In the previous subsection, the process of how the interferometric radar imagery made by SAR is already introduced. However, the information of elevation in an interferometric radar imagery is depressed. Hence, for example, the elevation of point A and B is located on the same horizontal level respectively (see Fig. 12). That results in that the interferometric radar imagery look flat (see Fig. 13 and Fig. 14). The interferometric radar imagery shown in Fig. 13 and Fig. 14 is made at the same geographic location but different time respectively. They could be made by the same platform or separate platforms. For example, the global DEM thus SRTM3 supplied by NASA is made by the same USA shuttle [40].

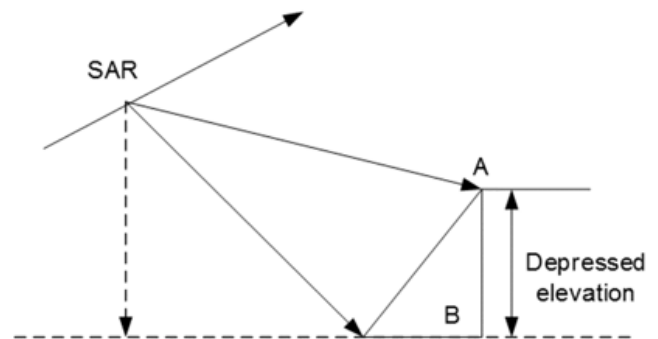


Figure 12. Depressed elevation in interferometric radar imagery

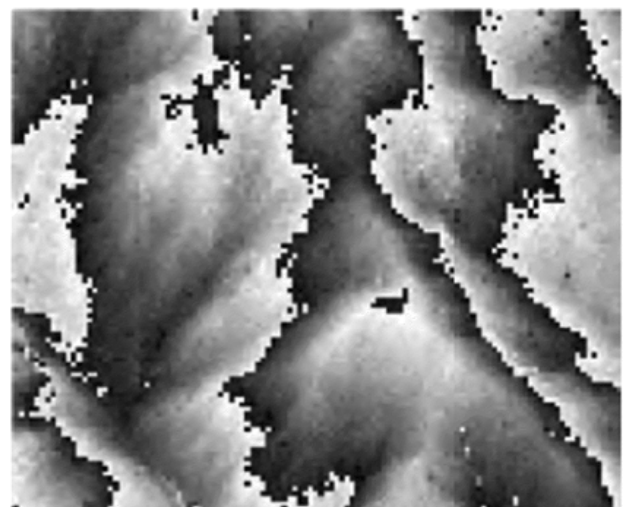


Figure 13. Interferometric radar imagery with the same geographic location at one time

However, the depressed elevations can be released by a technique called phase unwrapping [40, 53]. The main procedure of generating DEM is illustrated in Fig. 15. The process of phase unwrapping is mainly based on the

difference of phase for the same observed objects, for example, the phase difference exists between Fig. 13 and Fig. 14. Releasing the depressed elevations is only a first step. The second step is that the released elevations of the same observed objects having contour lines (see Fig. 16) have to be resampled into a geographic system such as WGS84 and located into a matrix-like grid. And then, DEM like Fig. 2 is formed eventually.

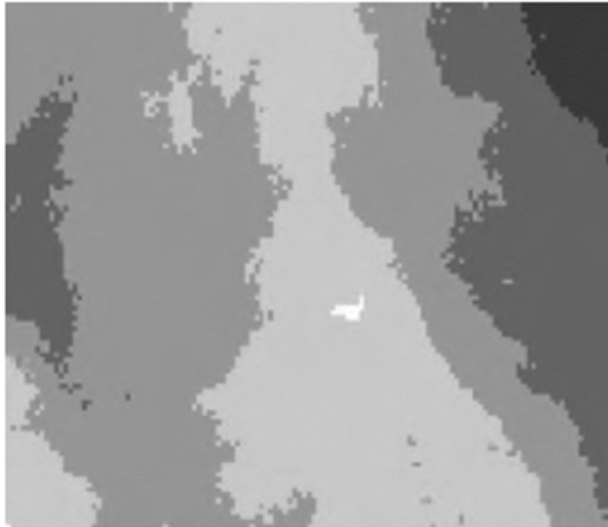


Figure 14. Interferometric radar imagery with the same geographic location at another time

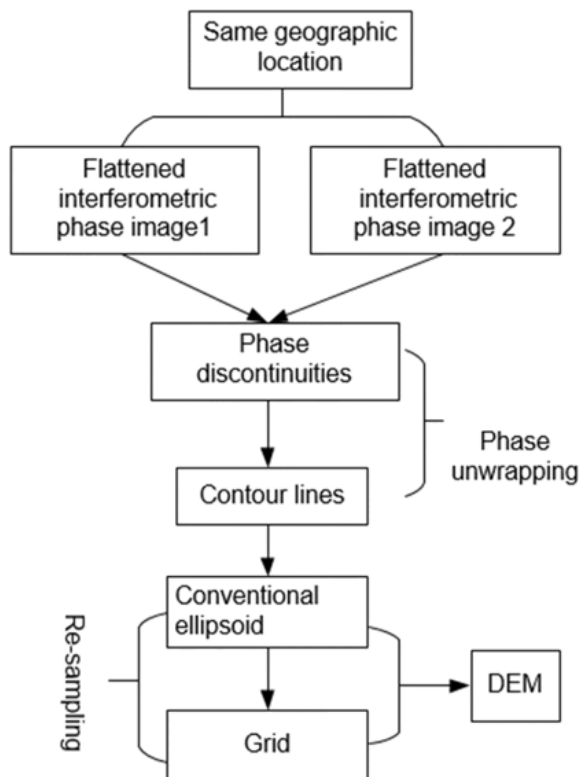


Figure 15. The procedure of unwrapping phase to generate DEM



Figure 16. Interferometric radar imagery with the same geographic location and contour lines

3.6. Important Data Melt into DEM

At this point, being in mind by following up previous remarks, some important phenomena including their corresponding unknown data are already captured by radar imaging. But only data of *elevation* are secretly “melt” into DEM in the process of the phase unwrapping.

