

Development of a Radiofrequency Sensor for Detecting Bacteria in the Food Industry

Youness Hsana^{1,2}, Anne-Gabrielle Mathot¹, Olivier Couvert¹, Philippe Talbot²,
Stéphane Rioual², Benoît Lescop²

¹ Univ Brest, INRAE, LUBEM, 29000 Quimper, France

² Lab-STICC, University Brest, CNRS, UMR 6285, 29200 Brest, France

Corresponding Author's e-mail address: lescop@univ-brest.fr

Summary:

Microbiological safety is a critical concern in the food industry, as it requires continuous monitoring for potential bacterial contamination along production lines. In this context, developing low-cost sensors capable of providing real-time data is of paramount importance. To this end, an open-ended coaxial probe controlled by a miniVNA Tiny (Vector Network Analyzer) was selected to detect bacterial growth. First, the effect of temperature on the sensor response was characterized. Subsequently, variations in the S11 reflection coefficient of the probe were correlated with the concentration of *Bacillus licheniformis*

Keywords: RF sensor, biofilm, bacteria, monitoring, low-cost sensor

1. Introduction

Controlling bacterial contamination is a key challenge for the food processing industry. Indeed, the contamination of food products by pathogenic and/or spoilage bacteria (*Bacillus cereus*, *Salmonella* spp., ...) can have serious sanitary and economic consequences [1]. As bacteriological analyses are often carried out by external laboratories, the detection of contamination is not immediate. The delayed recall of the products concerned therefore has a major impact on manufacturers, both financially and in terms of brand reputation.

Our team recently demonstrated the feasibility of real-time monitoring of bacterial growth and biofilm formation using Radio Frequency measurements [2]. A truncated coaxial line was immersed in the bacterial solution under study, and S11 parameter measurements were performed over a frequency range of 0.1 to 3 GHz. Application in the food processing industry requires not only *in situ*, real-time monitoring, but also the deployment of a large number of sensors. These constraints require the use of a low-cost system. We therefore opted to use of a mini-VNA tiny to carry out the measurements.

2. Materials and methods

The probe used consists of an open-ended coaxial line. Reflection measurements (S11 parameters) are performed using a mini-VNA Tiny. As illustrated in Figure 1, all measurements were carried out in an incubator using saline solutions

or bacterial cultures. Acquisition of the RF parameter values was made by a computer.

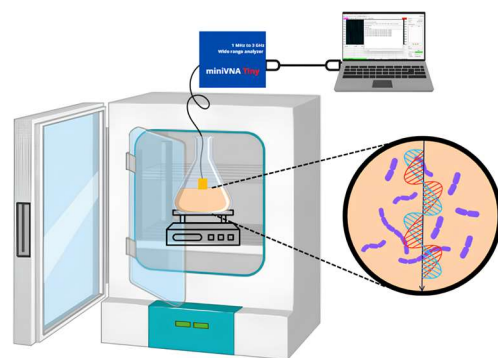


Fig. 1. Drawing of the experimental set-up

Prior to initiating measurements, the mini-VNA is allowed to warm up overnight, after which calibration is carried out using the SOL (Short – Open – Load) method. Temporal monitoring of the S11 parameter was conducted at a fixed frequency of 100 MHz.

The temperature monitoring of the solution was continuously performed by a thermometric data logger (Dutscher). This device is programmable and enables both temperature tracking and data storage.

Measurements were performed on the industrial spoilage bacterium *Bacillus licheniformis* 16 (BL16), a biofilm-forming bacterium isolated from skimmed milk powder by the LUBEM

laboratory. The bacterial growth was made in NB (Nutrient Broth) medium.

3. Results and discussion

Temporal stability

Monitoring bacterial growth requires measurement durations from 24 to 48 hours. We initially assessed the temporal stability of the sensor response by performing measurements on saline solutions. Measurements were conducted in the incubator at 40°C, which corresponds to the optimal growth temperature of the BL16 strain.

During the first four hours of measurement, the system was found to require a stabilization period. Subsequently, a drift of between 0.05 and 0.1 dB/day was observed. The system exhibits relatively stable behavior, although it may be sensitive to temperature fluctuations.

Temperature

As previously demonstrated [2], the RF sensor response is dependent on the solution's electrical conductivity, which is itself temperature-dependent. The sensitivity of the sensor to temperature variations was therefore investigated using a physiological liquid. A temperature gradient ranging from 33°C to 42°C was applied by incrementally increasing the temperature over a total experimental duration of eight hours.

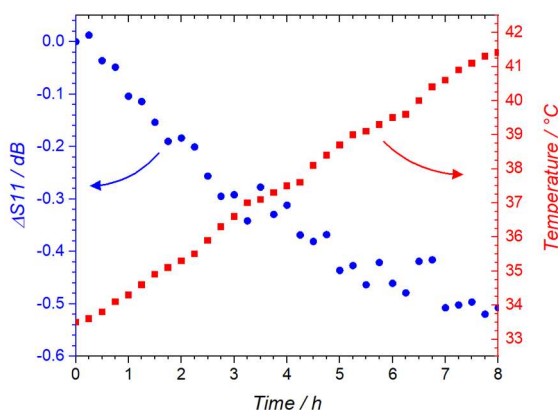


Fig. 2. $\Delta S11$ and temperature in function of time.

Figure 2 presents the $\Delta S11$ evolution and temperature in function of time. A negative correlation between temperature and the S11 parameter is reported: the S11 response decreases as temperature increases. Note that a linear behavior can be observed. These results therefore confirm the sensitivity of the sensor to temperature variations during experiments. Furthermore, this finding suggests that temperature-induced variations could be corrected for in subsequent bacterial analyses.

Bacteria concentration

Figure 3 illustrates the relative $\Delta S11$ response as a function of BL16 concentration in the liquid medium. $\Delta S11$ is normalized to the initial liquid medium value *i.e.*, in the absence of bacteria. The increase of bacteria concentration leads clearly to the variation of the S11 values, even if the $\Delta S11$ variation is weak for values below 2×10^7 CFU/ml. However, the highest concentration values show high $\Delta S11$ variation.

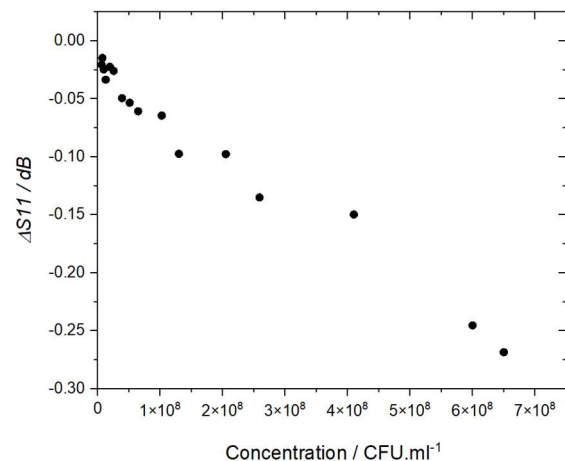


Fig. 3. Relative S11 data in function of BL16 concentration

Additional data on another *Bacillus licheniformis* strains present similar results. The comparison between our data and those reported by Longo *et al* [2] shows that the S11 variation seems to depend to the nature of the bacteria.

4. Conclusion

This work focuses on the application of an open-ended coaxial line for the detection of bacteria in the food processing industry. Our preliminary results demonstrate the capacity of the sensor to monitor changes in the test medium attributable to the presence of bacteria. This can be possible with a low-cost system. In upcoming experiments, bacteria growth will be monitored over time. In addition, the goal will be to test our sensor under conditions similar to those found in industrial settings.

References

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