UNIT 5 IMAGE RESOLUTIONS

Structure

5.1 Introduction

Objectives

5.2 What is Image Resolution?

5.3 Types of Image Resolutions

Spatial Resolution

Spectral Resolution

Radiometric Resolution

Temporal Resolution

5.4 Resolution in Microwave Remote Sensing

5.5 Relationship Between Different Types of Resolution

5.6 Activity

5.7 Summary

5.8 Unit End Questions

5.9 References

5.10 Further/Suggested Reading

5.11 Answers

5.1 INTRODUCTION

In the previous unit you have studied about remote sensing platforms and also the sensors, which are used to record the ground features. Utility and importance of any remote sensing data depend on its capability. Thus, image resolution refers to the ability of a remote sensing system to record and display the finer details, including the quality of data. One of the important characteristics of remote sensing system is their capability to capture details of the ground features. These details are broadly referred to as resolution, which can be described in terms of time, space, spectral and radiometry. *Resolution* of a sensor system is its capability to discriminate two closely spaced objects from each other. In this unit, you will study about the resolution and its types.

Objectives

After reading this unit, you should be able to:

- discuss the basic concepts and importance of image resolution in remote sensing;
- describe the types of image resolution;
- explain resolution in microwave remote sensing; and
- discuss the relationship between different types of resolution.

5.2 WHAT IS IMAGE RESOLUTION?

The term image resolution is applied to digital images, film images, and other types of images and it describes the details that an image holds. Resolution can be broadly defined as ability of a remote sensor to capture and display details of the ground features. In other words, resolution refers to the level of detail to which a ground feature can be described and mapped. Resolution varies from sensor to sensor. Resolution is broadly described as coarse and fine. Data having coarse resolution have coarser information whereas data with fine resolution provide finer details. Resolution characteristics of remote sensing data determine its application potential because data of different resolutions provide different levels of details and hence are useful for mapping particular features at a specific mapping scale.

The image resolution also depends on the character of the scene that has been imaged, apart from atmospheric conditions, illumination and experience and ability of an image interpreter. Finer details can be seen in high resolution image. On the other hand a coarse or low resolution image is one with large resolution size i.e., only coarse features can be observed in the image (Fig. 5.1).

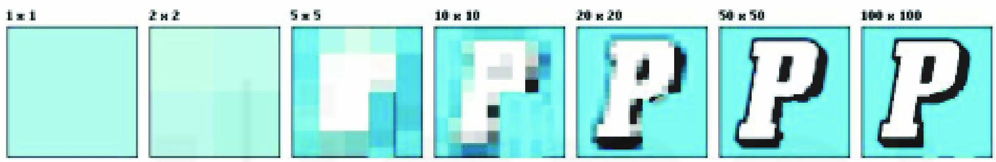


Fig. 5.1: Schematics explaining concept of resolution. How close can two points be before you cannot distinguish them?

5.3 TYPES OF IMAGE RESOLUTION

Image resolution can be measured in various ways like spatial, spectral, temporal and radiometric. Based on these parameters image resolution is categorised into following four types:

- spatial resolution – it refers to variations in the reflectance/emittance determined by the shape, size and texture of the target
- spectral resolution – it infers changes in the reflectance or emittance as a function of wavelength
- temporal resolution – it involves diurnal and/or seasonal changes in reflectance or emittance and
- radiometric resolution – it includes changes in the polarisation of the radiation reflected or emitted by an object.

We will discuss in detail about each of these types of resolution.

5.3.1 Spatial Resolution

There are different definitions of spatial resolution but in a general and practical sense, it can be referred to as the size of each pixel. It is commonly measured in units of distance, i.e. cm or m. In other words, spatial resolution is a measure of the sensor's ability to capture closely spaced objects on the ground and their discrimination as separate objects. Spatial resolution of a data depends on altitude of the platform used to record the data and sensor parameters. Relationship of spatial resolution with altitude can be understood with the following example. You can compare an astronaut on-board a space shuttle looking at the Earth to what he/she can see from an airplane. The astronaut might see a whole province or country at a single glance but will not be able to distinguish individual houses. However, he/she will be able to see individual houses or vehicles while flying over a city or town. By comparing these two instances you will have better understanding of the concept of spatial resolution. This can be further elaborated by considering an example shown in Fig. 5.2.

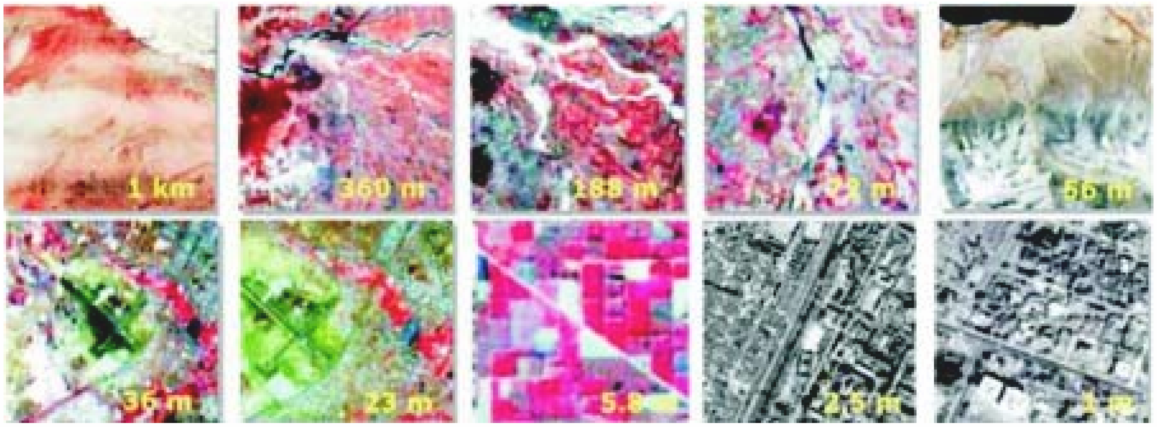


Fig. 5.2: Spatial variations of remote sensing data. Note the variations in resolution from 1 km till 1 m, in the series of photographs. The photograph taken from 1 km shows lesser details as compared to that at 1m (source: Navalgund et. al, 2007)

Suppose you are looking at a forested hillside from a certain distance. What you see is the presence of the continuous forest; however from a great distance you do not see individual trees. As you go closer, eventually the trees, which may differ in size, shape, and species, become distinct as individuals. As you draw much nearer, you start to see individual leaves (Fig. 5.3). You can carry this even further, through leaf macro-structure, then recognition of cells, and with further higher spatial resolutions individual constituent atoms and finally subatomic components can be done.

