2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (APS/URSI) | 978-1-7281-4670-6/21/$31.00 ©2021 IEEE | DOI: 10.1109/APS/URSI47566.2021.9704048

Remote Destruction of the Coronavirus by Dual-Polarized Wireless Power Transmission

Konstantinos Kossenas,* Maksim V. Kuznetcov,* Davide Comite,† Symon K. Podilchak*
*The Institute for Digital Communications, School of Engineering, The University of Edinburgh, Edinburgh, UK
†Department of Electronics and Telecommunications, Department of Information Engineering,
Sapienza University of Rome, Rome, Italy
Email: k.kossenas@sms.ed.ac.uk, s.podilchak@ed.ac.uk

***Abstract*—This paper proposes a remote sterilization technique through microwave radiation. The innovative approach requires the heating of a liquid water film layer, which can be sprayed onto the area of interest. Applications include the deactivation of the coronavirus and other pathogens by physically increasing the liquid film temperature achieving thermal sterilization. The proposed technique can be implemented by various antenna systems and retrodirective arrays. In this study, a dual-polarized antenna array is adopted and designed to increase the transmitted power levels without physically including more antenna elements. As reported in the paper, this dual-polarized approach has the benefit of reduced sterilization time when compared to a single-polarization system having the same number of antenna elements.**

I. Introduction

Thousands of death are reported every year due to viruses such as malaria and H1N1. Over the last two years a new coronavirus (SARS-CoV-2) has been spread across the entire world, causing the COVID-19 disease. At the time of writing, the virus outbreak is still a global pandemic, leading to the death of more than 3.35 million people globally [1].

When people infected with COVID-19 cough or exhale, droplets are expelled from their nose or mouth and they can diffuse in the air and onto objects and surfaces. The high virus transmissibility, in combination with its long-time survival capability on surfaces, makes sterilization essential to reduce the virus spread. It has also been demonstrated that the virus in aerosols can survive for 3 hours and on cardboard for 24 hours [2]. Therefore, the development and research into new ventilation and sterilization systems, such as remote thermal heating by microwaves, as proposed in this paper, is important for virus control and suppression, especially in public facilities such as hospitals, ambulances, schools, and public transportation vehicles.

It should be mentioned that sterilization using microwave radiation is included in the list of disinfection methods by The Centers for Disease Control and Prevention (CDC) in the United States. This approach can involve the sterilization of medical equipment, such as urinary catheters, dental instruments, and others similar devices [3]. Additionally, ionizing and infrared radiation are also other sterilization methods but these systems can have high cost, whilst requiring significant levels of input power [4]. This can make such approaches disadvantageous and difficult to implement [3]. Most recent guidelines on contactless thermal sterilization suggest that temperatures greater than 60°C are needed to produce bio-chemical destruction of SARS-CoV-2 structure [5].

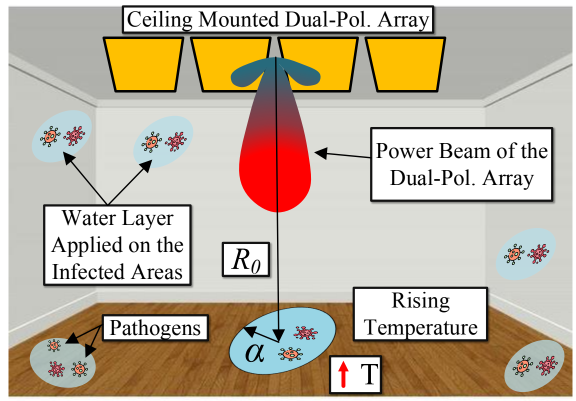

Fig. 1. Illustration of the proposed microwave sterilization method by thermal heating enabling remote pathogen deactivation. The transmitter which includes a single antenna element or an array, could be mounted on the ceiling for radiation onto the water sprayed infected surfaces, devices, and air droplets.

