

# Microwave drilling

Study reference number: 14-9301  
Type of activity: Standard study (25k€)

## Project Summary

### Objective

This project will study the effectiveness of fracturing relevant soil materials (Mars/Moon) using microwave radiation and assess the power levels required.

### Target university partner competences

Applied Physics, Mechanical Engineering, Material Science, Electrodynamics

### ACT provided competences

Microwave Antenna, Plasma Physics, Material Science

### Keywords

Microwave, drilling, planetary exploration, electrodynamics

## Study Objective

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## Background and Study Motivation

The study of the subterranean composition of planets is an important tool for understanding the history and evolution of our solar system. In the investigation of the composition of Lunar, Mars and even asteroid surfaces, mechanical drills are currently being used in a variety of robotic explorers (NASA Curiosity, ExoMars, Rosette/Philae). ESA's ExoMars Rover is fitted with a Drill and Sampling System [7] that is specifically designed to drill down to 2m depths using a rod extension mechanism, linking up to three 50cm extension rods. To ensure remote drilling in a harsh environment like Mars, a robust drill technique is required. Therefore, most drill designs are based on an electrically driven mechanical drill. There are several issues that need to be addressed:

- Wear and tear of the drill
- Low drill speed due to low available power
- Total weight/structure of the drill box
- Forces, torques and vibrations on the drill box as well as the rover
- Reliability (possible single-point of failure when the drill and thereby the rover gets stuck)

An alternative method that has been proposed is drilling by localized microwave energy [1]. The principle of a microwave (MW) drill is to concentrate microwave radiation (e.g. 2.45GHz) into hard non-conductive materials (see figure 1). Experiments on basalt rocks, which are similar in composition as what is expected from rocks on the Mars/Moon surface, show that it is possible to melt surrounding materials when the power density is sufficiently high [1,2]. However, the input microwave power in these experiments was around 1kW and only a drill depth of a few cm could be

reached (limited by the antenna insertion). The benefits of a microwave drill are the lack of (fast) rotating parts, no mechanical friction (no wear and tear) and no vibrations.

In recent work, it has been shown that one can leverage microwaves to perform stepwise mechanically assisted drilling at much lower microwave powers [3]. At power levels of 10-100W, pre-fracturing of the surrounding rocks occurs, thereby reducing the drill requirements of the mechanical drill. Such low power levels can be achieved by more compact solid-state generators [3]. Miniaturized versions of a drill using this technology have in fact already been realized [4] and could possibly be integrated inside the housing of a normal drill.

Important for the working of a microwave drill is the absorption of electromagnetic radiation in the surrounding rock (determined by the dielectric properties of the material). Once surrounding rock is elevated in temperature, the microwave radiation is efficiently absorbed by the hot rock, which thereby enforces the effect near the drill head leading to a runaway process [5,6].

The main benefits of a microwave-assisted drill are:

- Lowered risk of a jammed drill
- Compact (conventional 2.45GHz Magnetron or solid state)
- Cheaper than high-energy lasers
- Dust free
- Quiet operation

However, certain drawbacks/issues have to be considered:

- Power requirements ( $>1\text{kW}$  to melt surrounding rock, with fracturing at low power)
- High reflection (at low soil temperature)
- Compatibility with sample return mechanisms
- Complexity of the antenna head integration
- Limited depth (requiring some type of insertion mechanism)
- Possible interference with surrounding equipment (e.g.: communication and diagnostics)

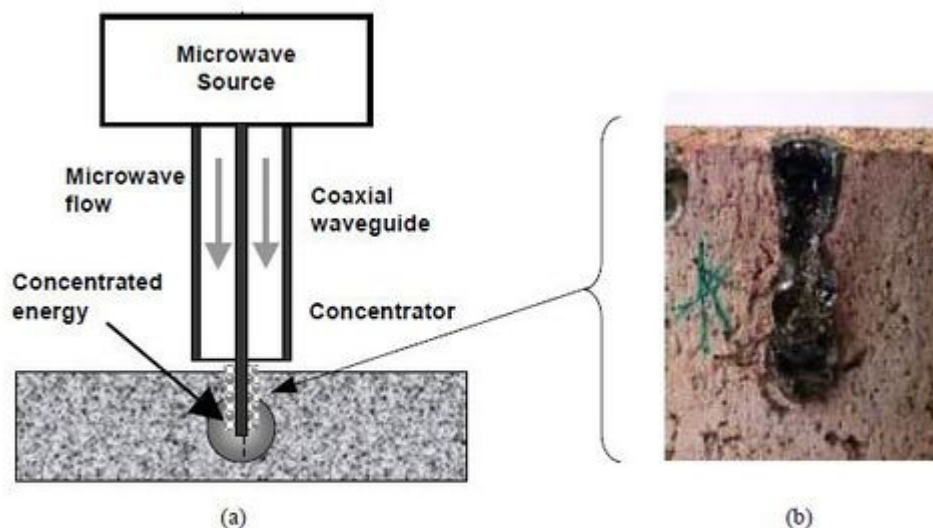


Fig. 1. (a) A simplified scheme of the microwave drill, and (b) its effect on concrete (the crosscut shows the glossy material before its removal).

Figure 1: Basic principle of microwave drill (images taken from [5])

## Proposed Methodology

Studies on the drilling capability of conventional mechanical drill designs (e.g.: ExoMars, Curiosity) have been carried out for various types of rocks that can be found on the Moon and/or Mars [7]. Stepwise mechanically assisted microwave drilling could pose a valid additive for future missions. It is therefore of particular interest to experimentally investigate the drill properties of relevant rock types after exposure to low-power microwave near-field radiation.

The following methodology is proposed for this study, though applicants are invited to propose alternative approaches, which they see fit within the scope of this work.

- Assess different microwave sources and experimental parameters of testing microwave-assisted drilling of relevant soil materials
- Assess material properties (e.g. Knoop hardness, compressive strength and abrasivity index) and mechanical drill operating conditions (friction, strain, wear) in various materials both with and without microwave pre-treatment
- Propose integration of microwave technology in currently used drilling tools and investigate the reachable drill depth

## ACT Contribution

The project will be conducted in close scientific collaboration with ESA researchers. In particular, ESA researchers will provide technical expertise in the background requirements for rover design (e.g. power requirements, etc.) as well as microwave technologies and relevant materials.

## Bibliography

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