

INTRODUCTION TO MICROWAVE REMOTE SENSING - II

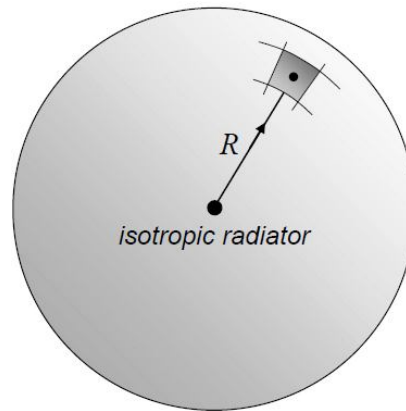
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The Radiation Framework

- The information about features on the Earth's surface using RS depends on measuring energy emanating from the region of interest
- The energy can originate from
 - The Earth's surface
 - Reflected energy incident on the Earth's surface from an external source → Sun
 - Artificial source
- Important to look at expression that describe the actual energy levels generated by the Sun and the Earth

The Radiation Framework

- Energy propagates outwards in free space from a **point source**
- The Sun radiates its energy approximately uniformly in all directions in space → **Isotropic Radiator**



- Because we see the Sun from a large distance we will assume it be isotropic

The Radiation Framework

- The properties of the radiator is described in terms of power (energy per unit time: J/s = Watt) rather than absolute energy (Joules)
- The energy is carried forward by EM wave as expanding wavefront
- We are generally not interested in the total power output from the point source, but only that portion being radiated in a given direction → **Power Density**

$$p = \frac{P_t}{4\pi R^2} \quad \text{Wm}^{-2}$$

The Radiation Framework

- We can determine the levels of power available from the Sun or Earth for imaging purpose
- Planck's radiation law → Black body radiation

Spectral Radiant Exitance or Spectral Power Density

$$M_{\lambda} = \frac{c_1}{\lambda^5 (e^{c_2 / \lambda T} - 1)} \text{ Wm}^{-2} \mu\text{m}^{-1}$$

$$c_1 = 2 \pi h c^2 \quad c_1 = 3.74176 \times 10^8 \text{ Wm}^{-2} \mu\text{m}^4$$

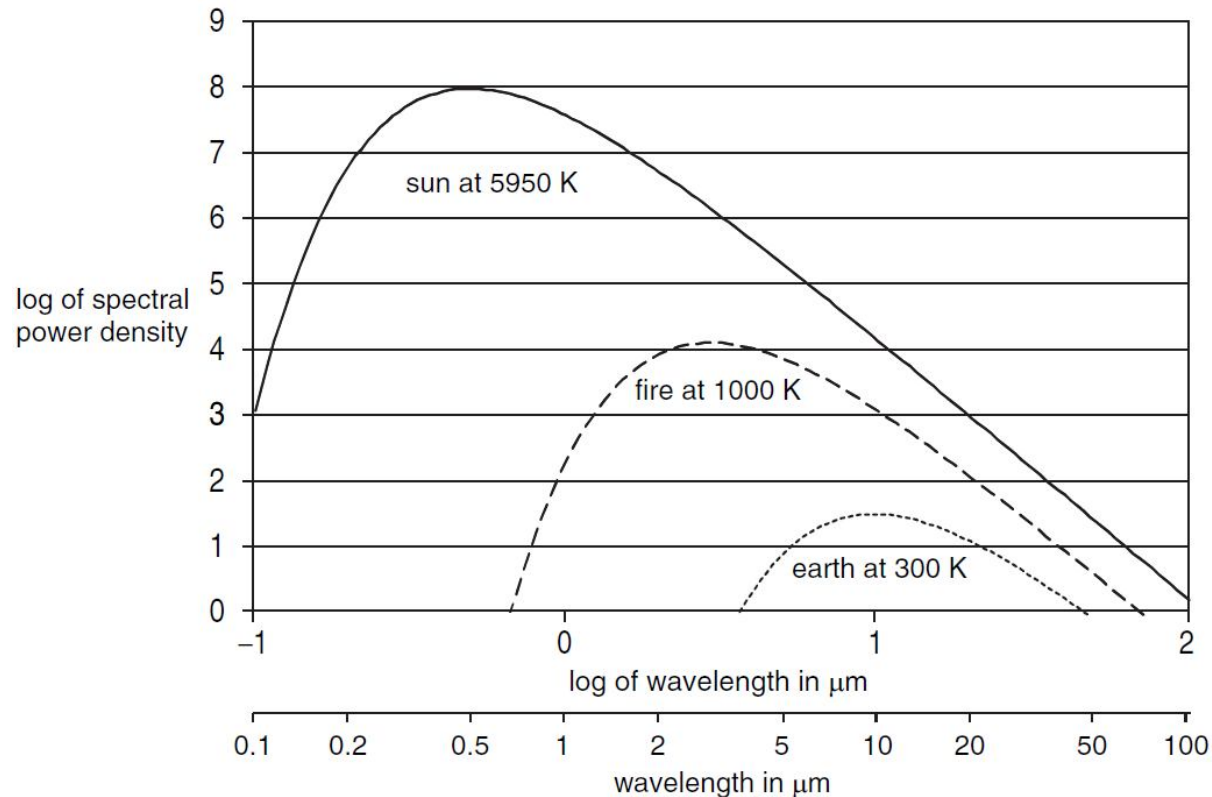
$$c_2 = \frac{hc}{k} \quad c_2 = 1.43877 \times 10^4 \mu\text{mK}$$