The data captured by radar imaging could include those which have not been discovered yet. However, whether the properties of those data are able to be fully extracted and displayed in data processing or not is decided by the following extended extra factors:

1. What kind of substance on the earth, which is concerned by researchers and is capable of being detected by optical imaging and handled by the digital image processing respectively.
2. What a sort of physical property generated by the interaction between microwave and scatters, which can be detected and received by radar imaging, as SAR does.

Of course, the melt data of interest in this research are bathymetric data. However, as mentioned before, to reveal those melt data in DEM as shown in Fig. 3, it has to rely on the unique technique created by author. Otherwise, it is too difficult to discover them.

4. Approach to Correlating Signals of SAR with Behaviours of Molecules in Water Body

In above sections, the tasks only illustrated the process of forming DEM starting from the basic concepts of electromagnetic wave and how the hidden data are secretly melt into DEM. The less attentions were paid to the radar

engineering in detail. As to the mechanisms of how those hidden data are formed, it is still not explained yet. Consider interpreting the mechanisms in theory is a very complicated process. It could be better to offer a bridging introduction so as to further discuss or for ones who do not feel interested in the analysis at the level of the molecular structure in the following subsections. The quick explanation should be

understandable even if ones do not have much knowledge of physical chemistry.

Fig. 17 is a big picture of that not only precisely summarizes the contents introduced above but also moves the focuses and concerns from visible terrain to water body in inland lakes or rivers.

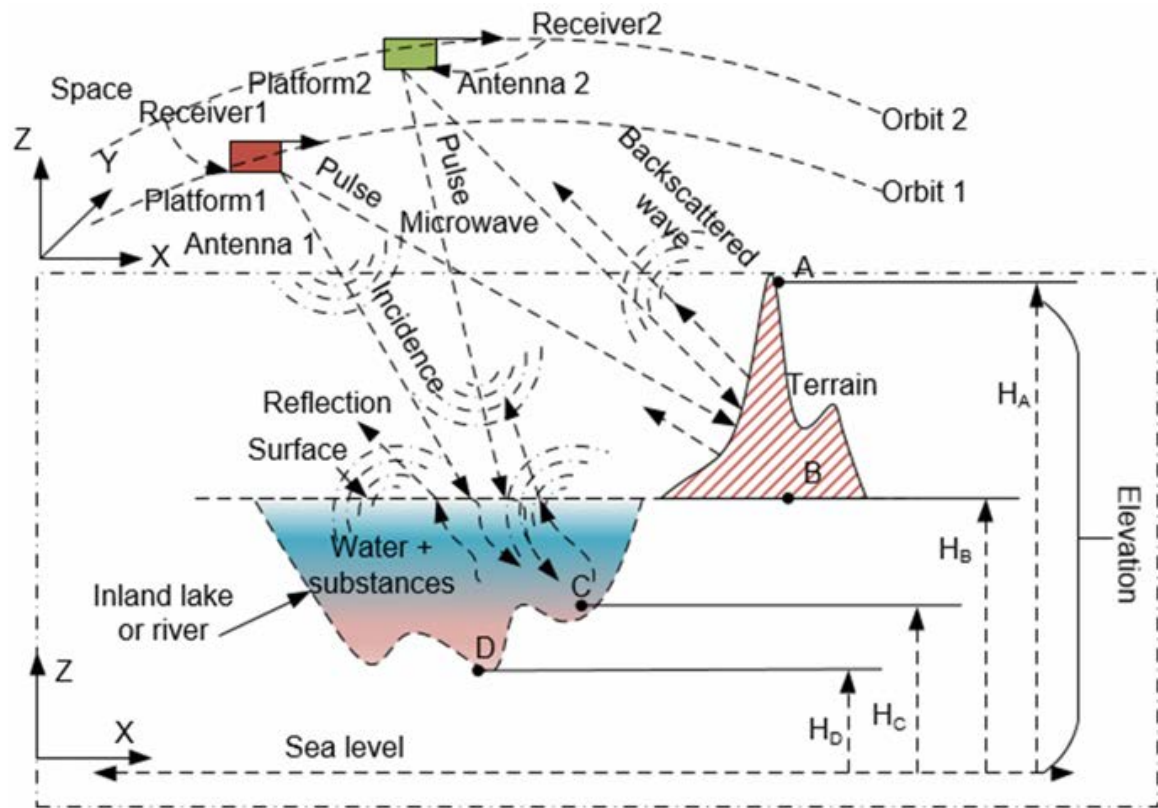


Figure 17. Global view of correlation between external microwave and elevation of terrain and lake

