

Microwave Radiation—Therapeutic Application for Cure of Subcutaneous Bacterial Infections

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This research investigates the potential for using high-frequency microwave energy for selectively killing bacteria while producing minimal damage to surrounding healthy human tissue. This technology could be used to treat bacterial infections with minimal use of antibiotics as well as for decontamination of selective subsystems onboard space transport vehicles, the Space Station, and future lunar outposts. Potential Earth-based applications include the treatment of infections, pain associated with compression fractures or broken vertebrae, and tumors. These studies represent a joint effort between personnel from the Electromagnetic Systems Branch in the Engineering Directorate and the Biomedical Research and Countermeasures Projects Branch in the Space Life Sciences Directorate at Johnson Space Center (JSC).

Microwave heating can be used to kill human tissue. At JSC, we have shown deep microwave heating to be effective for the treatment of ventricular tachycardia—a heartbeat rate malfunction. Currently, although there is no method available

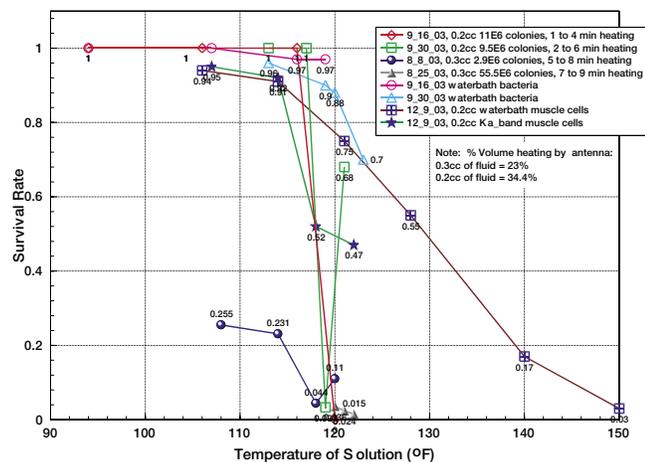
for killing bacteria while minimizing damage to healthy tissue, this is theoretically possible since bacteria have unique properties of conductivity as a function of frequency. The overall purpose of these studies was to determine whether specific microwave frequencies could effectively destroy bacteria at temperatures lower than frequencies that could damage human tissue.

The objectives of this research are to:

- Determine the percent survival of bacteria and human cells for three microwave frequencies ranges; i.e., 2.45 GHz (S-band), 5.8 GHz (C-band), and 29.8 GHz (Ka-band). We selected the 2.45-GHz and 5.8-GHz frequency ranges because they are in the allowable industrial, medical, and scientific radiation bands. We expected the lower two frequency ranges to kill primarily by thermal heating, and predicted that the higher Ka-band frequency would kill the bacteria to a greater degree than the human cells due to their unique microwave properties
- Ensure statistical accuracy of the data collected by performing repeat experiments with replicate samples
- Test omni and directional microwave antennas to assess their ability to most effectively target the bacteria
- Investigate the feasibility of using directional microwave antennas with a focused beam for treatment of pain associated with broken vertebra or compression fractures.

The experimental approach used was to irradiate bacteria and different types of human cells, such as muscle and nerve cells, found in the body to determine the percent survival as functions of:

- radiated microwave power
- frequencies
- length of exposure
- temperature of the medium containing the samples.



Survival rate of bacteria after Ka-band exposure.

We used a temperature-controlled water bath for both bacteria and human cells as a control for the effects of heat (without microwave radiation). This allowed thermal heating effects to be distinguished from microwave interaction effects.

We performed 35 microwave heating tests involving 400 samples using 2.45-GHz, 5.8-GHz, and 29.8-GHz frequencies. We measured survival rates for bacteria, muscle, and nerve cells as functions of microwave energy input and media temperature. We compared survival rates vs. temperature for microwave and water bath heat exposure, allowing us to distinguish the microwave interactions with the bacteria at Ka-band frequencies from heating effects at lower frequencies.

Burkholderia cepacia, the bacteria used for testing, has been problematic in the water system of the Space Station. There is a current critical need to decontaminate the water system without internal intrusions to the system. The Ka-band microwave sterilization could be performed externally, making it particularly appropriate for this type of application.

Test results showed that microwave energy at 20 GHz strongly affected the bacteria while we observed only weak effects below 20 GHz. In contrast, human muscle and nerve cells exhibited the opposite reactions. Specifically, the experimental results were:

1. S-band and C-band microwaves likely induced cell kill through thermal heating of the fluids containing viable cells or bacteria. A temperature of 120°F–125°F was the approximate threshold for survival.
2. For the Ka-band, the bacteria appeared to be killed by microwave absorption rather than thermal heating. Muscle cells did not exhibit this same degree of susceptibility. The Ka-band test data in the figure show that the bacteria have a very low percent survival at temperatures below the thermal thresholds identified for both bacteria and muscle cells.

This approach is currently under investigation with regard to its applicability for decontamination of the Space Station water recycling system. It also has potential applications to future space transport vehicles and outposts. In addition, this technology has led to the development of useful spin-offs, including several medical applications, such as localized thermal ablation of tumor cells (with heat confined to the core of the tumor) and thermal ablation of selected nerve cells to relieve the pain associated with compression fractures or broken vertebra.

A disclosure on a directional catheters antenna for selective heating of human tissue has resulted in a patent application (MSC-23781-1). Two other disclosures based on these research results are currently in preparation.

The results show that the Ka-band microwave frequency can effectively kill *Burkholderia cepacia*, common bacteria, while producing minimal damage to healthy human cells. This device could be useful for the prevention, treatment, and cure of medical infections in astronauts engaged in space exploration. Additional applications of this technology include its potential use for the external sterilization of water filters and surfaces on the Space Station, space transport vehicles, and outposts. On Earth, applications include the treatment of various infections, including burn-related injuries, pain associated with spinal compression fractures, and tumors.