

PASSIVE MICROWAVE IMAGING

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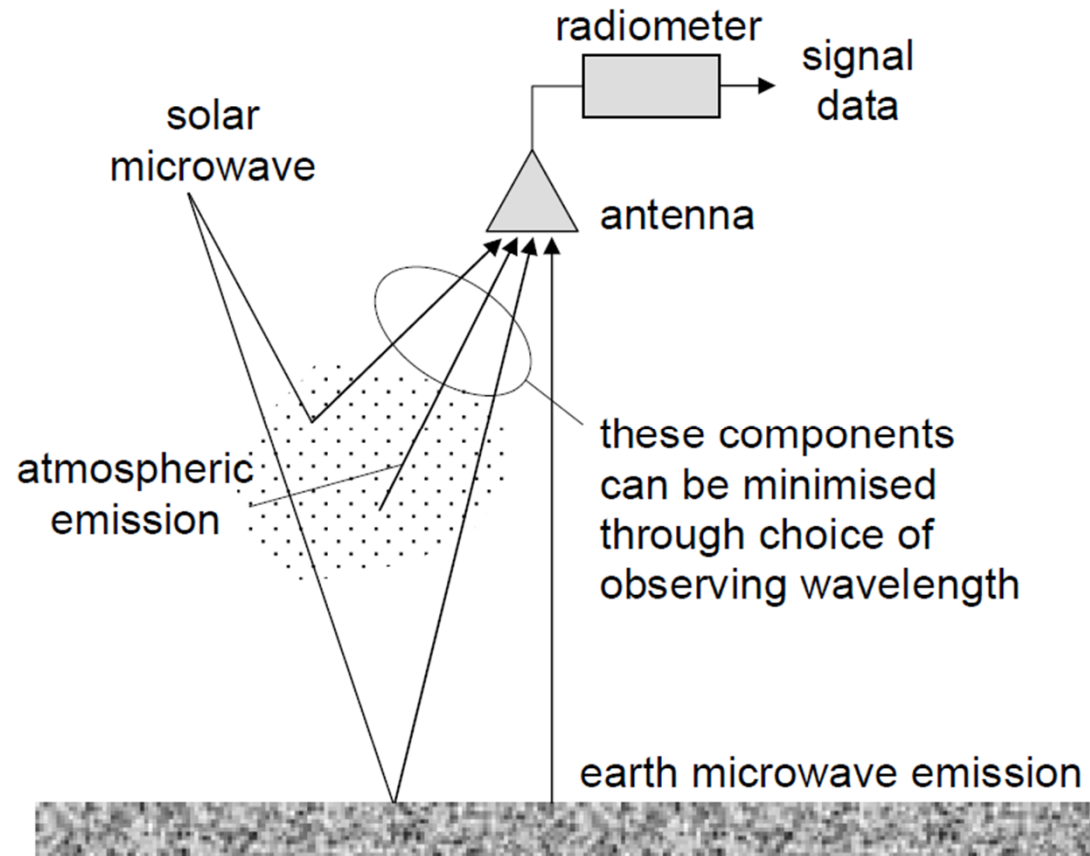
Basic Principles of Passive Microwave Imaging

- **Imaging with passive microwave is a complementary technology that needs an introduction to identify its role alongside radar**
- **Passive MRS is possible provided sufficiently large resolution cells are used so that measurable power levels available from the Earth can be obtained**
- **Passive MRS is an important RS technology, particularly for**
 - **Sea, Ice and Snow mapping**
 - **Assessment of soil moisture**
- **Passive microwave imaging is similar to image data gathering at optical wavelengths**

Basic Principles of Passive Microwave Imaging

- The upwelling radiation is detected (using a *Radiometer*) and converted to a *brightness* value from which an image is formed
- The source of energy **MAY NOT** always be just the Earth's surface
 - The atmosphere can also generate measurable energy at certain wavelengths as can sub-surface features
- There is finite level of solar microwave radiation scattered from the Earth's surface which can contribute to the total power level detected

Basic Principles of Passive Microwave Imaging



Components of passive microwave energy theoretically available for measurement

Basic Principles of Passive Microwave Imaging

- As it is a passive technology the ***Synthetic Aperture Techniques*** (SAR) used with radar are **NOT** available for generating fine spatial resolutions with microwave radiometry
- Consequently, pixels sizes are generally of the order of 10km or more
- The terms “*Aperture Synthesis*” and “*Synthetic Aperture*” are still found in connection with passive imaging !
 - They refer to the use of arrays of small antennas to synthesize the large aperture needed to gather the weak radiometric signal
 - **NOT** to enhance spatial resolution as in active microwave imaging

Basic Principles of Passive Microwave Imaging

Radiometric Brightness Temperature

- Similar to active radar techniques, in passive, the received power level is used to build up the microwave image of a scene
- The received power is itself not a good indicator of the intrinsic properties of the material being imaged as it varies with
 - Bandwidth over which the measurements are made
 - Pixel size used
- Instead, a quantity is needed that can be derived from the received power but which is *invariant* with system parameters like spatial resolution and measurement bandwidth

Basic Principles of Passive Microwave Imaging

Radiometric Brightness Temperature

- In microwave range of the spectral power density emitted by an object is directly proportional to the **temperature** (T) of its surface and inversely proportional to **wavelength** (λ)

$$M_{\lambda} = \frac{aT}{\lambda^4} \text{ MWm}^{-2}\mu\text{m}^{-1}$$
$$a = 2.6 \times 10^4 \text{ Wm}^{-2}\mu\text{m}^3\text{K}^{-1}$$

- The power density detected by a radiometer will also be directly proportional to the temperature of the object being observed
- The actual power received by an antenna when it is irradiated by a blackbody is expressed as

$$P = kTB$$

$T \rightarrow$ Surface temperature of the body (K)
 $B \rightarrow$ Bandwidth (Hz)
 $k \rightarrow$ Boltzmann's constant = $1.3805 \times 10^{-23} \text{ JK}^{-1}$

Basic Principles of Passive Microwave Imaging

Radiometric Brightness Temperature

- A real scene does not behave as an ideal black body but emits a lower level of energy, described by its emissivity ϵ , with $0 \leq \epsilon \leq 1$

- Then the actual power (P_r) received from a real surface

$$P_r = \epsilon k T \mathcal{B}$$
$$P_r = k(\epsilon T) \mathcal{B} = k T_B \mathcal{B}$$

- $T_B \rightarrow$ **Radiometric Brightness Temperature (K)**

$$T_B = \epsilon T = \frac{P_r}{k \mathcal{B}}$$

- It is determined by the real (physical) temperature of the material and its emissivity

Basic Principles of Passive Microwave Imaging

Radiometric Brightness Temperature

- The brightness temperature (T_B) is important for passive microwave imaging in the same way as scattering coefficient (σ^0) for radar imaging system
- T_B can be polarization dependent $\rightarrow$ the upwelling microwave energy or power can be a function of the polarization of observation
- So Stokes vector representation is used to summarize the polarization dependence of the brightness temperature

$$\mathbf{s} = \begin{bmatrix} |E_V|^2 \\ |E_H|^2 \\ 2 \operatorname{Re}\langle E_H E_V^* \rangle \\ 2 \operatorname{Im}\langle E_H E_V^* \rangle \end{bmatrix} = \frac{\lambda^2}{k\eta} \begin{bmatrix} T_V \\ T_H \\ T_U \\ T_V \end{bmatrix} = \frac{\lambda^2}{k\eta} \mathbf{T}_B$$

T_U and T_V $\rightarrow$ Relate to the ellipticity of the polarization and the correlation between the horizontal and vertical components; *usually negligible*

Basic Principles of Passive Microwave Imaging

Radiometric Brightness Temperature

- T_U and T_V are known to provide important discriminating information when the region being image is *anisotropic* or *asymmetric* in its emissive properties

$$\vec{T}_B = T\vec{\epsilon}$$

- Emissivity is unity for an ideal black body
 - $\vec{\epsilon} = [1 \quad 1 \quad 0 \quad 0]^T$
 - It radiates only horizontally and vertically
 - There is no relation between the horizontal and vertical radiation