Fig. 5 3: Understanding concept of spatial resolution

IFOV is a measure of the area on the Earth surface viewed by a single detector on a sensor system from a given altitude at a given moment in time. It may be described as the angle viewed (è) or the widths on the ground (AB) of the area viewed (Fig. 5.4). It is important for you to note that AB is the diameter of the circle but radiance recorded from the area is displayed as a square pixel in an image.

The details of features in an image are dependent on the spatial resolution of the sensor and refer to the size of the smallest possible feature that can be detected. Spatial resolution depends primarily on the Instantaneous Field of View (IFOV) (Fig. 5.4A) of the sensors which refers to the size of the smallest possible feature that can be detected by each sampling unit of the sensor. Usually, people think of resolution as spatial resolution, i.e. the fineness of the spatial detail visible in an image.

The most commonly quoted quantity of the IFOV is the angle subtended by the geometrical projection of single detector element to the Earth's surface.

Remote sensing instrument is located on a sub-orbital or satellite platform, where è of IFOV, is the angular field of view of the sensor (Fig. 5.4B). The segment of the ground surface measured within the IFOV is normally a circle of diameter D given by

D = è* H ………………...(1)

where,

D = diameter of the circular ground area viewed,

H = flying height above the terrain, and

è = IFOV of the system (expressed in radians).

The ground segment sensed at any instant is called ground resolution element or resolution cell.

As you go up in the sky/ space, your field of view (FOV), i.e. the total view angle of the sensor, increases. The FOV defines the swath. Swath is the width of the strip of the ground, i.e. recorded by the camera or sensor.

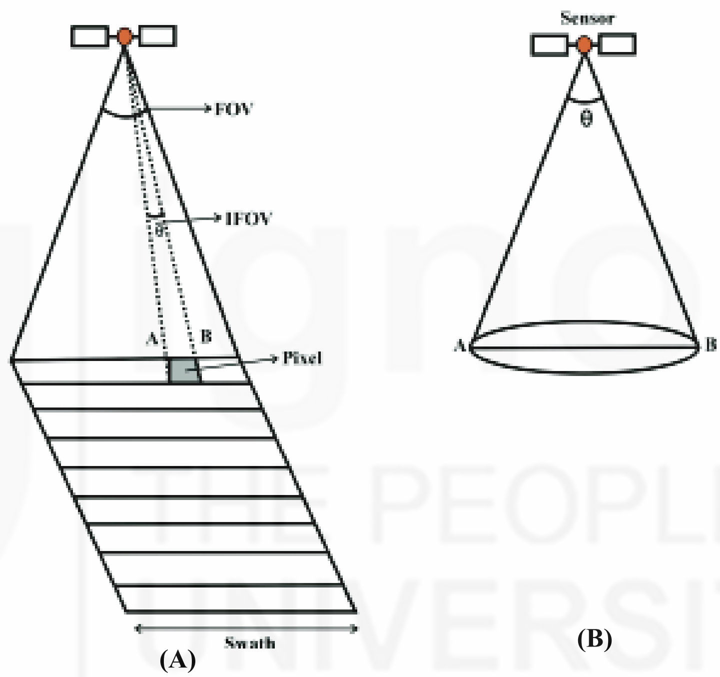
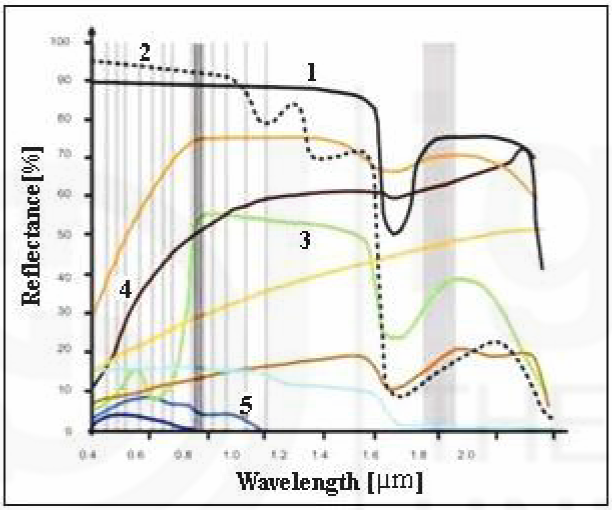


Fig. 5.4: Schematics showing (A) relationship of IFOV and FOV and (B) concept of IFOV