$$h = 6.62607 \times 10^{-34} \text{ Js} \quad (\text{Planck's constant})$$

$$c = 299.792 \text{ Mms}^{-1} \quad (\text{velocity of light})$$

$$k = 1.38065 \times 10^{-23} \text{ JK}^{-1} \quad (\text{Boltzmann's constant})$$

The Radiation Framework



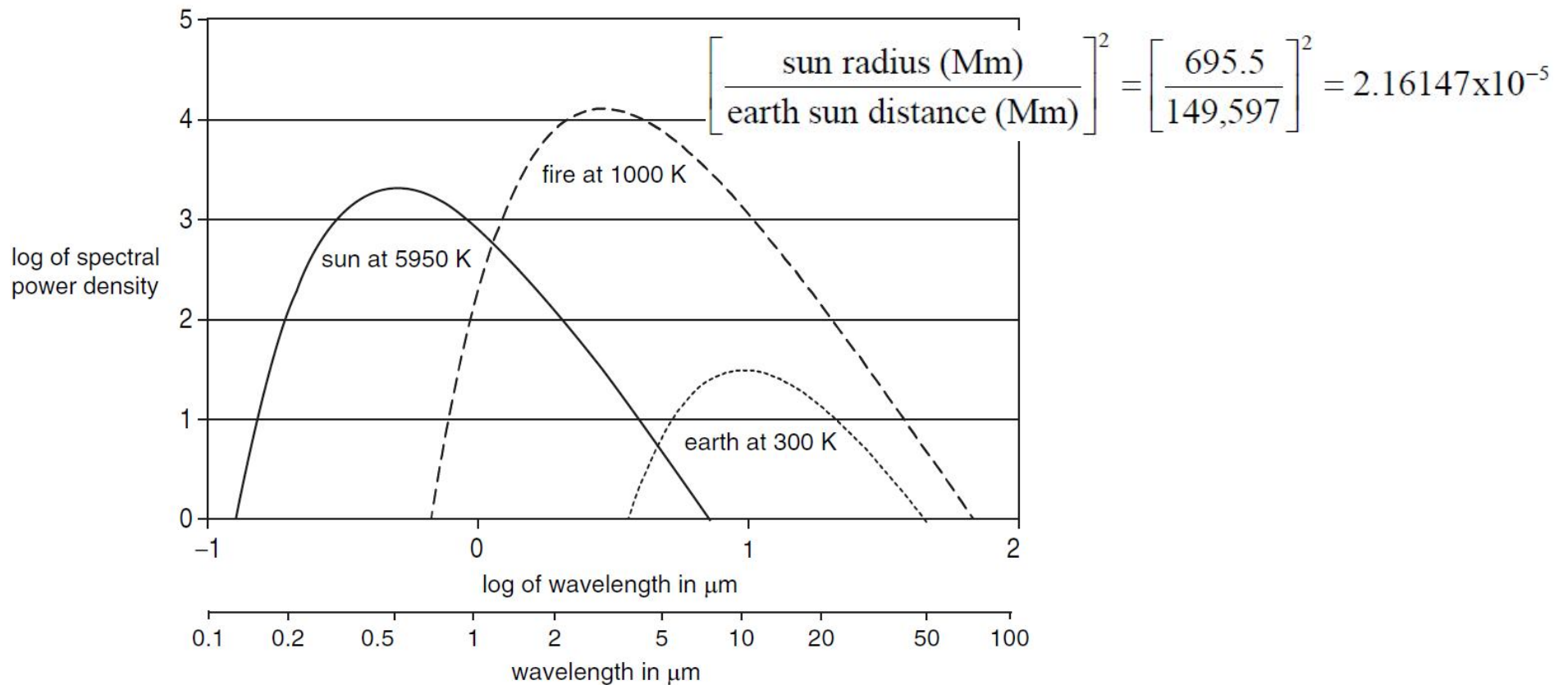
❑ Spectral power density (log scale) emitted by black body at different temperatures as a function of wavelength

