McQueen-Cairns Technology - Celsius System

- The Celsius system operates by 'Microwave Thermometry', which is the noninvasive, nondestructive measurement of temperature using the natural thermal electromagnetic radiation from the material of an object. The partial microwave transparency of organic materials allows the Celsius System to measure the thermal radiation generated over most of the volume of many food products.

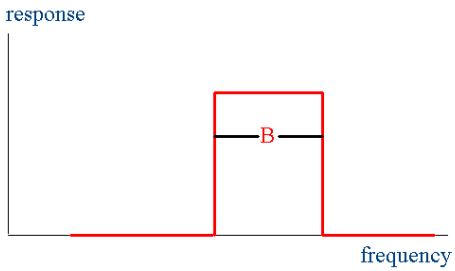
"All objects emit natural thermal radiation"

Example of Object emitting radiation

- Radio to infrared waves emit below 200°C:
  - ***Infrared radiation:***
    - o can only from about 0.1 mm depth of material
    - o dependent on surface state of a material - the emissivity
  - ***Microwave Thermometry:***
    - o Is based on the partial transparency to microwaves of biological organic materials.
    - o Can measure microwave emissions sourced from a 10 to 50 mm depth of an organic material.

➢ Overview of Microwave Thermometry:

- Microwave Thermometry is the measured microwave power is kTB with k Boltzmann's universal thermal constant and T the apparent microwave temperature of the source. B is the microwave "window" of the measurement equipment.

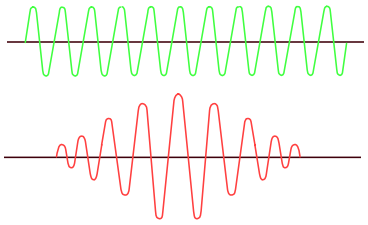


- The microwave power radiated depends on:
  - o Absolute temperature of the material (Celsius + 273 K)
  - o Microwave absorption of the material.
  - o Change in microwave properties at the surface (emissivity).

➢ *Microwave Thermometry in relation to Food Products:*

- The microwave properties of biological and organic materials depend most on their water content, with salt content also having a an important effect.
- Fats, oils and proteins are relatively transparent to microwaves

- Air is transparent to microwaves: A large change in microwave properties causes a large reflection at the change - e.g. at a meat to air surface there can be 50% reflection of microwaves.
- Water absorbs and thus generates relatively more microwave power than fats, sugars, starches and proteins.
- In a mixed material product the higher water content components will be the main source of the microwave signal.

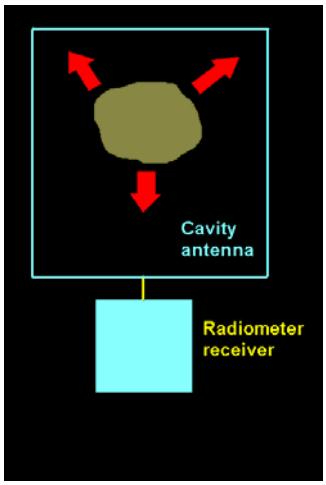


Example of mixed material product

- The microwave properties of the materials to be measured have a major influence on the microwave "window" frequency or wavelength chosen for making measurements.
- 3 GHz frequency, 10 cm wavelength, is a good compromise for foods.

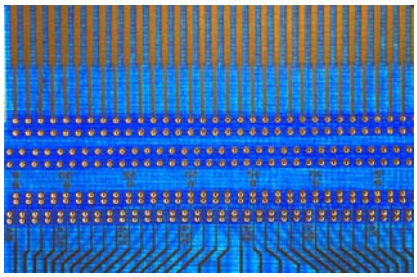
➢ ***Measurement of Microwave Temperature in relation to the Celsius System:***

- Measurement of microwave temperature requires the microwave radiation to be "collected" by an **antenna** (aerial), or in the case of the Celsius System a 'Cavity'; and its microwave signal to be measured by a special microwave receiver calibrated to read degrees Celsius.
- The cavity, coupling to the microwave radiation has important advantages:
  - Immunity from external influences (electromagnetic, thermal and mechanical).
  - Collects radiation from "all round" the source material.
  - Has no operator dependence.
  - Can be designed for a wide range of products.



- A **receiver** measures the Absolute temperature of the antenna signal to better than 1 part in 1000. It does this by making a comparison with internal sources of known temperature.

Receiver measures Absolute Temperature of the antenna signal



Computer processes receiver amplified signals

- Special *microwave circuits* are used to make the comparison with two internal reference sources at different, electrically measured temperatures. These circuits are in a "head unit" close to the antenna.

- A **computer** with electronic signal interfacing is used to process the receiver amplified signals to give the equivalent Celsius microwave temperature of the signal from the source material.

➢ ***Temperature measurement range and proven accuracy of the Celsius System:***

- Celsius has a temperature test range between -30°C to 110°C with an accuracy to ±0.2°C:
- Temperatures are comparable to calibrated thermocouple and PRT measurements to ±0.2°C as illustrated by the following chilled product temperatures: