organic and inorganic material and by the depth of the water body. Fig. 1.8 shows the spectral reflectance curves for visible and near-infrared wavelengths at the surface and at 20 m depth.

Suspended solids in water scatter the down welling radiation, the degree of scatter being proportional to the concentration and the color of the sediment. Experimental studies in the field and in the laboratory as well as experience with multispectral remote sensing have shown that the specific targets are characterized by an individual spectral response. Indeed, the successful developmentof remote sensing of environment over the past decade bears witness to its validity. In the remaining part of this section, typical and representative spectral reflectance curves for characteristic types of the surface materials are considered.

Imagine a beach on a beautiful tropical island. of electromagnetic radiation with the top layer of sand grains on the beach. When an incident ray of electromagnetic radiation strikes an air/grain interface, part ofthe ray is reflected and part of it is transmitted into the sand grain. The solid lines in the figurerepresent the incident rays, and dashed lines 1, 2, and 3 represent rays reflected from the surfacebut have never penetrated a sand grain. The latter are called specular rays by Vincent and Hunt(1968), and surface-scattered rays by Salisbury and Wald (1992); these rays result from first-surface reflection from all grains encountered.

For a given reflecting surface, all specular rays reflected in the same direction, such that the angle of reflection (the angle between the reflected rays and the normal, or perpendicular to the reflecting surface) equals the angle of incidence (the angle between the incident rays and the surface normal). The measure of how much electromagnetic radiation is reflected off a surfaceis called its reflectance, which is a number between 0 and 1.0. A measure of 1.0 means the 100% of the incident radiation is reflected off the surface, and a measure of 0 means that 0% is reflected.

ENERGY INTERACTIONS WITH EARTH SURFACE FEATURES

Energy incident on the Earth ‘s surface is absorbed, transmitted, or reflected depending on the wavelength and characteristics of the surface features (such as barren soil, vegetation, water body). Interaction of the electromagnetic radiation with the surface features is dependent on the characteristics of the incident radiation and the feature characteristics. After interaction with the surface features, energy that is reflected or re-emitted from the features is recorded atthe sensors and are analyzed to identify the target features, interpret the distance of the object,and /or its characteristics. This lecture explains the interaction of the electromagnetic energy with the Earth ‘s surface features.

Energy Interactions

The incident electromagnetic energy may interact with the earth surface features in threepossible ways: Reflection, Absorption and Transmission.

Reflection occurs when radiation is redirected after hitting the target. According to the law of reflection, the angle of incidence is equal to the angle of reflection the EM energy which is absorbed by the Earth‘s surface is available for emission and as thermal radiation at longer wavelengths.

Transmission occurs when radiation is allowed to pass through the target. Depending upon the characteristics of the medium, during the transmission velocity and wavelength of the radiation changes, whereas the frequency remains same. The transmitted energy may further get scattered and / or absorbed in the medium.

These three processes are not mutually exclusive. Energy incident on a surface may be partially reflected, absorbed or transmitted. Which process takes place on a surface depends on the following factors:

- Wavelength of the radiation
- Angle at which the radiation intersects the surface
- Composition and physical properties of the surface

The relationship between reflection, absorption and transmission can be expressed through the principle of conservation of energy. Let *EI* denotes the incident energy, *ER* denotes the reflected energy, *EA* denotes the absorbed energy and *ET* denotes the transmitted energy. Thenthe principle of conservation of energy (as a function of wavelength λ) can be expressed as

$$EI(\lambda) = ER(\lambda) + EA(\lambda) + ET(\lambda) \qquad (1)$$

Since most remote sensing systems use reflected energy, the energy balance relationship can be better expressed in the form.

$$ER(\lambda) = EI(\lambda) - EA(\lambda) - ET(\lambda) \qquad (2)$$

The reflected energy is equal to the total energy incident on any given feature reduced by the energy absorbed or transmitted by that feature.

Reflection

Reflection is the process in which the incident energy is redirected in such a way that the angleof incidence is equal to the angle of reflection. The reflected radiation leaves the surface at the same angle as it approached. Scattering is a special type of reflection wherein the incident energy is diffused in many directions and is sometimes called diffuse reflection.

When electromagnetic energy is incident on the surface, it may get reflected or scattered depending upon the roughness of the surface relative to the wavelength of the incident energy.If the roughness of the surface is less than the wavelength of the radiation or the ratio of roughness to wavelength is less than 1, the radiation is reflected. When the ratio is more than 1or if the roughness is more than the wavelength, the radiation is scattered.