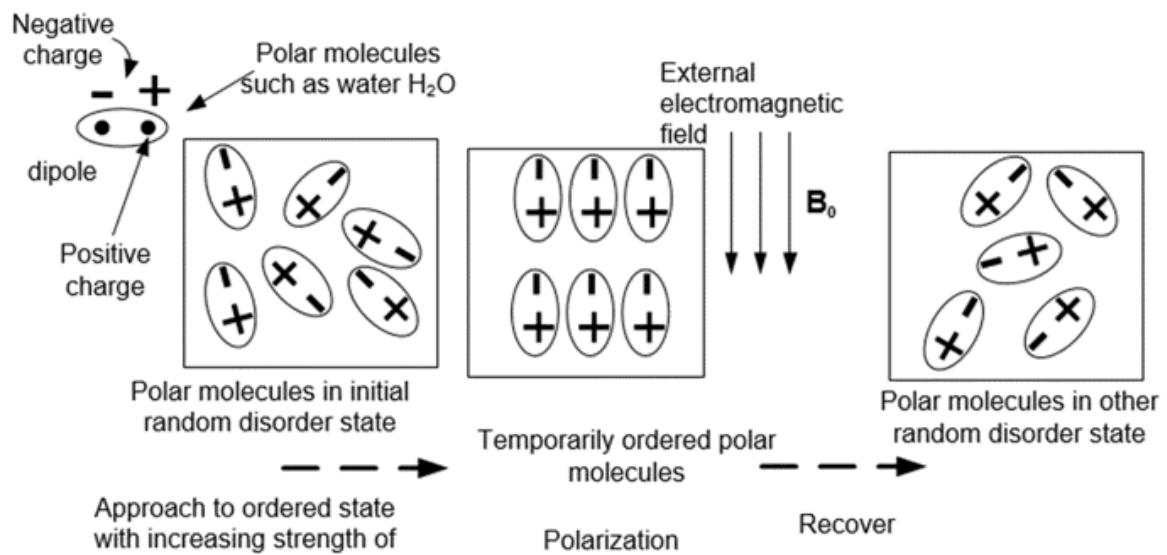


Figure 18. The sketch of process of polar molecules in lake being temporarily polarized under influence of external electromagnetic fields

On the basis of it, it is helpful to further think some unknown facts. For most of data users, they may intuitively conclude that nothing exists underneath water surface in terms of Fig. 1 and Fig. 2. Nevertheless, the depths of water body shown in Fig. 3 tell ones that the quick conclusion without further investigating it is incorrect. The reason resulting in such error or misunderstanding is that some researchers in the field of GIS or remote sensing always treat DEM and remote sensing imageries as results (or gifts) offered by satellites. They usually analyses some phenomena generated by imageries or DEM so as to seek for other quick results or conclusions only relying on the superficially captured results without integrating them with multidisciplinary knowledge. Such an approach is not always successful in interpreting some complex cases.

In fact, the platform flying in space is a laboratory containing analytical devices sent by human to perform a series of large scale physical and chemical experiments for human within a very complicated environment. The information sent back on the earth could be lost or even fool human due to many intervening factors including human's miss-observation and misunderstanding them.

In this case, the result shown in Fig. 3 implicitly indicates a fact that the microwave emitted by antenna must interact with molecules and atoms in water body and the corresponding signals generated by such interaction are also received by the receiver based on the knowledge of chemical experiments being performed in the laboratories under similar conditions on the earth.

There could be many different sorts of molecules, atoms and ions existing in the fresh water of lakes and rivers or seawater. Water H_2O is a typical polar molecule. Therefore, the scenario can be imagined as shown by Fig. 18. The molecules having unpaired elections and charged ions could be instantly polarized (activated) from one random state to one temporarily ordered and polarized state when the external electromagnetic fields are applied into them. Then the ions, atoms and molecules are activated and transited from the lower energy state to higher energy state by absorbing an amount of the external energy (electromagnetic Radiation). When the platform flies away quickly, the external electromagnetic fields disappears immediately. However, the electromagnetic waves within one certain region (see Fig. 9) are emitted by the activated molecules, atoms and ions when they return to another random state accompanying with releasing their internal energies from the higher level to the lower level. The time spending on this process is called *relaxation time* [47, 51, 55, 56]. Those electromagnetic waves are also received by the receiver in the platform as introduced before. There is an equation to calculate the frequencies of those electromagnetic waves based on the quantized energy which is to be further discussed in the following subsections.

However, from the angle of macro-state, the water mixture is a fluid, whole lake or river is full of it. Therefore the elevations of water body bottom can be revealed as the visible terrain is shown at surface levels (see Fig. 2, Fig. 3

and Fig. 17).

Up to this point, the mechanism of how the depths of water body in lakes or rivers are formed is briefly introduced and explained. A fact should be pointed out is that there are many complex processes simultaneously happening in above overall process. In the following subsections, the task of interpreting them is to be further implemented from general level to the one of molecular structure. Such an approach is certainly useful and helpful in the process of exploring more unknown facts. However, as reminded before, reviewing some contents of physical chemistry may be required especially quantum mechanics or quantum chemistry-based analytical chemistry. The valuable references such as [36, 37, 47, 51, 55, 56] are already supplied. The evidences of theories relevant to the contents to be introduced and discussed in the following subsections can be found from them. For sake of simplicity, if unnecessary, the references are not to be specified one by one.

5. Structure and Spectra of Substances in Water Body

5.1. Overview

The remote sensing is a technology relying on the electromagnetic radiation. According to the source type of the electromagnetic radiation, it can be classified into *passive* and *active* manner respectively. In order for ones to conveniently to access the core of discussions. Based on the different sources of the electromagnetic wave which is emitted or received by either physical devices or substances (molecules or atoms), Fig. 19 provides ones with a brief profile of how they correlate each other. It is better to consider their potential correlation by means of combing it with the spectra shown by Fig. 9.

The passive electromagnetic radiation is reflected from the surface of the earth. The solar beam is the main provider of electromagnetic radiation for the surface. Such an electromagnetic radiation is not controllable. However, the controllable electromagnetic radiation which is often used in remote sensing is emitted by laser and radar respectively. The different mechanism of them acting on atoms and molecules results in the different region of spectra whose signals are emitted by micro-scale substances and received by the receiver as well (see Fig. 9).