❑ The curves in the figure are those at the surface of the respective black bodies i.e. they are the power available per unit of surface area of the body per unit of wavelength

The Radiation Framework

- Real emitters of radiant energy do not behave as ideal black bodies instead the power spectral density is smaller by a factor ε , referred to as the **emissivity** of the body (or its surface)
- Emissivity is generally wavelength dependent and is in the range $0 < \varepsilon < 1$
- The level of solar energy available at the Earth can be found by reducing the magnitude of the solar curve as result of the inverse square law dispersion of solar power density during its passage to the Earth

The Radiation Framework



❑ The corrected solar curves explains that sensing the Earth at 10-12 μm can reveal its thermal properties

❑ The corrected solar curve however does not take into account the effect of the Earth's atmosphere

Wavelength Ranges Used in Remote Sensing

- **Lower Radio frequencies (longer wavelengths) can be used in RS**
 - **The most interesting wavelengths to employ in sensing surface features are those in the microwave portion of the EM spectrum**
- **The microwave energy of interest in RS is largely in the range of about 300 MHz – 20 GHz**

Wavelength Ranges Used in Remote Sensing

- It is important to know the total available energy over a given range of wavelengths

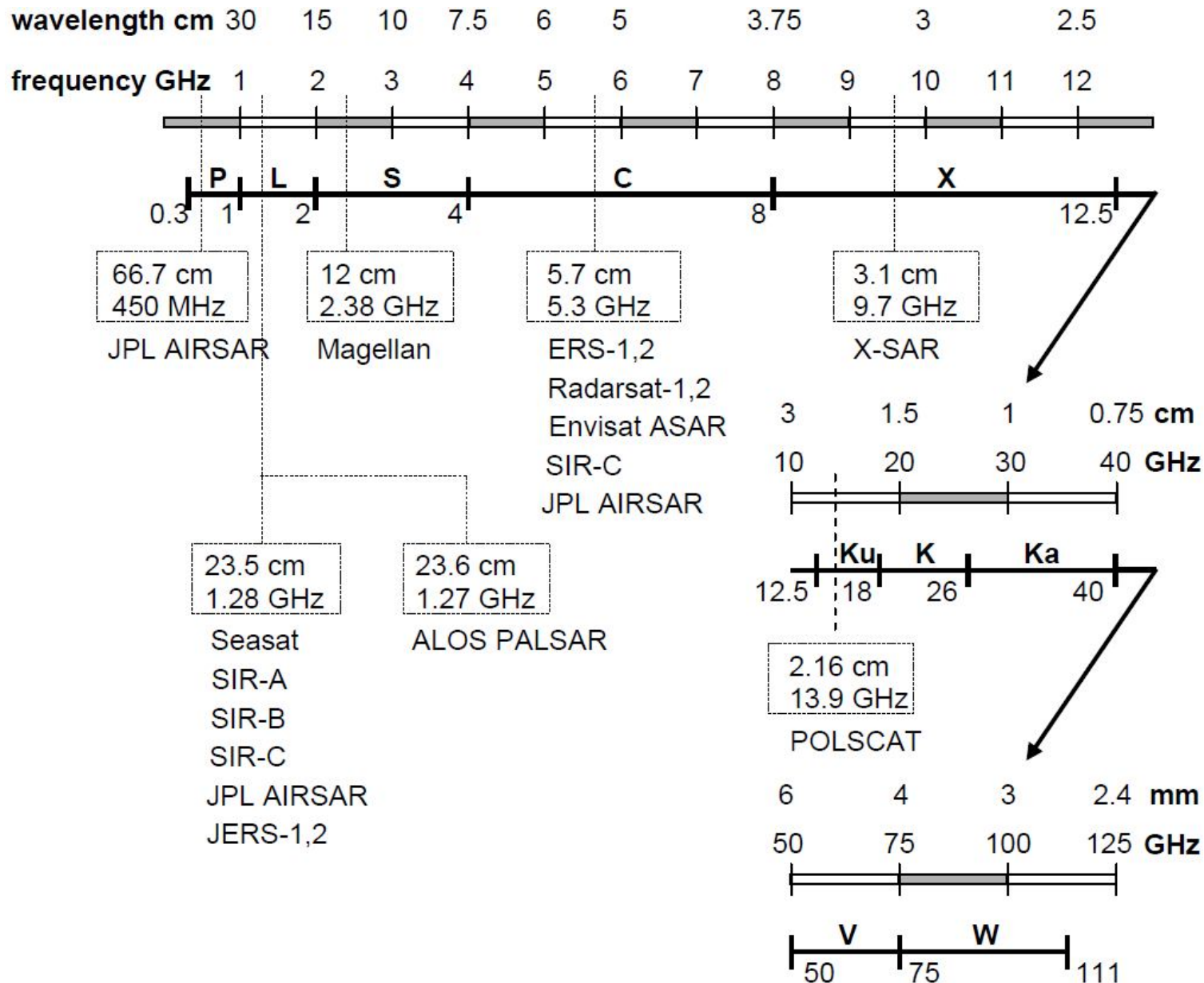
$$M = \int_{\lambda_1}^{\lambda_2} M_{\lambda} d\lambda \quad \text{Wm}^{-2}$$