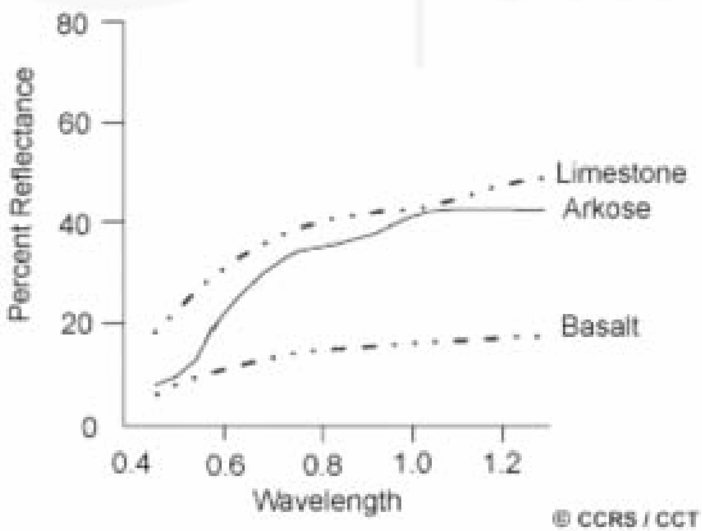
Spatial resolution of remote sensing system is influenced by the swath width. Spatial resolution and swath width determine the degree of detail that is revealed by the sensors and the area of coverage. Remote sensing sensors are generally categorised into coarse, intermediate and high spatial resolution sensors based on their spatial resolution. Sensors having coarse resolution provide much less detail than the high spatial resolution sensors. Because of the level of details the sensors provide, they are used for mapping at different scales. High spatial resolution sensors are used for large scale mapping (small area mapping) whereas coarse spatial resolution data are used for regional, national and global scale mapping.

5.3.2 Spectral Resolution

We all know that the Sun is a major source of electromagnetic radiation used in the optical remote sensing. Different materials on the Earth's surface exhibit different spectral reflectance and emissivities. The differences (variations) in reflectance and emissivities are used to distinguish features. However, the spectral signature does not give continuous spectral information and rather it gives spectral information at some selected wavelengths. These wavelength regions of observation are called gives spectral information at some selected wavelengths. These wavelength regions of observation are called *spectral bands*. The spectral bands are defined in terms of a 'central wavelength' and a 'band width'. For example, a sensor which is making measurements at green wavelength region (0.5 µm-0.6 µm) will have central wavelength 0.55 µm and band width is 0.1 µm. Besides the location of the central wavelength and band width, total number of bands is also another important aspect of spectral band selection. The number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a remote sensing instrument is sensitive is called *spectral* resolution. The use of well-chosen and sufficiently numerous spectral bands is a necessity. The selection of spectral band location primarily depends on the feature characteristics. The finer the spectral resolution, narrower the wavelengths range for a particular band (Fig. 5.5) and as you know the values of spectral reflectance of objects averaged over different, well-defined wavelength intervals comprise spectral signature of the object or feature by which they can be distinguished.



(a)



(b)

Fig. 5.5: Spectral reflectance signature of (a) different targets including (1) cloud, (2) snow, (3) vegetation, (4) soil and (5) water along with location of IRS-P3 MOS-A, B and C sensor channels and (b) various rock types (source: Navalgund et. al, 2007 and www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/2234)

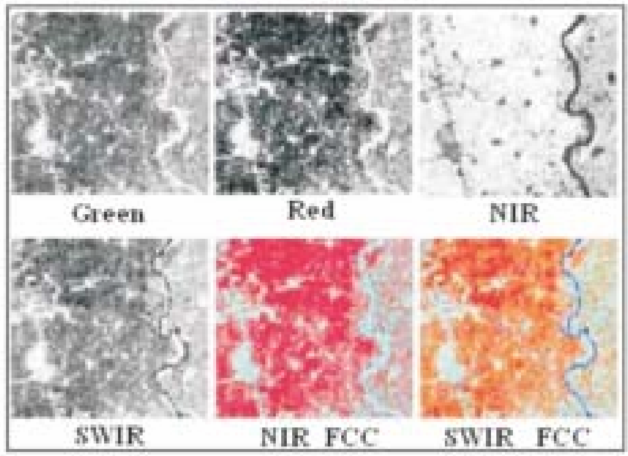


Fig. 5.6: Spectral variations of remote sensing data (source: Navalgund et. al, 2007). NIR – near infrared, SWIR – shortwave infrared, NIR FCC – near infrared false colour composite and SWIR FCC – shortwave infrared false colour composite

Spectral resolution describes ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength ranges for a particular channel or band. It can also be defined as the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a remote sensing instrument is sensitive. High spectral resolution means that sensor distinguishes between very narrow bands of wavelength. Spectral channels containing wide intervals in the electromagnetic spectrum are referred to as coarse spectral resolution and narrow intervals are referred to as fine spectral resolution. Black and white film records wavelength extending entire visible portion of the electromagnetic spectrum. Colour film has higher spectral resolution, as it is individually sensitive to the reflected energy at blue, green, and red wavelengths of the spectrum.

Refer to Unit 10 *Characteristics of Digital Remote Sensing Images* for details on quantisation, bits and bit depth.

Spectral response and emissivity curves characterise the reflectance and/or emittance of a feature or target over a variety of wavelengths. Different classes of features and details in an image can often be distinguished by comparing their responses over distinct wavelength ranges. Broad classes, such as water and vegetation, can usually be separated using very broad wavelength ranges (Fig. 5.6).

Other more specific classes, such as different rock types, may not be easily distinguishable using either of these broad wavelength ranges and would require comparison at much finer wavelength ranges to separate them (Fig. 5.5). Sensors are designed to record a specific portion of the electromagnetic spectrum. Sensors which record radiation over a wide part of visible spectrum in a single waveband are called *panchromatic*. Many remote sensing sensors record energy over several separate wavelength ranges at various spectral resolutions such sensors are referred to as *multi-spectral* sensors having few wide bands. Individual bands and their widths determine the degree to which individual targets (vegetation species, crop or rock types) can be determined on a multi-spectral image. Advanced multi-spectral sensors called *hyperspectral* sensors, detect dozens or hundreds of very narrow spectral bands throughout the visible, near-infrared, and mid-infrared portions of the electromagnetic spectrum. As you have been briefly introduced to the hyperspectral remote sensing in Unit 2 *Recent Trends in Geoinformatics*, Block 1 of MGY-001. Hyperspectral remote sensing deals with imaging at narrow spectral bands over a continuous spectral range and produce the spectra of all pixels in the scene. Hence, hyperspectral data is used to detect the subtle changes in vegetation, soil, water and mineral reflectance.