Following these developments, we propose a new method that can achieve remote sterilization of coronaviruses (and other pathogens) by microwave radiation principles. The proposed thermal sterilization technique requires the use a thin water film, which needs to be sprayed over the infected area. To improve the efficiency of the wireless power transmission (WPT) link, we consider dual-polarized antennas forming an array, which operate in the S-band. Basically, by means of microwave radiation, the antenna transmitter radiates power onto the area of interest or surface which has been deposited with active virus. We also consider target ranges in the near field (NF) and far field (FF) of the transmitting antenna. The proposal thermal sterilization technique requires the use of a thin water film, which needs to be sprayed over the infected area. In addition, the benefit of dual-polarization is that it offers increased radiated power levels with less antenna hardware, thus reducing the sterilization time.

This approach can also be applicable to virus deactivation within infected air droplets, which has been demonstrated to be a vehicle of infection [1], [2]. Moreover, conventional thermodynamic concepts, WTP techniques, and radar principles are adopted to test the approach. Fig. 1 illustrates the proposed system installed onto the ceiling of an enclosed space. In contrast to a more conventional disinfectant spray, this standard cleaning approach typically requires the generation of a liquid vapor followed by manual wiping and cleaning; it requires, therefore, the presence of an operator. Depending on the position of the target to be sterilized, only a single-element

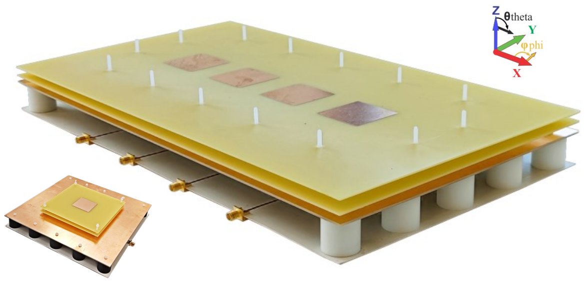

Fig. 2. Dual-polarized and multi-layer 4x1 array and single-element patch.

can be activated, or an array for increased transmitter gain and beam steering. The choice may depend on the different factors, such as the distance of the area of interest and the available time. The radiated beam can also be electronically steered towards the area, automating the sterilization, while maintaining the operator safe.

II. Dual-Polarized Antenna

The feeding network of the dual-linear polarized antenna is constituted by four H-shaped slots connected to two power dividers, and two FR-4 patch antennas placed on top of the slot configuration (Fig. 2). In particular, the fully integrated and compact feeding system consists of two slot-line dividers and strut-like vertical connectors for simple manufacturing and assembly. The H-shaped slots serve as an excitation mechanism for the top square patches. This multilayer design and stacked patch arrangement can increase the bandwidth (BW) of the antenna system, so that more power can be transmitted over frequency for improved wireless energy transfer and reduced sterilization times. Also, the single-element and array offers high port-to-port isolation with values of 50 dB or more.

III. Remote Thermal Sterilization by Microwaves

The method and an estimation of the required time for the microwave sterilization is described here through theoretical and full-wave simulations. The infected area is initially sprayed with a liquid water layer of thickness 0.25 mm and the target can be modeled as a circular plate with radius $\alpha = 3.5$ cm (Fig. 1). The antenna transmits RF/microwave power, which then hits this water layer. This increases its temperature leading to sterilization of the infected area (60°C is needed for the SARS-Cov-2 [5]). Basically, the temperature increases, similar to heating of foods in a conventional microwave oven.

The incident power onto the target can be calculated as function of input power (2 W in this case to keep the safety margins), the distance (R_0) between the antenna and the target, the azimuthal (ϕ) and elevation (θ) incident angles, the gain of the antenna, and the monostatic radar cross section (RCS) of the circular plate target. The time needed for the sterilization of the infected area can be calculated evaluating the stored energy and the power impinging on the area being sterilized.

Fig. 3 reports the required sterilization times (simulated) as a function of R_0 (from 0.3 m to 2.5 m), and of the elevation incident angle ($-10°$, $-20°$, $0°$, $10°$, $20°$) considering dual-pol. operation. The single-element is also compared to the 4x1 array (see Fig. 2). The array operates in the NF, while the single-element operates in the NF until 1.7 m, and then

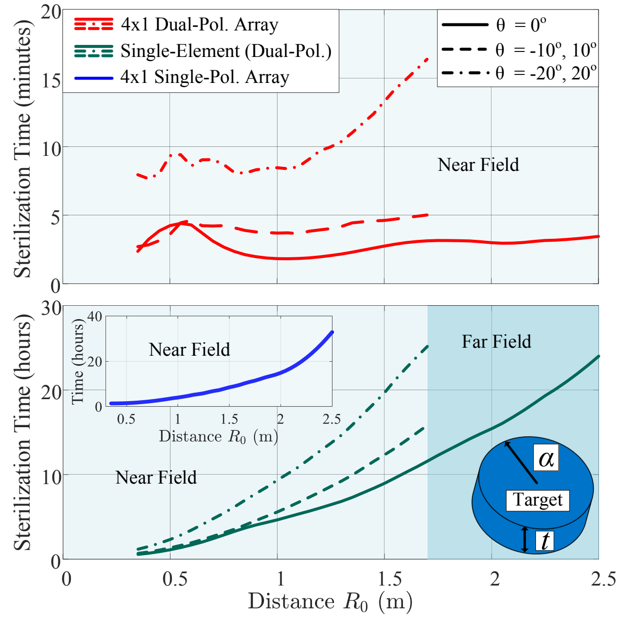

Fig. 3. Sterilization time needed to deactivate the coronavirus versus R_0 considering the dual-pol. array (top) as well as the single-element and single-pol. array (bottom). A thin circular plate is the target for remote sterilization.

in the FF. The 4×1 array operation time for sterilization was calculated to be in the order of 5 minutes, whereas for the single-element, hours were required for some scenarios. Also, the operation of both setups is optimum at broadside ($\theta = 0°$), as expected. Additionally, as reported in the inset of Fig. 3, a single-polarization 4x1 array was examined. It can be observed that the sterilization time significantly increases when compared to the dual-polarization arrangements.

IV. Conclusion

A remote microwave thermal sterilization technique is presented in this work for operation at the 2.4 GHz ISM band. The method, which provides an alternative sterilization approach to combat SARS-CoV-2 (the virus causing the COVID-19 disease), can employ single or dual-polarized antennas or arrays. In particular, by inducing an adequate temperature increase of the infected target area, through high-power antenna radiation, remote sterilization can be achieved. Results suggest that sterilization times of about 3 minutes can be achieved when adopting a dual-polarized 4×1 array. To the best knowledge of the authors, no similar remote sterilization approach has been proposed which follows WPT concepts whilst adopting dual-polarization antenna systems.

References

[1] WHO. (2021) Coronavirus disease (COVID-19) pandemic.

[2] J. Otter *et al.*, "Transmission of SARS and MERS coronaviruses and influenza virus in healthcare settings: The possible role of dry surface contamination," *Journal of Hospital Infection*, vol. 92, 10 2015.

[3] R. A. William, D. J. Weber, and the Healthcare Infection Control Practices Advisory Committee (HICPAC). (2008) Guideline for disinfection and sterilization in healthcare facilities.

[4] V. Mata-Portuguez, L. Sanchez, and E. Acosta-Gio, "Sterilization of heat-resistant instruments with infrared radiation," *Infection control and hospital epidemiology: the official journal of the Society of Hospital Epidemiologists of America*, vol. 23, pp. 393–6, 07 2002.

[5] J. Abraham, B. Plourde, and L. Cheng, "Using heat to kill SARS-CoV-2," *Reviews in Medical Virology*, vol. 30, p. e2115, 07 2020.