Fraction of energy that is reflected / scattered is unique for each material. This will aid in distinguishing different features on an image. A feature class denotes distinguishing primitive characteristic or attribute of an image that havebeen classified to represent a particular land cover type/spectral signature. Within one feature class, the proportion of energy reflected, emitted or absorbed depends on the wavelength. Hence, in spectral range two features may be indistinguishable; but their reflectance propertiesmay be different in another spectral band. In multi-spectral remote sensing, multiple sensors are used to record the reflectance from the surface features at different wavelength bands and hence to differentiate the target features.

Variations in the spectral reflectance within the visible spectrum give the colour effect to the features. For example, blue colour is the result of more reflection of blue light. An object appears as –green‖ when it reflects highly in the green portion of the visible spectrum. Leaves appear green since its chlorophyll pigment absorbs radiation in the red and blue wavelengths but reflects green wavelengths. Similarly, water looks blue-green or blue or green if viewed through visible band because it reflects the shorter wavelengths and absorbs the longer wavelengths inthe visible band. Water also absorbs the near infrared wavelengths and hence appears darker when viewed through red or near infrared wavelengths. Human eye uses reflected energy variations in the visible spectrum to discriminate between various features.

For example, shows a part of the Krishna River Basin as seen in different bands of the Landsat ETM+ imagery. As the concepts of false colour composite (FCC) have been covered in module4, readers are advised to refer to the material in module 4 for better understanding of the colour composite imageries as shown in Fig. 5. Reflectance of surface features such as water, vegetation and fallow lands are different in different wavelength bands. A combination of more than one spectral band helps to attain better differentiation of these features.

Diffuse and Specular Reflection

Energy reflection from a surface depends on the wavelength of the radiation, angle of incidenceand the composition and physical properties of the surface. Roughness of the target surface controls how the energy is reflected by the surface. Based onthe roughness of the surface, reflection occurs in mainly two ways.

Specular reflection: It occurs when the surface is smooth and flat. A mirror-like or smooth reflection is obtained where complete or nearly complete incident energy is reflected in one direction. The angle of reflection is equal to the angle of incidence. Reflection from the surfaceis the maximum along the angle of reflection, whereas in any other direction it is negligible.

Diffuse (Lambertian) reflection: It occurs when the surface is rough. The energy is reflected uniformly in all directions. Since all the wavelengths are reflected uniformly in all directions, diffuse reflection contains spectral information on the "color" of the reflecting surface. Hence,in remote sensing diffuse reflectance properties of terrain features are measured. Since the reflection is uniform in all direction, sensors located at any direction record the same reflectanceand hence it is easy to differentiate the features.

Based on the nature of reflection, surface features can be classified as specular reflectors, Lambertian reflectors. An ideal specular reflector completely reflects the incident energy with angle of reflection equal to the angle incidence. An ideal Lambertian or diffuse reflector scatters all the incident energy equally in all the directions.

The specular or diffusive characteristic of any surface is determined by the roughness of the surface in comparison to the wavelength of the incoming radiation. If the wavelengths of the incident energy are much smaller than the surface variations or the particle sizes, diffuse reflection will dominate. For example, in the relatively long wavelength radio range, rocky terrain may appear smooth to incident energy. In the visible portion of the spectrum, even a material such as fine sand appears rough while it appears fairly smooth to long wavelength microwaves.

Most surface features of the earth are neither perfectly specular nor perfectly diffuse reflectors. In near specular reflection, though the reflection is the maximum along the angle of reflection, a fraction of the energy also gets reflected in some other angles as well. In near Lambertian reflector, the reflection is not perfectly uniform in all the directions. The characteristics of different types of reflectors are Near diffusive Near specular Ideal diffusive Ideal specular Angle of reflection Angle of incidence.

Lambertian reflectors are considered ideal for remote sensing. The reflection from an ideal Lambertian surface will be the same irrespective of the location of the sensor. On the other hand, in case of an ideal specular reflector, maximum brightness will be obtained only atone location and for the other locations dark tones will be obtained from the same target. Thisvariation in the spectral signature for the same feature affects the interpretation of the remote sensing data.

Most natural surfaces observed using remote sensing are approximately Lambertian at visible and IR wavelengths. However, water provides specular reflection. Water generally gives a dark tone in the image. However due to the specular reflection, it gives a pale tone whenthe sensor is located in the direction of the reflected energy.