5.3.3 Radiometric Resolution

As the arrangement of pixels describes spatial structure of an image, the radiometric characteristics describe actual information content in an image. The information content in an image is determined by the number of digital levels (quantisation levels) used to express the data collected by the sensors. In other words, a definite number of discrete quantisation levels are used to record (digitise) the intensity of flow of radiation (radiant flux) reflected or emitted from ground features. The smallest change in intensity level that can be detected by a sensing system is called *radiometric* resolutions. The quantisation levels are expressed as *n* binary bits, such as 7 bit, 8 bit, 10 bit, etc. 8 bit digitisation implies 2^8 or 256 discrete levels (i.e. 0-255). Similarly, 7 bit digitisation implies 2^7 or 128^{th} discrete levels (i.e. 0-127).

The radiometric resolution of an imaging system determines its ability to discriminate very slight differences in energy. Coarse radiometric resolution would record a scene using only a few brightness levels (i.e. at very high contrast) whereas fine radiometric resolution would record the same scene using many brightness levels. A 7 bit data is considered having coarse radiometric resolution in comparison to a 8 bit or 10 bit data. The higher the radiometric resolution of a sensor the more sensitive it is in detecting small differences in reflected or emitted energy. In other words, the higher the radiometric resolution, the better subtle differences of intensity or reflectivity can be represented. In practice, the effective radiometric resolution is typically limited by the noise level, rather than by the number of bits of representation.

As seen in Fig. 5.7, 4-bit quantisation (16 levels) seems acceptable as digitisation using a small number of quantisation levels does not affect very much the visual quality of the image. Each photograph has a dynamic range that is determined by its physical properties. Radiometric resolution also refers to the dynamic range or number of possible data-file values in each band. Dynamic range is the difference between a photograph's lightest and darkest areas.

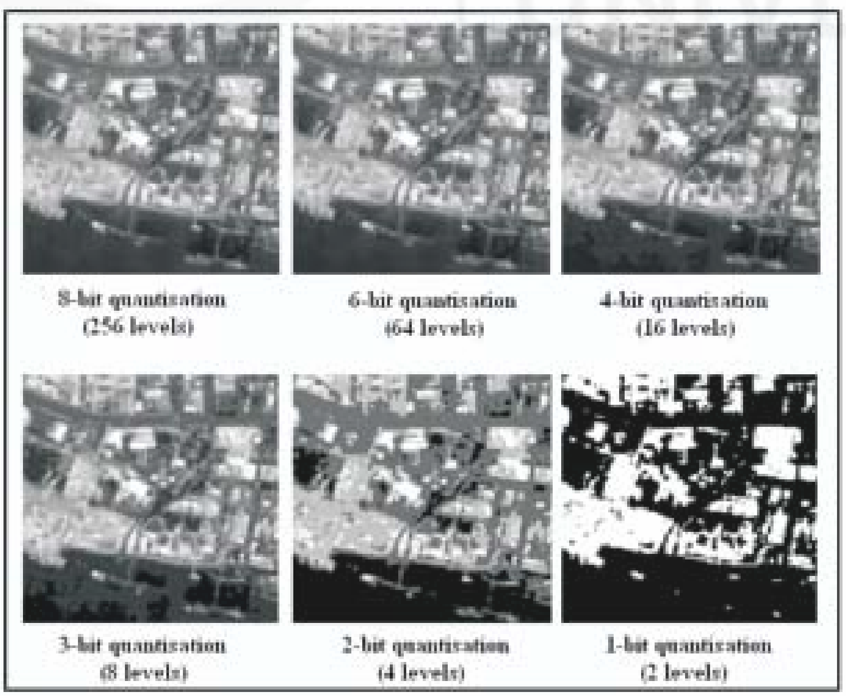


Fig. 5.7: Images showing the effect of degrading the radiometric resolution (source: www.crisp.nus.edu.sg/~research/tutorial/image.htm)

5.3.4 Temporal Resolution

In addition to spatial, spectral and radiometric resolution, it is also important to consider the concept of temporal resolution in a remote sensing system. As we have studied in Unit 1 *Principles of remote Sensing*, one of the advantages of remote sensing is its ability to observe a part of the Earth (scene) at regular intervals. The interval at which a given scene can be imaged is called *temporal* resolution. Temporal resolution is usually expressed in days. For instance, IRS-1A has 22 days temporal resolution, meaning it can acquire image of a particular area in 22 days interval, respectively. Low temporal resolution refers to infrequent repeat coverage whereas high temporal resolution refers to frequent repeat coverage. Temporal resolution is useful for agricultural application (Fig. 5.8) or natural disasters like flooding (Fig. 5.9) when you would like to re-visit the same location within every few days. The requirement of temporal resolution varies with different applications. For example, to monitor agricultural activity, image interval of 10 days would be required, but intervals of one year would be appropriate to monitor urban growth patterns.