Knowledge Required in Applications of Remote Sensing

Although the concentration in this research is on how the electromagnetic wave emitted by radar at the region of *microwave* impacts on water body, from the view of scatters, it is still quite necessary to understand some knowledge of how the water body containing other substances (molecules and ions) is affected by the incident electromagnetic radiation whose bands locating at the *visible* and *infrared* region when it impacts upon water body. It is because

1. The external electromagnetic radiation imposing on water body is a *time-dependent* dynamic process.

2. The internal orientation and configuration of molecules responding to the external electromagnetic radiation a time-dependent dynamic process too. Meanwhile, being similar to *spectroscopy* in analytical chemistry, several spectrums are generated due to the internal energy change of molecules, atoms and metal complexes when the external electromagnetic fields are applied into them. Because of that, those spectrums have a broadened range on spectra, which may include IR and Radio bands and so on. In order to capture those information, sensors are also installed in satellites in addition to SAR.
3. Whether the signals of radio band are able to be captured or not relies on the functionalities of antenna (see Fig. 19).
4. The Raman shift could exist, which could happen in rotational transitions, vibrational transitions of molecules or their mixed mods and electric transitions.
5. The interferometric radar imagery may be captured at the day time, therefore the mixed spectrums should

include the partial contribution of solar radiation in the process of activating molecules and so on accompanying with the electromagnetic radiation emitted by SAR.

Difference of Electromagnetic Radiation Used in Two Disciplines

In the radar engineering, the most interest in electromagnetic radiation may be the transmitting form of electromagnetic *wave*, however in the physical chemistry, the concentration is located on both of them (thus, both *wave* and *particle*, the more relevant discussions are to be carried out in the subsections).

Accordingly, the electromagnetic wave is treated as a common media and term in depicting and establishing the substantial correlations between the *internal energy level changes* happening in molecules when the external electromagnetic fields are applied into the molecules and the *interferometric radar imagery* generating DEM finally (see Fig. 19).

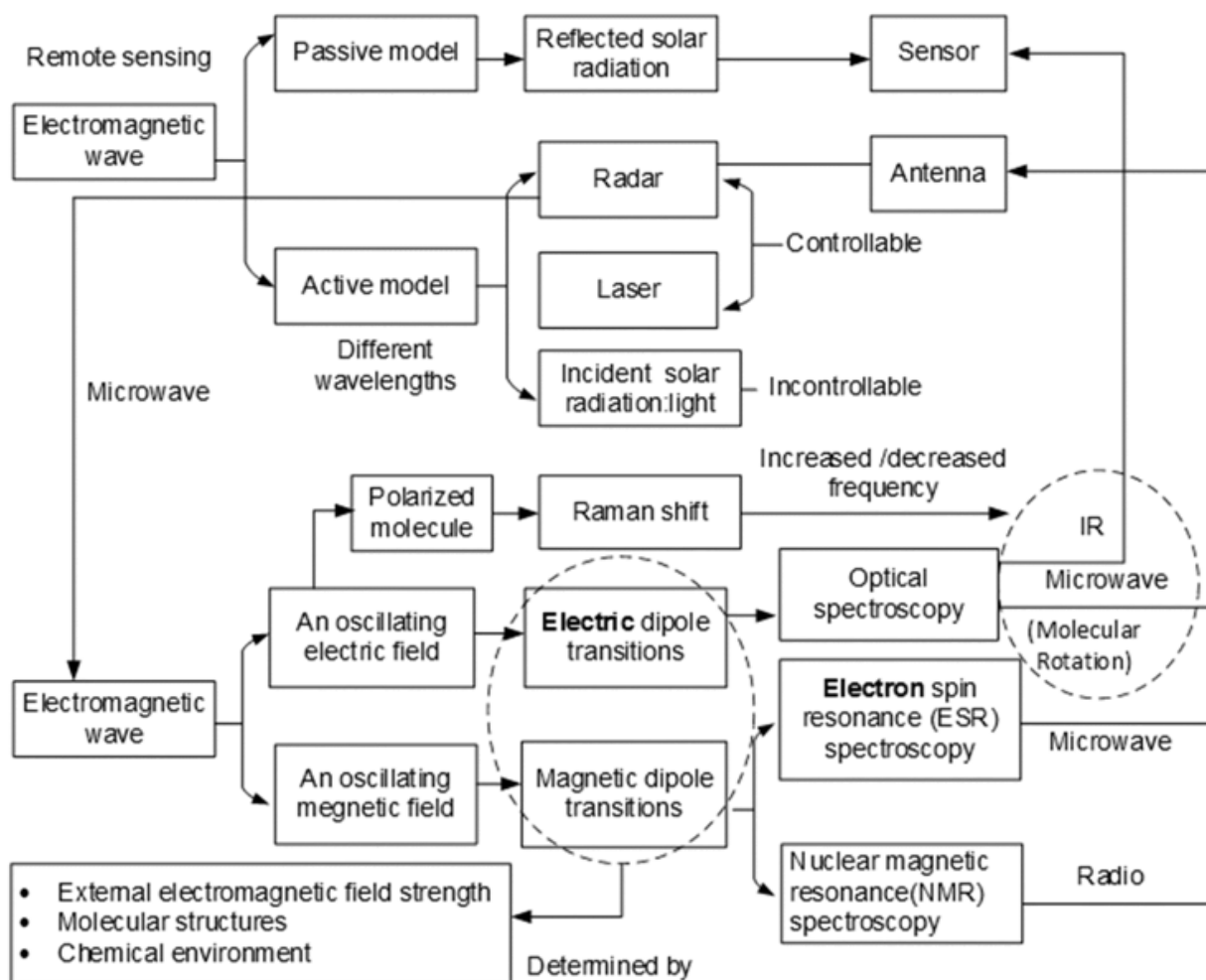


Figure 19. The sketch of interaction between the external electromagnetic fields and chemical substances in lake and the linkage by microwave

More about Electromagnetic Radiation in Physical Chemistry

As shown in Fig. 8, the electromagnetic radiation consists of an *oscillating electric field* and an *oscillating magnetic field*. These two coexisting fields play similar or different roles in interacting with molecules due to their individual physical features. Such features can be represented as

1. The electric field imposes a force on any charged particles (subjected to *Coulomb's law*) and produce an electric dipole. The electric dipole is a transient dipole. The magnitude of the transition dipole can be regarded as a measure of the charge redistribution accompanying with a transition.
2. The increasing strength of magnetic field can accelerate a moving charged particle and produce a magnetic dipole. An orbiting charge is equivalent to a current, so subjected to *Ampère's circuital law*.
3. Therefore, both of two fields are able to interact with the nuclei and electrons of an atom or molecule, and are capable of causing absorption or emission of energy.
4. A transition produced by the electric field is called an *electric dipole transition*, and a transition due to the magnetic field is called a *magnetic dipole transition*.
5. Of importance to generate a transition accompanying with specific frequencies of either absorbed photons or emitted photons is the existence of a transient dipole when two fields impose on substances.

Refined Substantial Target of Investigating Structures of Substances

As discussed above, even if both the electromagnetic radiation and the electromagnetic wave are chosen and to be focused on, the scope of investigating substances is still too large because physical chemistry has massive concepts and wide range. Accordingly, in order to reduce the contents of this research and remain the most important contents, the following introductions and discussions are to be carried out in terms of the traditional classification in analytical chemistry integrating them with some necessary knowledge from physics and quantum chemistry. But the concentration is different. The further refined targets and their features are those:

1. Assume that the receiver installed in the flying platform only receives the band of microwave.
2. Then, the focus in the process of explanation is *mainly* on tracing the potential outcomes of microwave emitted from the substances (molecules, atoms and protons) influenced by the external microwave emitted by the antenna neglecting of other complicated external conditions affecting them and omitting the detailed mathematical derivations so that ones can quickly understand.

The *optical spectroscopy* is employed by the electric dipole transitions, which is to be firstly introduced and then focus on the magnetic dipole transition based *magnetic*

resonance spectroscopy.

5.2. Optical Spectroscopy

Energy Levels and Energy Transitions

As well known, in the modern physics, it is already indicated and well approved that the electromagnetic radiation has *wave-particle duality*, namely the light has the duality of electromagnetic wave-photon. The corresponding energy of it is *quantized*. This concept already established the subject of modern *quantum mechanics* and *quantum chemistry* respectively.

The energy levels of atoms and molecules can be determined by measuring the wavelengths of the light that is emitted, absorbed, or scattered in transitions between energy levels (see Fig. 20).

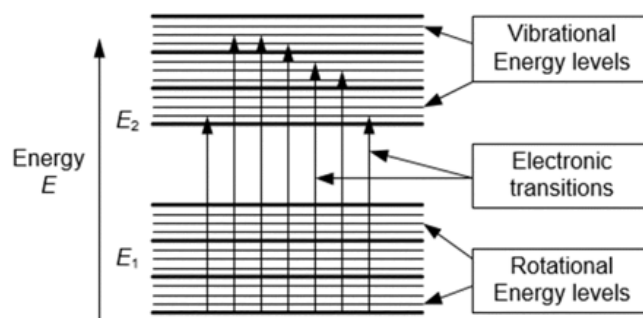


Figure 20. Different energy levels in molecules and atoms

Rotational, Vibrational and Electronic Spectra

Above correlation (thus *Bohr frequency rule*) can be expressed by

$$\left\{ \begin{array}{l} \Delta E = E_2 - E_1 \\ = h\nu \\ = h \frac{c}{\lambda} \end{array} \right. \quad (7)$$

Where, h is Planck's constant (6.625×10^{-34} J·s/molecule). ν is the frequency of photons. In fact, multi-photons can be involved in the transitions. The wave characteristics of photons have the same one shown in (2). In order to distinguish the source of electromagnetic wave coming from, the different symbol ν is especially used to demonstrate the electromagnetic wave generated from molecules. E_2 and E_1 denotes the higher energy level (the excited state) and the lower energy level (the ground state) respectively.

The photons can be absorbed or emitted by both atoms and molecules. Therefore, the external *physical conditions* and the internal *chemical environments* directly affect the behaviours of photons if all of molecules and atoms are located into a designed system or an existing system such as water mixture in a lake or river. The external physical conditions mean that the observed system is influenced by a physical field such as electromagnetic fields offered by laser or radar. The internal chemical environments mean that molecules or atoms are affected each other due to many

different forces existing. For the mixtures consisting of different molecules, atoms and protons, the more complicated signals are emitted by them. These signals appear and span at a wider region containing different bands on the spectra (see Fig. 9). The emitted photons are then classified into *spontaneous emission* and *stimulated emission*. Generally speaking, the spontaneous emission has a very less chance to be taken place for water body in lake and river without external physical conditions.

As seen from (7), the energy difference (ΔE) determines the frequency (ν) of photons when transitions take place. In general, there are following simple rules to be easily referred.

1. Transitions between electronic energy levels produce the spectrums that are in the *visible* and *ultraviolet* regions.
2. Transitions between rotational states of molecules produce the spectrums that are in the *microwave* region.
3. Transitions between vibrational states of molecules produce the spectrums that are in the *infrared* region.

Above rules are illustrated in Fig. 20 and represented in Fig. 9.

Optical Spectroscopy in Quantum Theory

Molecular Rotation

In above sections, the discussions only offered a general rules in terms of the transitions occur within different energy levels. In fact, not all of transitions happen, which have to meet with corresponding selection rules.

For diatomic and linear polyatomic rotating molecules with permanent dipole moments, the selection rule is

$$\Delta J = \pm 1 \quad (8)$$

Where, J is a rotational quantum number to separate rotational energy levels.

The molecules and atoms with no permanent dipole moment fail to have a microwave spectrum. The microwave spectra of nonlinear polyatomic molecules are more complicated, but as mentioned before, the presence of a permanent dipole moment is needed for a microwave spectrum to occur.

The state of water body in lake or river is almost concerned when microwave radiation imposes upon it. As indicated by(7), water and lower molecular weight molecules absorbs the radiation and may be raised into the higher rotational states, the excess rotational energy in these molecules are instantly released in the form of either the heat absorbed by other molecules to active other molecules or the back-scattered wave received by the antenna immediately. Namely, a series of electromagnetic wave having different frequencies are chain-reaction-like generated in water body. However, the ratio of microwave to these signals may occupy prominently if the effects from other processes are not considered at this energy levels.

Molecular Vibration

Transitions between vibrational levels lead to spectra existing in the infrared region. For diatomic vibrating molecules with permanent dipole moments, the selection rule is

$$\Delta \nu = \pm 1 \quad (9)$$

Where, ν is a vibrational quantum number to separate vibrational energy levels.

Similarly, water and lower molecular weight molecules also have the features of vibration, however, the molecular vibration of them are represented within the bands of IR.

However, the internal motions of molecules are not simply classified above, which is also affected by many other factors such as linearity of molecules, symmetry and so on. It leads to many combined selection rules and many spectra generated at rotational and vibrational energy levels. Therefore, it is very complicated.

Electric Transitions

Atomic and molecular spectra in the visible and ultraviolet regions arise from transitions from one electronic state to another. Vibrational and rotational transitions occur concurrently with the electronic transitions, producing complicated band spectra (see Fig. 20). The electronic transitions take place rapidly compared with rotational and vibrational periods. When laser is applied into water body, the signals emitted by the vibrational and rotational transitions of water molecules are also received by antenna and sensors respectively. This is the reason why NOAA is using laser (thus LIDAR) to detect depths of Great Lakes and near coast [57]. But it is not only expensive but also has many errors because the penetrations of laser in the water body. It can easily be to be understood at this stage.

Raman Shift

In Raman spectroscopy, the electromagnetic radiation is scattered by the molecules in the manner of either giving energy to or accepting energy from the molecules, or passing through them thus Rayleigh scattering.

The Raman shift is a phenomenon that the frequency change between the frequencies of the incident electromagnetic radiation and re-radiated incident electromagnetic radiation occurs when the electromagnetic radiation is incident on molecules. In order to further illustrate it. The frequency ν' is assumed as the frequency of re-radiated radiation, f is the frequency of electromagnetic wave (microwave) from SAR. Therefore, the exchange of energy can be expressed by the following cases.

Case1: the incident microwave loses energy into molecules

$$\begin{cases} h(f - \nu') = E_{\text{upper}} - E_{\text{lower}} = \Delta E \\ \nu' = f - \frac{\Delta E}{h} \end{cases} \quad (10)$$

Case2: the incident microwave gains the energy from molecules

$$\begin{cases} h(\nu' - f) = E_{\text{upper}} - E_{\text{lower}} = \Delta E \\ \nu' = f + \frac{\Delta E}{h} \end{cases} \quad (11)$$

Where term $(\nu' - f)$ or $(f - \nu')$ is the mathematical expression of Raman shift. h is Planck's constant. In addition to them, the more attentions should be drawn to the following points:

1. The physical meaning of (10) and (11) differs from (7). The difference of energy level ΔE could be rotational, vibrational or electric transitions'. Therefore, Ramona shift or effect could happen at above energy levels of molecular internal motion modes. If so, Raman effect obeys both rotational and vibrational selection shown in (8) and (9).
2. The output frequency ν' is either increased or decreased if the effect of Ramandoes happen.
3. On the basis of microwave, if ν' is increased, Ramona spectrum may be shifted into IR otherwise it may be shifted in Radio depending on how large the input frequency f is and which mode of molecular motion the ΔE belongs to.
4. The frequency f can be also replaced by ν' to repeat another similar process. In other words, molecules affects each other within a very short time interval.
5. Furthermore, the degree of Raman scattering is determined by its polarizability α which is a measure of how the electrons are displaced relative to their nuclei when the external electric field E is applied into the molecule.

The polarizability is depicted by an ellipsoid and related to the direction influenced by the external electric field as shown in (1). Thereby, the polarizability has the properties of a tensor.

An induced electronic dipole μ in a molecule is then expressed by as follows.

$$\mu = \alpha E \quad (12)$$

If Raman active is true, the molecular rotation and vibration must be changed in a component of the polarizability such as magnitude or direction of the polarizability of ellipsoid. For example, the polarizability of water molecule is different along its three major axes. Accordingly, Raman spectra are quite complex.

Once the external oscillating electric field E disappeared, molecules return to another random state as shown in Fig. 18. The *van der Waals* force then plays dominant role in interaction amongst molecules.

5.3. Magnetic Resonance Spectroscopy

In the preceding subsections, the potential mechanisms of producing the microwave from the electric dipole transition are already discussed briefly. In this subsection, the attention

is to be located on how *oscillating magnetic field* affects the *electrons and nuclei*.

Both electron spin and nuclei associate with the spin angular momentum when a magnetic field is applied into them (see Fig. 21). The magnetic dipole transitions are involved in electron spin resonance (ESR) spectroscopy and nuclear magnetic resonance (NMR) spectroscopy. However, more attention is paid to ESR is because the electromagnetic wave generated by the electric transition within two spin states (α or β) in magnetic field belongs to the band of microwave, the one produced by NMR is located in the band of radio. But, the RF is very useful too in both substance analysis and medical diagnosis although it is ignored to discuss in this research.