- If the power density over *all wavelengths* is of interest it can be shown that

Stefan-Boltzmann radiation law

$$M = \int_0^{\infty} M_{\lambda} d\lambda = \sigma T^4 \text{Wm}^{-2}$$
$$\sigma = 5.67040 \times 10^{-8} \text{Wm}^{-2}\text{K}^{-4}$$

Wavelength Ranges Used in Remote Sensing



Wavelength Ranges Used in Remote Sensing

- The power density at the surface of the Sun (at an assumed temperature of 5950 K)

$$M = 5.67040 \times 10^{-8} \times (5950)^4 = 71 \text{ MWm}^{-2}$$

- The solar power density at the top of the Earth's atmosphere

$$M_e = M \times \left[\frac{\text{sun radius (Mm)}}{\text{earth sun distance (Mm)}} \right]^2$$

$$M_e = 71 \times 10^6 \times 2.16147 \times 10^{-5} = 1.53 \text{ kWm}^{-2}$$

- This is the Earth surface solar power density in the absence of any atmospheric absorption, assuming that the Sun acts as an ideal black body radiator (Planck's law)

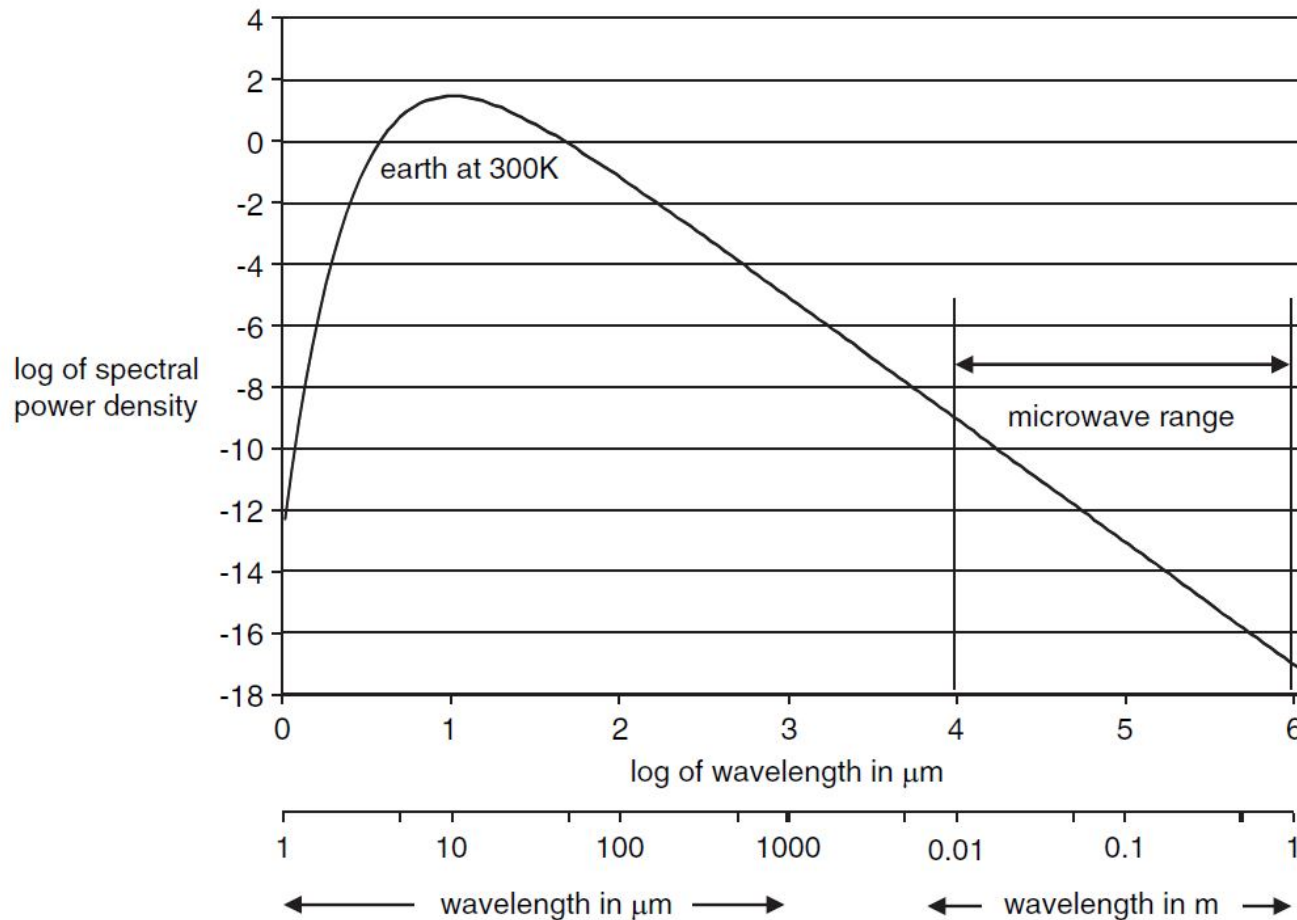
Wavelength Ranges Used in Remote Sensing

