# Applications of Microwaves

## Communication

- Before the advent of fiber-optic transmission, most long distance telephone calls were carried via microwave point-to-point links through sites like the AT&T Long Lines. Starting in the early 1950s, frequency division multiplex was used to send up to 5,400 telephone channels on each microwave radio channel, with as many as ten radio channels combined into one antenna for the *hop* to the next site, up to 70 km away.

- Wireless LAN protocols, such as Bluetooth and the IEEE 802.11 specifications, also use microwaves in the 2.4 GHz ISM band, although 802.11a uses ISM band and U-NII frequencies in the 5 GHz range. Licensed long-range (up to about 25 km) Wireless Internet Access services have been used for almost a decade in many countries in the 3.5–4.0 GHz range. The FCC recently carved out spectrum for carriers that wish to offer services in this range in the U.S. — with emphasis on 3.65 GHz. Dozens of service providers across the country are securing or have already received licenses from the FCC to operate in this band. The WIMAX service offerings that can be carried on the 3.65 GHz band will give business customers another option for connectivity.

- Metropolitan-area networks: MAN protocols, such as WiMAX (Worldwide Interoperability for Microwave Access) based in the IEEE 802.16 specification. The IEEE 802.16 specification was designed to operate between 2 to 11 GHz. The commercial implementations are in the 2.3 GHz, 2.5 GHz, 3.5 GHz and 5.8 GHz ranges.

- Wide Area Mobile Broadband Wireless Access: MBWA protocols based on standards specifications such as IEEE 802.20 or ATIS/ANSI HC-SDMA (e.g. iBurst) are designed to operate between 1.6 and 2.3 GHz to give mobility and in-building penetration characteristics similar to mobile phones but with vastly greater spectral efficiency.

- Some mobile phone networks, like GSM, use the low-microwave/high-UHF frequencies around 1.8 and 1.9 GHz in the Americas and elsewhere, respectively. DVB-SH and S-DMB use 1.452 to 1.492 GHz, while proprietary/incompatible satellite radio in the U.S. uses around 2.3 GHz for DARS.

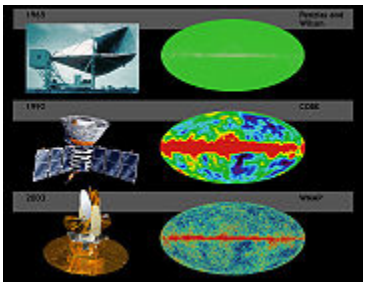
- Microwave radio is used in broadcasting and telecommunication transmissions because, due to their short wavelength, highly directional antennas are smaller and therefore more practical than they would be at longer wavelengths (lower frequencies). There is also more bandwidth in the microwave spectrum than in the rest of the radio spectrum; the usable bandwidth below 300 MHz is less than 300 MHz while many GHz can be used above 300 MHz. Typically, microwaves

are used in television news to transmit a signal from a remote location to a television station from a specially equipped van. See broadcast auxiliary service (BAS), remote pickup unit (RPU), and studio/transmitter link (STL).

- Most satellite communications systems operate in the C, X, Ka, or Ku bands of the microwave spectrum. These frequencies allow large bandwidth while avoiding the crowded UHF frequencies and staying below the atmospheric absorption of EHF frequencies. Satellite TV either operates in the C band for the traditional large dish fixed satellite service or Ku band for direct-broadcast satellite. Military communications run primarily over X or Ku-band links, with Ka band being used for Milstar.

## Remote sensing

- Radar uses microwave radiation to detect the range, speed, and other characteristics of remote objects. Development of radar was accelerated during World War II due to its great military utility. Now radar is widely used for applications such as air traffic control, weather forecasting, navigation of ships, and speed limit enforcement.
- A Gunn diode oscillator and waveguide are used as a motion detector for automatic door openers (although these are being replaced by ultrasonic devices).
- Most radio astronomy uses microwaves.



Galactic background radiation of the BigBang mapped with increasing resolution

- Microwave imaging

## Navigation

- Global Navigation Satellite Systems (GNSS) including the Chinese Beidou, the American Global Positioning System (GPS) and the Russian GLONASS broadcast navigational signals in various bands between about 1.2 GHz and 1.6 GHz.

## Power

- A microwave oven passes (non-ionizing) microwave radiation (at a frequency near 2.45 GHz) through food, causing dielectric heating by absorption of energy in the water, fats and sugar contained in the food. Microwave ovens became common kitchen appliances in Western countries in the late 1970s, following development of inexpensive cavity magnetrons.

- Microwave heating is used in industrial processes for drying and curing products.

- Many semiconductor processing techniques use microwaves to generate plasma for such purposes as reactive ion etching and plasma-enhanced chemical vapor deposition (PECVD).

- Microwaves can be used to transmit power over long distances, and post-World War II research was done to examine possibilities. NASA worked in the 1970s and early 1980s to research the possibilities of using Solar power satellite (SPS) systems with large solar arrays that would beam power down to the Earth's surface via microwaves.

- Less-than-lethal weaponry exists that uses millimeter waves to heat a thin layer of human skin to an intolerable temperature so as to make the targeted person move away. A two-second burst of the 95 GHz focused beam heats the skin to a temperature of 130 °F (54 °C) at a depth of 1/64th of an inch (0.4 mm). The United States Air Force and Marines are currently using this type of Active Denial System.[3]

## Spectroscopy

- Microwave radiation is used in electron paramagnetic resonance (EPR or ESR) spectroscopy, typically in the X-band region (~9 GHz) in conjunction typically with magnetic fields of 0.3 T. This technique provides information on unpaired electrons in chemical systems, such as free radicals or transition metal ions such as Cu(II).