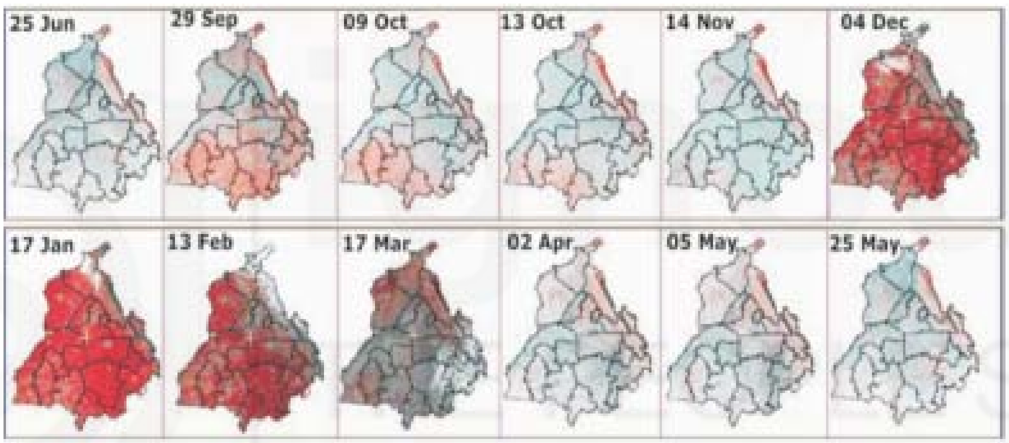


Fig. 5.8: Temporal variations of remote sensing data used to monitor changes in agriculture, showing crop conditions in different months (source: Navalgund et. al, 2007)

Fig. 5.9: Showing the importance of temporal resolution. View of the flood situation at Brisbane, Australia (a) pre flood and (b) post flood (source: http://abc.net.au)

approximately 0945 h and 1030 h local sun time, respectively. However, this is subject to slight variation due to orbital perturbations. Both satellites pass overhead earlier in the day north of the equator and later to the south. The cross track width of the imaging strip is an important parameter in deciding temporal resolution.

Check Your Progress I

1) Name the types of resolution in optical remote sensing.

.... ***Spend 5 mins***

....

....

....

....

2) What is image resolution?

....

....

....

....

....

3) Differentiate between coarse and fine radiometric resolution.

....

....

....

....

....

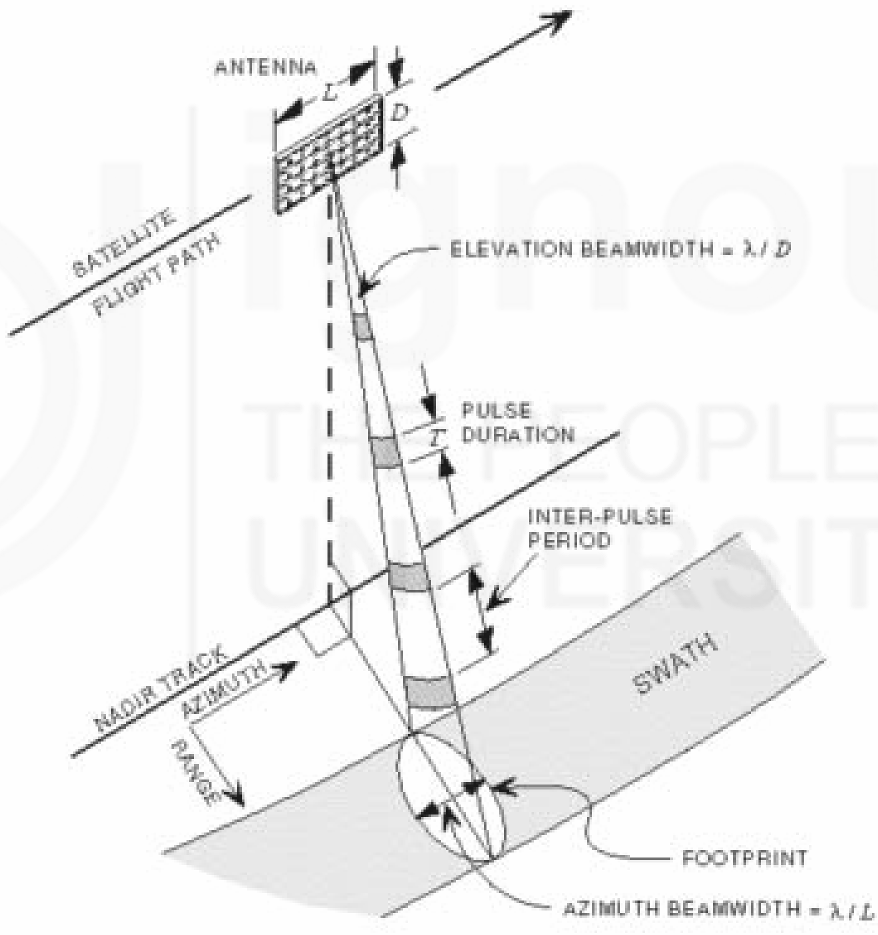
5.4 RESOLUTION IN MICROWAVE REMOTE SENSING

The types of resolutions which you have studied in previous section pertain to the optical remote sensing. In microwave remote sensing, resolution is described in different terms. Now in this section we will be discussing about the resolutions in microwave remote sensing.

Microwave remote sensing employs microwave radiation using wavelengths that range from about 1 mm to 1 m, in particular, in the frequency interval from 40,000 to 300 MHz. This enables observations in all weather conditions without any restriction by cloud or rain. This is an advantage that is not possible with the optical remote sensing.

There are two types of microwave remote sensing: **Passive and Active.** In passive microwave remote sensing the wavelength are so long, the energy available is quite small compared to optical wavelengths. Thus, IFOV must be large to detect enough

There are two types of microwave remote sensing: **Passive and Active.** In passive microwave remote sensing the wavelength are so long, the energy available is quite small compared to optical wavelengths. Thus, IFOV must be large to detect enough energy to record a signal. Most passive microwave sensors are therefore characterised by low spatial resolution. Active remote sensors are generally divided into two distinct categories: imaging and non-imaging. The most common form of imaging active microwave sensors is imaging RADAR. RADAR is an acronym for *Radio Detection And Ranging*, which essentially characterises the function and operation of a radar sensors. Unlike optical systems, radar's spatial resolution depends on specific properties of the microwave radiation and its geometrical effects. Imaging radar is classified into *real aperture radar* (RAR) and *synthetic aperture radar* (SAR). Spatial resolution varies in these two cases. Radar resolution has two dimensions which are *range* (across-track) and *azimuth* (along-track) as shown in Fig. 5.10.



γ

Fig. 5.10: Range (D) refers to the across-track dimension perpendicular to the flight direction, while azimuth (E) refers to the along-track dimension parallel to the flight direction. Similar to optical systems, the platform travels forward in the flight direction with the nadir directly beneath the platform. The microwave beam is transmitted obliquely at right angles to the direction of flight illuminating a swath which is offset from nadir (source: Gonzalez and Woods, 2002)

The ground resolution cell size of a SLAR (Side-Looking Airborne Radar) system is controlled by two independent sensing system parameters: pulse length and antenna beam width. A shot of electromagnetic energy that radar sends out in a straight line to detect a target is known as *pulse*. It is measured in terms of time (the interval between two such successive burst). The radar beam width is inversely proportional to the antenna length (also referred to as aperture), which implies that a longer antenna (or aperture) produces a narrower beam and finer resolution. Finer along-track resolution can be achieved by increasing the antenna length. Unlike optical systems, radar's spatial resolution depends on specific properties of the microwave radiation and its geometrical effects. If a RAR is used for imaging purpose (as in SLAR), a single transmit pulse and the back scattered signal are used to form the image. In this case, the resolution is dependent on the effective length of the pulse in the slant range direction and on the width of the illumination in the azimuth direction. Resolution is determined by antenna beam width in the along-track direction.

The *range* or *across-track* resolution is the ability of the radar to discriminate two targets that are closely spaced in range. For example, a range resolution of 10 m means that two targets that are on the same azimuth and 10 m apart in range can be resolved. It is dependent on the length of the pulse (P), as shown in Fig. 5.11 and Fig. 5.13. Two distinct targets on the surface are resolved in the range dimension if their separation is greater than half the pulse length. For example, in Fig. 5.11, targets 1 and 2 are not separable while targets 3 and 4 can be easily separated into ground range coordinates; the resolution in ground range is dependent of the incidence angle. Thus, for fixed slant range resolution, the ground range resolution decreases with increasing range.

$$R_r = \frac{Tc}{2 \cos \gamma} \qquad \text{.......................................} (2)$$

Where,

T = duration of the radar pulse,

c = speed of light, and

γ= depression angle

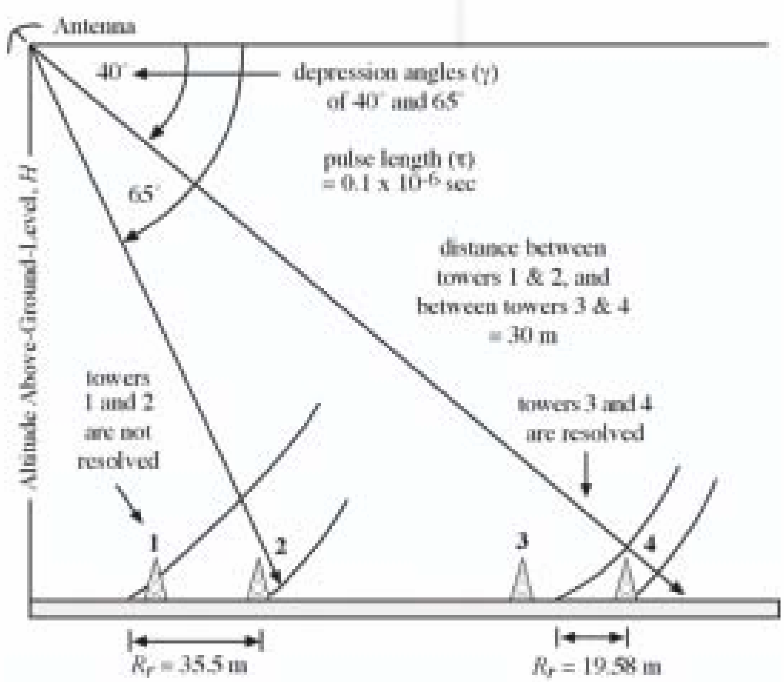


Fig. 5.11: Range or across-track spatial resolution (source: Gonzalez and Woods, 2002)

The *azimuth or along-track* resolution is determined by the angular width of the radiated microwave beam and the slant range distance. Thus, beam width is a measure of the width of the illumination pattern (Figs. 5.12 and 5.13). As the radar illumination propagates to increasing distance from the sensor, the azimuth resolution decreases (becomes coarser). The radar beam width is inversely proportional to the antenna length (also referred to as the aperture), which implies that a longer antenna (or aperture) produces a narrower beam and finer resolution. Finer along-track resolution can be achieved by increasing the antenna length. In Fig. 5.12, targets 1 and 2 in the near range are separable, but targets 3 and 4 at further range are not, though the distance between 1 and 2 is equal to the distance between 3 and 4.