- The actual solar power density at the Earth is known as the **solar constant** = 1.37 kWm^{-2}
- It differs from the value computed (1.53 kWm^{-2}) because
 - The corrected temperature to use in the computation of Planck's law depends on the wavelength
 - The solar emission at different wavelengths comes from differing portions of the Sun's outer layers, an average Sun temperature of 5800 K gives a value of 1.39 kWm^{-2} for the solar constant

Energy Available for Microwave Imaging

- **The infinite wavelength range in Planck's law implies there is also microwave energy available from the Sun**
- **Energy emanating from the Earth itself is studied because beyond 10 μm wavelength the energy available at the Earth's surface from sunlight is significantly below that from the Earth itself**

Energy Available for Microwave Imaging



❑ The figure shows the black body radiation curve for the Earth at 300 K extended out to microwave wavelengths with the maximum at 10 μm

Energy Available for Microwave Imaging

- For a radiator at 300 K

$$M_{\lambda} = \frac{c_1}{\lambda^5 (e^{c_2/\lambda T} - 1)} \text{ Wm}^{-2} \mu\text{m}^{-1} \quad c_2/\lambda T = \frac{1.43877 \times 10^4}{3 \times 10^4 \times 300} \approx 1.6 \times 10^{-3}$$

$$e^{c_2/\lambda T} \approx 1 + c_2/\lambda T \quad \Rightarrow \quad M_{\lambda} = \frac{c_1 T}{c_2 \lambda^4} = \frac{a T}{\lambda^4} \text{ MWm}^{-2} \mu\text{m}^{-1}$$
$$a \approx 2.6 \times 10^4 \text{ Wm}^{-2} \mu\text{m}^3 \text{K}^{-1}$$

Rayleigh-Jeans law (Rayleigh-Jeans approximation to Planck's law)

Energy Available for Microwave Imaging

- **For a radiator at 300 K**

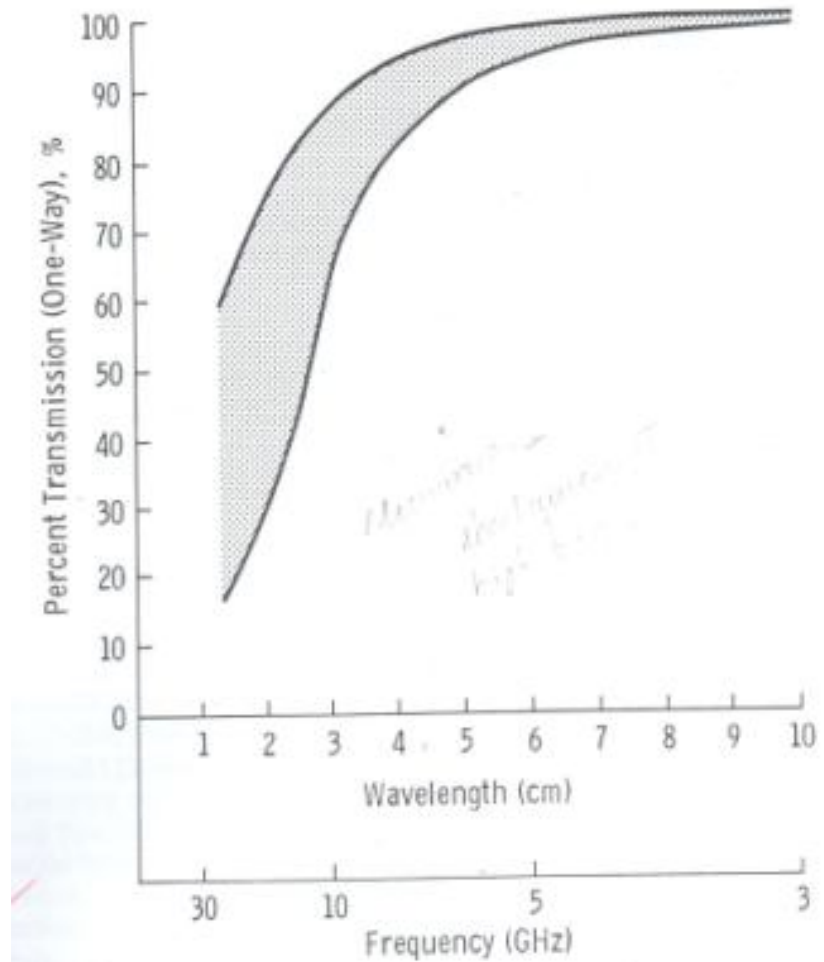
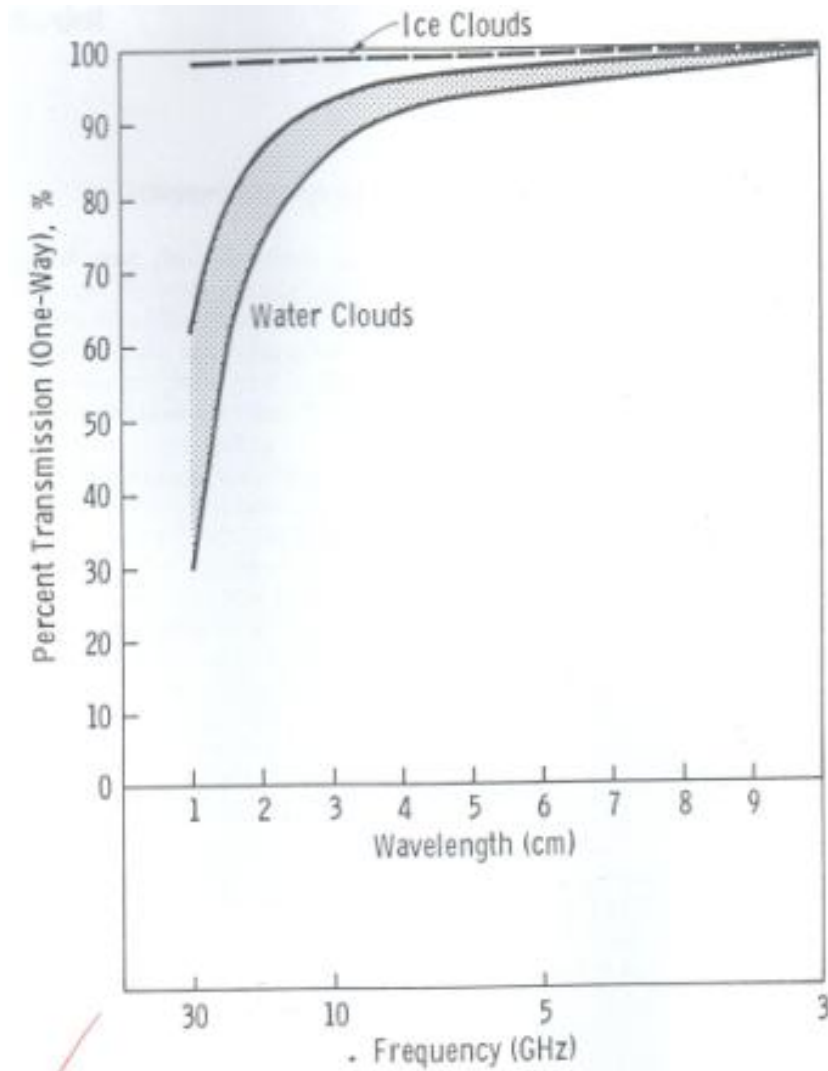
$$\begin{aligned} M &= \int_{0.03m}^{0.3m} M_{\lambda} d\lambda \\ &= aT \int_{0.03m}^{0.3m} \lambda^{-4} d\lambda \\ &= -\frac{780 \times 10^{-14}}{3} \lambda^{-3} \Big|_{0.03m}^{0.3m} \\ &= 96.2 \text{ nWm}^{-2} \end{aligned}$$

