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Electromagnetic Analysis of a Complete Omnidirectional Dual-Reflector Antenna fed by a Coaxial Horn

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In cellular communications, the losses at millimeter wave (mm-Wave) frequencies (30 GHz to 300 GHz) are addressed with smaller cells and increased number of transmission stations, which results in increased power consumption [1]. Thus, developing a high-quality, reliable and sustainable telecommunications framework for 5G, 6G and beyond will require energy efficient transmitters. One of the alternatives to energy efficient devices for operation in mm-Waves is the dual-reflector antenna. Its wide-band behavior, provided by the coaxial horn feeder, allows multiple carriers to share the same radio frequency system and the antenna's omnidirectional high gain characteristic counteracts the disruptive losses, making it possible to reduce the number of transmission stations.

The dual-reflector antenna was studied in [2] and [3], however, the first presents a complex implementation of coupling and support structures for the coaxial horn, resulting in a difficult manufacturing process, and the last uses a simplified feeder that does not represent a functional model. This work aims to design a novel geometry for the coaxial horn feeder that facilitates its manufacturing process, maintaining its performance throughout the Ka band (26 GHz - 40 GHz). Later, the entire antenna structure comprising the optimized feeder and classic reflector configuration was analyzed to verify the electromagnetic behavior of the complete dual-reflector antenna.

The novel coaxial horn's design process began with the simulation in Ansys HFSS of the control model, identical to the simplified model presented in [3]. Any following modifications, i.e. the implementation of novel coupling and support structures, were made so that the performance of the modified horn is not significantly different from that of the control model. This was achieved primarily by the use of an optimization based on HFSS' built-in genetic algorithm, set up with the single goal of keeping the reflection coefficient smaller than -20 dB ($|S_{11}| \leq -20$ dB), throughout the operating frequency band (26 GHz $\leq f \leq$ 40 GHz).

To simulate the complete antenna and reduce computational costs, the reflectors in their classical configuration [4] were solved with physical optics method, while the optimized horn was solved with finite element method.

Simulation results are presented in Figure 1. From the comparison of the reflection coefficients (Figure 1a) one can verify that the modifications made to the coaxial horn feeder did not affect considerably the device's performance. The radiation pattern behaviour also remained approximately the same, comparing the outcome shown in Figure 1b to the results presented in [3]. Antenna gain has a growing trend across the operating frequency band, with reduced efficiency at 40 GHz, as shown in Figure 1c. This significant decrease in gain at 40 GHz can be justified by the analysis of the feeder's radiation pattern, shown in Figure 1d. At 40 GHz, the coaxial horn's radiation pattern displays a null at an angle that is less than the subreflector edge angle ($\theta_E = 55^{\text{o}}$) [2], leading to a poorly illuminated reflector and reduced gain.

Further optimizations targeting the feeder's aperture region should be performed to enhance efficiency at 40 GHz; still, it is possible to conclude by the presented analysis that the modifications

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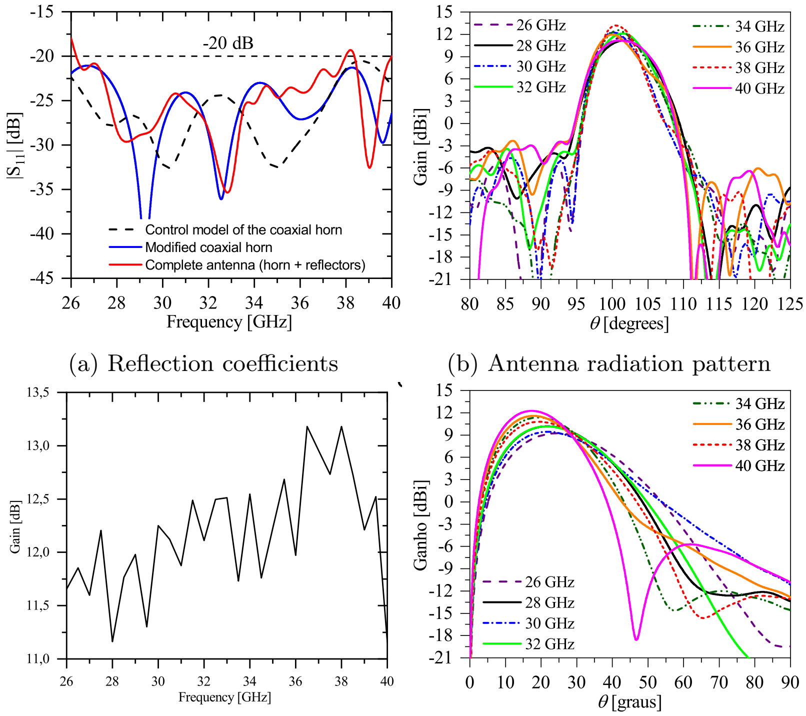
made to the coaxial horn provided a solution for a dual-reflector antenna that both facilitates the feeder manufacturing process and maintains the desired performance.



(a) Reflection coefficients (b) Antenna radiation pattern

(c) Gain vs. Frequency (d) Coaxial horn radiation pattern

Figura 1: Antenna and feeder parameters

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