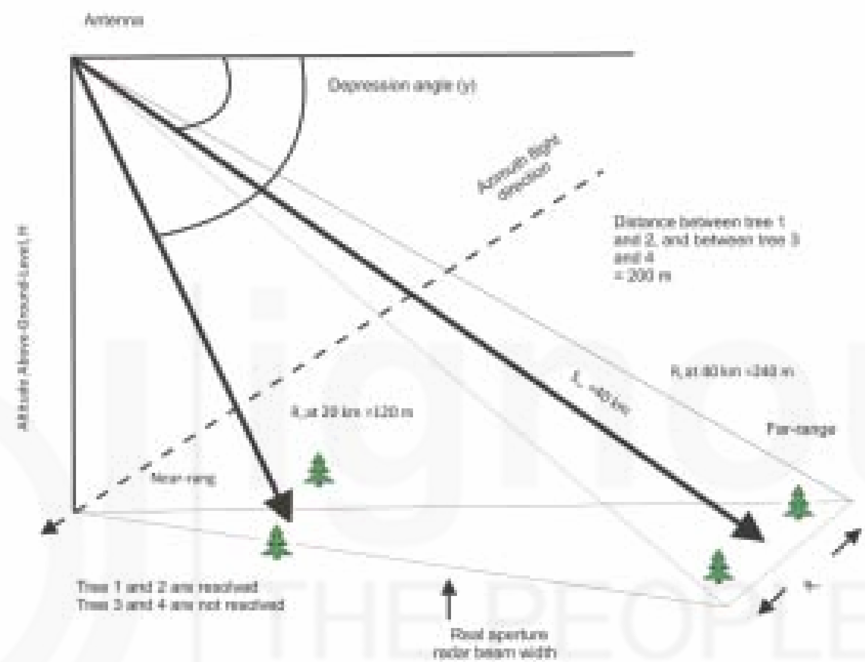


Fig. 5.12: Azimuth resolution or along track spatial resolution (source: Gonzalez and Woods, 2002)

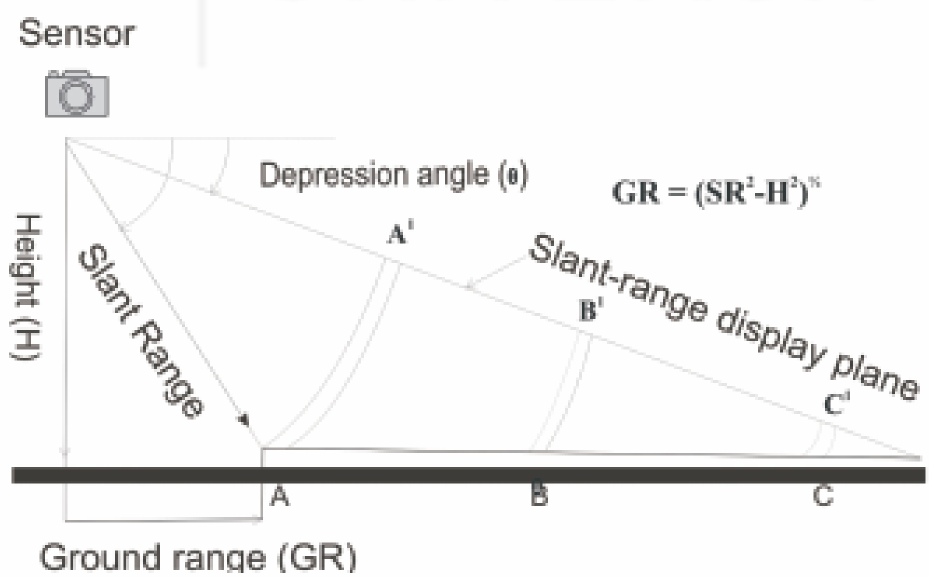


Fig. 5.13: Relationship between slant range resolution and ground range resolution (source: Gonzalez and Woods, 2002)

5.5 RELATIONSHIP BETWEEN DIFFERENT TYPES OF RESOLUTION

You have read in earlier sections that the arrangement of pixels describes spatial structure of an image whereas radiometric characteristics describe the actual information content in an image. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy. The finer the radiometric resolution of a sensor; the more sensitive it is to detecting small differences in reflected or emitted energy. In addition to above basic parameters, sensor must also have a high geometric fidelity, and images of different bands should be well registered to enable multi-spectral classification.

Most first-time users of remote sensing assume that higher resolution provides more detail which, in turn, must yield more information for feature identification and analyses. Although it is true that higher resolution generates more data, however, it is not always synonymous with more information.

The particular challenge in monitoring land areas is to capture the patterns of spatially detailed land cover change, within the context of seasonal land cover dynamics (Fig. 5.14). Imagery is always acquired within a spatial, spectral and temporal context. Fig. 5.14 depicts the relation between spatial resolution and temporal resolution in various types of data.

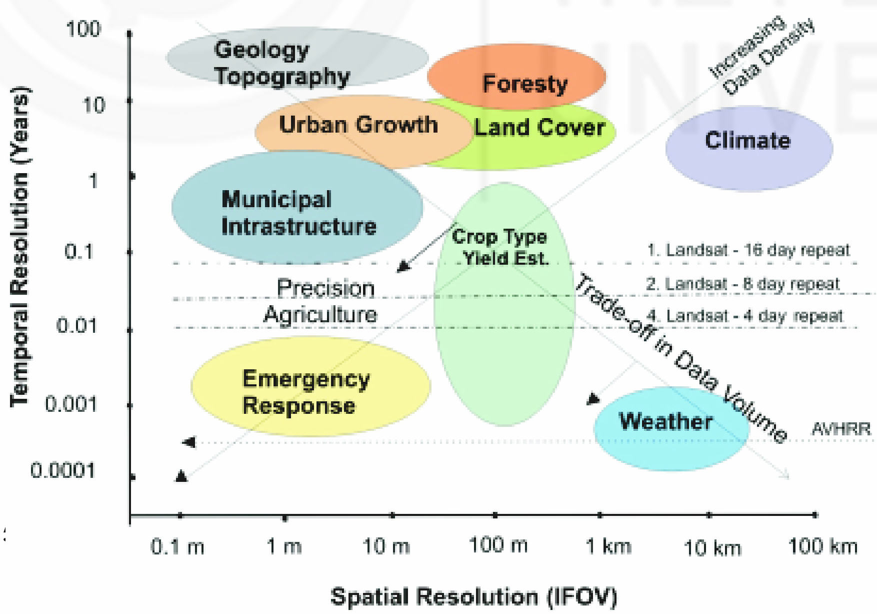


Fig. [illegible]

Images acquired repetitatively through time record the dynamics of surface cover change that result from biophysical, geochemical, and socio-economic processes operating within the Earth system. Remote sensing provides the facility of monitoring the sudden and short lived changes, requiring swift data acquisition and analyses to monitor and evaluate the impact of events such as storms, tsunamis, hurricanes, flood, effluent discharge, droughts, forest fire, locust plagues, dispersion rate of oil slicks and development and movement of phytoplankton blooms in estuaries. In some instances, more detail merely introduces noise that obscures identification of features of interest, for example, we do not need to discern every grassy patch in order to determine whether the area is urban or farmland.

