CONTRIBUTIONS TO THE STUDY AND OPTIMIZATION OF LEAKY-WAVE ANTENNAS FOR SATELLITE COMMUNICATIONS

ABSTRACT

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The PhD thesis entitled "Contributions to the study and optimization of leaky-wave antennas for satellite communications" addresses the issue of satellite communications accessibility, with emphasis on the need for economical solutions for remote and disadvantaged regions.

The introductory chapter of the thesis presents the background and motivations of the research, highlighting the transformative impact of modern communication systems on everyday life. It emphasizes the importance of satellite communications, especially in emergency situations and in remote regions where terrestrial infrastructure is lacking. While these technologies are essential, high costs limit accessibility for many users and the digital divide remains a global challenge. This paper aims to develop an affordable leaky-wave antenna solution based on a simple coaxial feeder, avoiding complex and expensive reflectors, which could reduce costs and facilitate access to satellite communications for disadvantaged communities.

The chapter on satellite communications lays the necessary theoretical foundations for the development of the leaky-wave antenna adapted for Ku-band. The principles and evolution of satellite technologies have been presented, emphasizing their applicability in modern telecommunications. The analysis of the various types of antennas used in satellite communications allowed the identification of the technical solutions required for antenna manufacturing, with emphasis on Ku-band specific performance. The chapter has highlighted the historical and technological role of satellite communication equipment and advances in the field, thus providing the basis for the selection of appropriate materials and technologies at the antenna design and manufacturing stage. The accumulated information created a solid foundation for advancing the research and development of the proposed product, supporting both theoretical knowledge and practical applicability.

The chapter dedicated to the study of leaky-wave antennas in coaxial structures explores the principles of operation of these antennas and provides a detailed analysis of their electromagnetic behavior. The different types of leaky-wave structures, including uniform and periodically modulated ones, have been examined, each with their advantages and limitations. Periodic structures allow more precise radiation but are more complex in terms of design and control of spatial harmonics, while uniform structures offer simplicity of realization but with a performance trade-off due to continuous energy radiation. This chapter emphasizes the flexibility of leaky-wave antennas in beam steering and their ability to radiate continuously along the structure, making them ideal for modern communication applications. Phase constant and attenuation constant analysis provide a detailed understanding of how to optimize directivity. The conclusions of this chapter outline the technical knowledge required for the next stage of research, which involves the practical implementation of a leaky-wave antenna model in electromagnetic simulation software. This will facilitate the optimization of the antenna structure to achieve optimal performance in satellite communications, thus marking a crucial step in the development of the thesis and the realization of an experimental model.

The chapter on leaky-wave antenna analysis and development methods played an important role in the optimization of this type of antenna for satellite communications. Emphasis was placed on the construction and modeling of the antenna structure in HFSS, with

special attention to the helical elements essential for antenna performance. An important contribution has been the comparison of two distinct methods for extracting the parameters needed to construct the dispersion curves, essential elements in understanding the radiation mechanism. The first extraction method, although accurate, proved costly in terms of processing time and computationally demanding. The second method, based on a unit cell analysis, was more efficient and showed comparable accuracy, providing a very good alternative for further research. This analysis established a correlation between antenna parameters, such as helical slot width and periodicity, and electromagnetic radiation behavior, contributing to the optimization of antenna performance. The results of this chapter provide both a solid theoretical basis and essential practical tools for the construction and optimization of leaky-wave antennas, contributing significantly to the advancement of satellite communications research.

The chapter on leaky-wave antenna simulation and analysis presents an innovative design based on a coaxial helical slotted coaxial line, optimized to achieve the circular polarization required in satellite communications. The helical structure etched on the dielectric material of the coaxial cable ensured high radiation efficiency, maintaining over 75% efficiency in the 8-16 GHz frequency band. The design eliminates the open stopband effect, optimizing radiation even in the near beam direction perpendicular to the antenna. Simulation results and experimental measurements confirm the antenna performance, demonstrating circular polarization stability and maintenance of an axial ratio below 3 dB. The agreement between the simulated and experimental results attests to the reliability of the design, but small discrepancies were identified due to tolerances in the manual helical slot creation process. This simplified and compact leaky-wave antenna design has significant potential for satellite communications due to its compatibility with standard SMA connectors and ease of integration into existing systems. However, the manual manufacturing process introduced some performance deviations, suggesting the need for more precise manufacturing techniques. In addition, optimization of the weighting process for propagation constant control and phase constant maintenance remains an important research direction for future studies.

The conclusions of the thesis highlight the success of the research in the development of a leaky-wave antenna based on a coaxial feeder for Ku-band satellite communications. In a context where access to communications is limited for remote or disadvantaged regions, the thesis provides an affordable and efficient solution to meet the requirements of low-cost satellite communication.