❑ This is very small power density even though it was computed over a broad range of wavelength

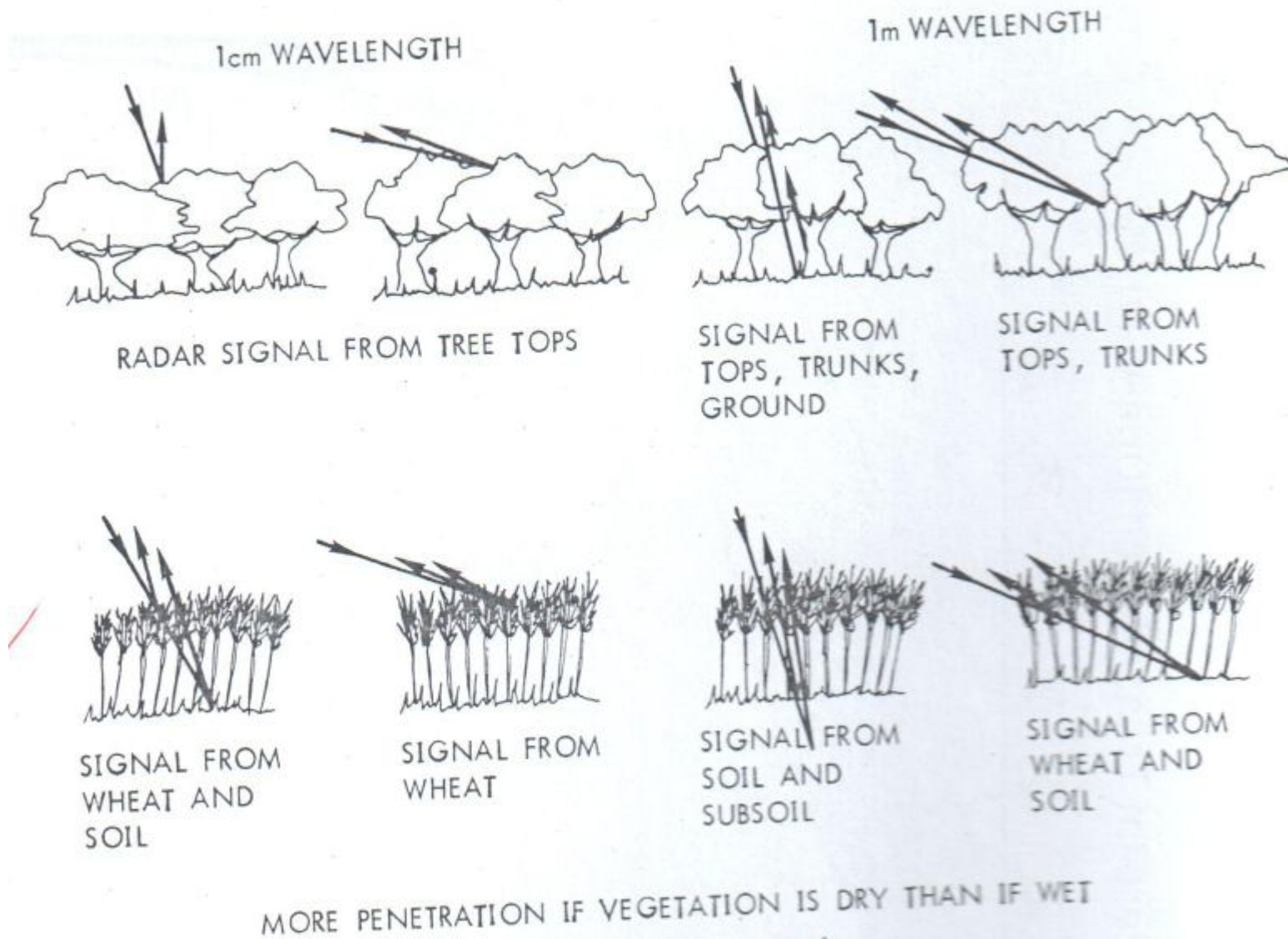
Energy Available for Microwave Imaging

- **At very low frequencies the ionosphere is a major problem for RS**
- **RS radars would not operated at those frequencies for which the ionosphere is opaque (~10 MHz and lower)**
 - **Faraday rotation can be a problem with L band (~1 GHz and lower**
 - **The free electron in the ionosphere coupled with the Earth's magnetic field can cause the plane of polarization of the wave passing through the ionosphere to rotate**

