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AI-DRIVEN MODELING OF ULTRA-LOW POWER RF-MEMS SWITCHES FOR 6G AND FUTURE SPACE NETWORKS

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ABSTRACT

The evolution toward 6G networks marks a paradigm shift where space is no longer a supplementary layer but a native component of the communication architecture. The concept of Space-Air-Ground Integrated Networks (SAGIN) aims to provide seamless, high-speed global coverage by layering terrestrial towers with Low Earth Orbit (LEO) satellite constellations. However, extending 6G to space environments introduces severe constraints regarding signal integrity at millimeter-wave frequencies and the extreme limitations of Size, Weight, and Power (SWaP) for satellite payloads. Providing high-speed connectivity to remote areas and mobile platforms requires thousands of orbiting nodes, making energy efficiency the primary bottleneck for sustainable Future Networks (FN).

Microelectromechanical Systems (MEMS) technology enables the development of highly-miniaturized sensors, actuators, and transducers bearing the potential to revolutionize aerospace instrumentation. Among this diverse plethora of microsystems, MEMS-based micro-switches for DC/AC and Radio Frequency (RF) signals, known as RF-MEMS switches, represent a Key-Enabling Technology (KET) to address current space-borne challenges. Unlike traditional solid-state switches, such as PIN diodes or Field Effect Transistors (FETs), which suffer from significant power leakage, RF-MEMS micro switches utilize electrostatic control to achieve virtually zero power consumption. These components can reduce power requirements

by 2-3 orders of magnitude, bringing consumption from tens of milliwatts down to the microwatt range. This drastic reduction is essential for the "energy transition" within the Internet of Things (IoT) and 6G edge, where remote devices must operate on limited battery or harvested energy while supporting complex, reconfigurable beamforming and switching tasks.

This research presents the results of a synergic collaboration between the University of Niš, Faculty of Electronic Engineering Niš (FEE) and Fondazione Bruno Kessler (FBK), focusing on the design optimization of ultra-low power switches, under the Serbia-Italy bilateral project „Ultra-low power consumption microsystems-based electrical switches for the energy transition in the frame of the Internet of Things, 6G and Future Networks“, 2025-2027. While FBK provides world-class micro-fabrication expertise, FEE contributes advanced multi-physical modeling based on Artificial Intelligence (AI) and Machine Learning (ML). The project exploits Artificial Neural Networks (ANN) to overcome the computational bottlenecks of traditional simulation methods, allowing for the rapid and precise modelling and optimization of MEMS devices in space environments. By combining traditional design approaches with AI-based optimization, this project establishes a robust framework for developing the next generation of intelligent, energy-efficient components for Future Networks and global space communications.