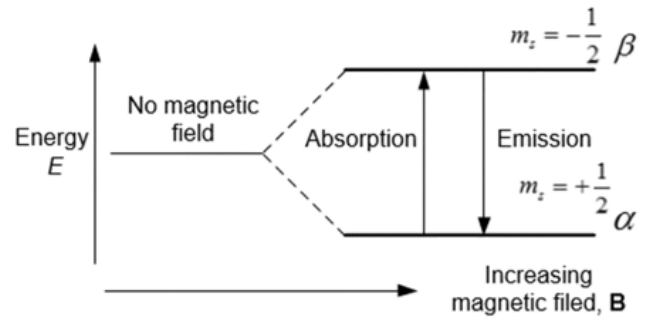


Figure 21. Spin energy level

Interaction between Spin and Magnetic Field

When a charged particle spins about an axis, a circular electric current exists, which produces a magnetic dipole in turn. The magnetic dipole of a point charge can be expressed as

$$\begin{aligned} \mu &= \frac{q}{2m} \mathbf{I} \\ &= \frac{qh}{4\pi m} \sqrt{I(I+1)} \end{aligned} \quad (13)$$

Where q and m are the charge and mass of the particle. \mathbf{I} is angular momentum. I , for each nucleus, takes one of values: 0, 1/2, 1, 3/2, ..., however, for an electron, it is 1/2 only, thus spin state. If a charged point is replaced by electrons and nuclei, the their corresponding magnetic dipoles are shown as

$$\begin{cases} \mu_{ez} = -g\beta_e I_z \\ \mu_{Nz} = g\beta_N I_z \end{cases} \quad (14)$$

Where the subscript e and N denote electrons and nuclei respectively. Because the angular momentum \mathbf{I} cannot point in any arbitrary direction. Its components can point along one particular direction (e.g. z in a three-dimensional coordinates). Therefore it is specified by z direction. The quantity g is named the *Landé splitting factor*.

The constant β_e is called *Bohr magneton* shown as follows,

$$\begin{aligned} \beta_e &= \frac{eh}{2m_e} \\ &= 9.273 \times 10^{-24} \text{ JT}^{-1} \end{aligned} \quad (15)$$

Where e is the electronic charge (1.60×10^{-19} C) and its mass is 9.11×10^{-31} kg.

β_N is nuclear magneton, which is defined by the mass of the proton.

$$\begin{aligned}\beta_N &= \frac{eh}{4\pi m_p} \\ &= 5.050 \times 10^{-27} \text{ J} \cdot \text{T}^{-1}\end{aligned}\quad (16)$$

Energy of Magnetic Moment

The energy of a magnetic moment μ in a magnetic field \mathbf{B} in z direction is then equal to the scalar product

$$E = \mu_z B_z \quad (17)$$

For a magnetic field \mathbf{B}_z in the direction of the z axis, the magnetic energy of an electron is

$$\begin{aligned}E &= g\beta_e B_z m_s \\ &= \pm \frac{g\beta_e B_z}{2}\end{aligned}\quad (18)$$

Where m_s is spin quantum number, replaces I_z in (14) and takes value of either $-1/2$ or $+1/2$.

The transitions between the spin states raise absorption of radiation. These transitions are magnetic dipole transitions and the selection rule is as follows

$$\Delta m_s = \pm 1 \quad (19)$$

Frequency of Emitted Electromagnetic Radiation

The frequency (ν) of electromagnetic radiation absorbed or emitted depends on B_z and is given by

$$\begin{aligned}\nu &= \frac{\Delta E}{h} \\ &= \frac{g\beta_e B_z}{h}\end{aligned}\quad (20)$$

In this research, B_z can be regarded as the vertical component of the external magnetic field \mathbf{B}_0 shown in Fig. 18. In order to demonstrate that how the emitted ν is influenced by the strength of the external magnetic field \mathbf{B}_0 . Assume that $g=2$, $B_0 = 3.0$ T, then inserting them into (20) yields

$$\begin{aligned}\nu &= \frac{2 \times 9.273 \times 10^{-24} \times 3.0}{6.63 \times 10^{-34}} \\ &= 83.919 \times 10^9 \text{ Hz} = 83.919 \text{ GHz}\end{aligned}$$

This frequency locates within the band of microwave. In other words, if the external magnetic field \mathbf{B}_0 supplied by SAR is able to cause ESR and its microwave is certainly received by the antenna. In contrast, if a SAR is capable of emitting 94 GHz microwave, the magnitude of magnetic field B_0 is equal to 3.3604T. Modern SAR is able to produce more strength of magnetic field than this figure.

5.4. Brief Summary of Microwave Produced by Polarized Water Body

As seen from above, the mechanisms of generating the microwave emitted by temporally polarized water mixtures and eventually received by the receiver installed in a high-speed platform are very complicated. However, the general features could be

1. The molecules affects each other when the external electromagnetic fields impose on them.
2. During the period of interaction, the electromagnetic wave having different frequencies are emitted within a very short time interval. Most microwaves are received by antenna.
3. Because the received microwaves are directly related to elevations of water body, in other words, the depths of water body in most lakes or rivers can be obtained within less than one minute.

The purpose of above illustrations is to demonstrate that such a phenomenon not only does exist but also has the evidences of theory, it may be very difficult to perform in situ experiment to prove it due to the platform has a very high speed in space. However, it completely does not affect its applications and significances based on this vital discovered phenomenon.

6. Conclusions

The topics of research discussed in this paper were brought out of the doubt when author performed a bathymetrically modelling a completely polluted large scale inland lake. Hence, why did the DEM hide such bathymetric data? Where did they come from? The answer is very positive after exploring from diverse theories. Although interpreting those existing data employs many individual procedures and corresponding theories, our summaries still focus on the final effect of them and main applications from the angle of theory.

Summary and Pratical Significances

Hidden Bathymetric data Produced by Interaction at Micro-level

The hidden bathymetric data are generated by the interaction between microwave emitted by antenna and atoms, molecules in lakes and rivers. And then, a series of continuous microwaves are captured by antenna installed in the platform. Those received microwaves are partial bands of electromagnetic waves emitted by transitions between different energy levels in atoms and molecules during the very short period of interaction.

This fact was already approved by the existing knowledge and theories.

Interactions Generates a Natural Physical Phenomena

Because the internal interaction is involved in the structures of atoms and molecules when external physical factors are applied into them, the mechanisms of interaction happening in the internal motions of atoms and molecules certainly belong to natural physical phenomena and the domains of study of physical chemistry. It therefore has a general rule and can be applied into investigation universally. Namely, on the basis of the known knowledge of physical chemistry, it can be predicated that all inland lakes and rivers have such bathymetric data hidden in DEM once the external microwave superimposes onto water body, because water is a polar molecule.