There are trade-offs between spatial, spectral, and radiometric resolution which are taken into consideration when engineers design a sensor. For high spatial resolution, the sensor has to have a small IFOV. However, this reduces the amount of energy that can be detected as the area of the ground resolution cell within the IFOV becomes smaller. This leads to reduced radiometric resolution i.e. the ability to detect fine energy differences. To increase the amount of energy detected (and radiometric resolution) without reducing spatial resolution, we have to broaden the wavelength range detected for a particular channel or band. Unfortunately, this reduces the spectral resolution of the sensor. Conversely, coarser spatial resolution would allow improved radiometric and/or spectral resolution. Thus, these three types of resolution must be balanced against the desired capabilities and objectives of the sensor.

You have seen that the timely use of remote sensing information, which has increased over past twenty years, provides information essential for monitoring and mitigating environmental problems that occur suddenly on a big scale. The ability to obtain data rapidly and inexpensively over large geographic regions means that remote sensing can help us document the local, regional and global consequences of acute and chronic changes in ecosystems and environment. Finally, in addition to its spatial and temporal advantages remote sensing offers the advantage of a wide spectral coverage. During the geological fieldwork our eyes are capable of detecting particular lithology based on the colour and we have no difficulty in distinguishing sandstone from granite based on colour. Because different lithology reflects radiation and their colour or spectral signature often contrasts with that of the background, we can use remote sensing to identify and detect rock-types within the landscape.

Check Your Progress II

Spend 5 mins

1) Name the types of resolution in microwave remote sensing.

....

....

....

....

2) Differentiate between azimuth and range resolution.

....

....

....

5.6 ACTIVITY

Take a photograph of an object in the maximum resolution (megapixel) of your digital camera. Take two or more photographs of the same object using the same camera but in reduced resolution (megapixel). Look at the quality and note down the details of each photograph at different resolutions.

5.7 SUMMARY

Let us summarise, what you have studied in this unit:

- Resolution of a sensor system may be defined as its capability to discriminate two closely spaced objects from each other.
- Image resolution can be measured in various ways like spatial, spectral, temporal and radiometric resolutions.
- Spatial resolution can broadly be described as the ground surface area that forms one pixel in the satellite image.
- Spectral resolution describes ability of a sensor to define fine wavelength intervals.
- Radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy.
- Temporal resolution is the shortest amount of time between image acquisitions of a given location.
- The resolution of radar is its ability to distinguish between targets that are very close in either range or bearing.
- Range resolution is the ability of a radar system to distinguish between two or more targets on the same bearing but at different ranges, while azimuth resolution refers to the along-track dimension parallel to the flight direction.

5.8 UNIT END QUESTIONS

Spend 30 mins

1) Explain in brief the different types of image resolution.
2) Mention the factors affecting image resolution.
3) What is the difference between spatial and temporal resolution?
4) What do you understand by resolution in microwave remote sensing?

5.9 REFERENCES

- Davis, F., Quattrochi, D., Ridd, M., Lam, N., Walsh, S., Michaelson, J., Franklin, J., Stow, D., Johanssen, C., and Johnston, C. (1991), *Environmental analysis using integrated GIS and remotely sensed data: some research needs and priorities*, Photogrammetric Engineering and Remote Sensing, V. 57(6), 689-697p.
- Estes, J. E., and Simonett, D. S. (1975), *Fundamentals of image interpretation,* In Manual of Remote Sensing, American Society of Photogrammetry, Washington DC, 869-1076p.
- Gonzalez, R.C. and Woods R.E. (2002), *Digital Image Processing*, 2nd Ed., Pearson Education, 793p.
- Goward, S. and Williams D. (1997), *Landsat and Earth system science:*

development of terrestrial monitoring, Photogrammetric Engineering and Remote Sensing, V. 63(7), 887-900p.

- http://abc.net.au.
- http://rst.gsfc.nasa.gov.
- Navalgund, R. R., Jayaraman, V. and Roy, P. S. (2007), *Remote sensing applications: an overview,* Current Science, V. 93(12), 1747-1766p.
- www.crisp.nus.edu.sg/~research/tutorial/image.htm
- www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/2234

All the above websites were retrieved on 25th February 2011.

5.10 FURTHER/SUGGESTED READINGS

- Campbell, J. B. (1996) *Introduction to Remote Sensing,* 2nd Ed., Taylor and Francis Co., 622p.
- Drury, S.A. (1990) *A Guide to Remote Sensing*, Oxford, 199p.
- Sabins, F.F. (1987) *Remote Sensing Principles and Interpretation*, 2nd Ed., W.H. Freeman & Co., 449p.

5.11 ANSWERS

Check Your Progress I

1) Spatial, spectral, radiometric and temporal
2) Refer beginning of the sections 5.1 and 5.2.
3) Refer section 5.3.3.

Check Your Progress II

1) Range or across-track resolution and azimuth or along-track resolution.
2) Refer section 5.4

Unit End Questions

For question, 1 and 2 refer section 5.1 and 5.2, respectively.

For question, 3 and 4 refer section 5.3 and 5.4, respectively.