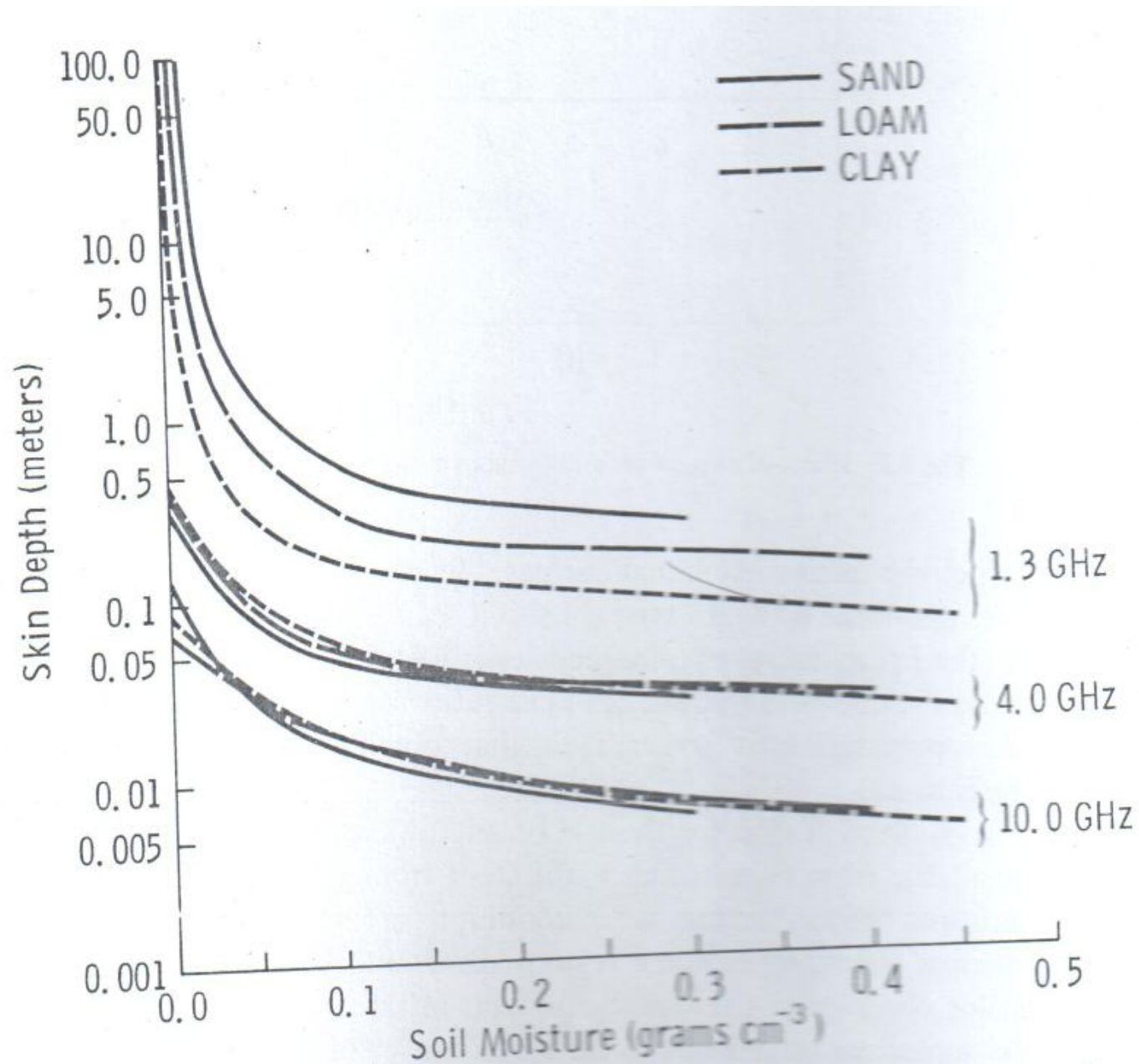
Energy Available for Microwave Imaging



Energy Available for Microwave Imaging



Energy Available for Microwave Imaging



Question ?

What is the significance of the colors observed in an image taken by a microwave sensor and sensors operating with visible and near IR wavelengths ?

The Underlying EM Fields

- So far we have been studying the levels of power and power density in the development of radar as an imaging modality
- It is now important to understand some of the properties of the Electric and Magnetic fields that carry the power to and from the Earth's surface