Explore Bathymetric Data of Seawater

Above knowledge can be also extended to seawater near coast. Regardless of how many components exist in seawater, at least, there are two components can be confirmed. One is water, which is already specified above, other extra chemical substance is sodium chloride (NaCl), which is disintegrated as the Na^+ and Cl^- ions surrounded by the polar water molecules. They are wonderful charged particles. The microwave is easily generated by them if the powerful external electromagnetic fields superimpose onto them.

In order to prove above fact, the more evidences are to be supplied in the part 2.

A Existing problem

Seeking for bathymetric data using DEM is exciting. Author has already discovered some depths near coast. Unfortunately, DEM supplied by NASA including NOAA and other organizations in the world does not cover such data near coast. The reasons why they do not supply them are

similar. Thus, they have

1. Realized such a phenomenon and hidden bathymetric data neither.
2. Thought that it is unnecessary to provide international users with DEM near coast, which is based on the sea level. This is another disjointed point between scientists and GIS researchers. Therefore, NOAA is still detecting bathymetric data by means of very expensive laser (thus, LIDAR).

Further Consideration

Eventually, as a final comprehensive summary for the part 1, another easily understanding picture (see Fig. 22) is provided for ones who have already owned knowledge in optical remote sensing imaging to quickly distinguish it from radar imaging and then further consider other concerned topics.

This picture tells researchers in the field of remote sensing that in the process of analysing any observed objects on the earth, any relevant knowledge and techniques cannot be isolated and used repulsively. There are massive topics which have been involved in. It seems that many different satellites exist in the world. However, their different functionalities can be quickly found from both the electromagnetic spectra (see Fig. 9) and their working mechanisms between electromagnetic wave and scatters.

Recently author is also paying an attention to researching the underground water using DEMs produced by ASTER (a USA and Japanese joint satellite) and SRTM respectively. A notable difference is that *the elevations of lakes shown by ASTER are lower than those shown by SRTM3 at the same geographic location.*

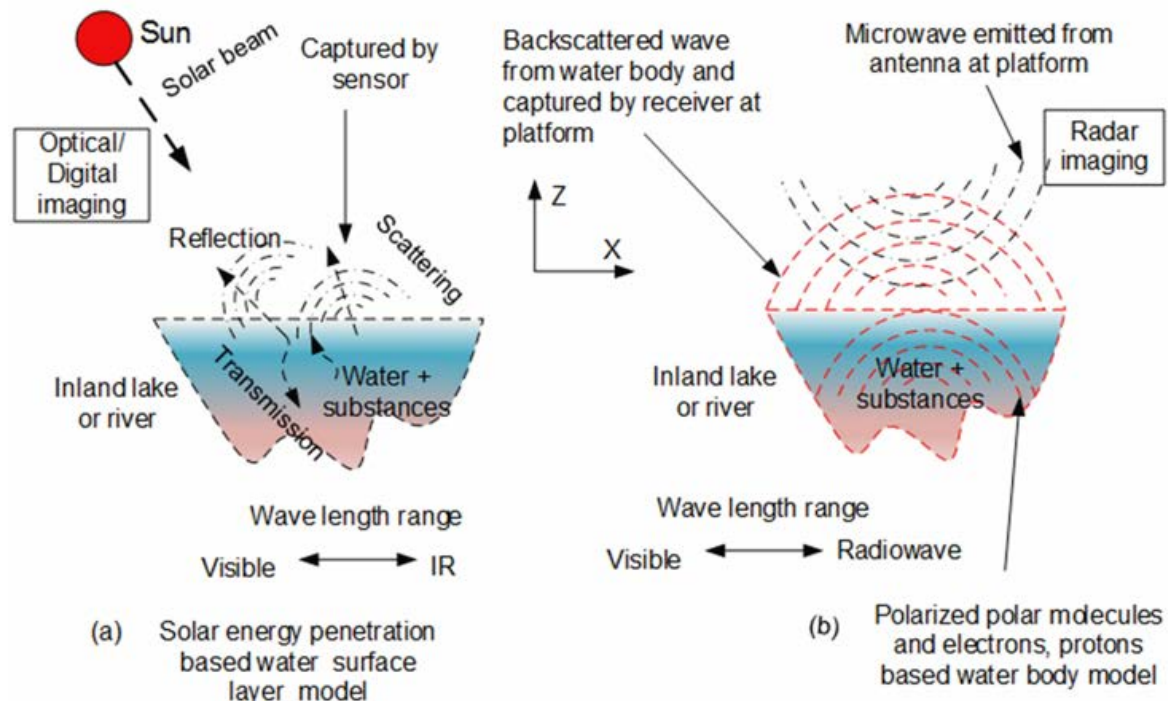


Figure 22. The schematic of difference and correlation between optical imaging and radar imaging

ASTER is a *thermal infrared* technique based Sun-synchronous satellite, which has some unique bands. DEM is one of its products, which mainly relies on the thermal conduction of materials (thus a passive model of optical imaging) rather than the interaction between microwave and polar molecules (an active model of radar imaging). Accordingly this is one of reasons leading to above difference.

NASA and Japanese organization spent a lot of time and money on correcting ASTER DEM (mainly atmospheric factors), finally the second version of its DEM was issued recently. They may have realized a fact that ASTER DEM and SRTM3 were built by different physical mechanisms. Therefore they did not assess and compare ASTER DEM with SRTM3 in NASA's report. They only give users some advices when users use this product. That is also the reason why SRTM3 was selected to investigate the bathymetric data in this research.

But from the point of technical view, it provides us a valuable hint to further consider. Are we able to detect the underground water making use of this difference of elevations at the same geographic location?

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