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Study and comparison of different Slow Wave Structures (SWS) for a W-band Traveling Wave Tube (TWT). (277)

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ABSTRACT

This poster presents possible solutions for a W-band Travelling Wave Tube (TWT) in space satellite applications. Various devices are commonly used in this context and we have analyzed folded waveguide configurations as potential Slow Wave Structures (SWS) operating between 95 and 100 GHz. In order to increase the TWT performance, two possible solutions with identical cathode areas were considered: one with a circular beam and the other with a rectangular one. The simulations were carried out using CST Studio Suite. The circular beam structure showed a gain of 7.3 dB and a bandwidth of -3 dB at 4.5 GHz, with a periodic structure of 18 periods. The device achieved these values with a cathodic voltage of 18.6 kV and a current density of 1.9 A/mm^2 . The sheet beam, with the same number of periods as the previous one, showed double the gain and a bandwidth of 5.5 GHz, supplied with a voltage of 17.8 kV and a current density of 1.7 A/mm^2. These preliminary simulation results provide a solid basis for promising improvements.

INTRODUCTION

In the field of space applications, millimeter amplifiers are widely used and extensively investigated. The choice between solid-state and TWT amplifiers typically depends on the required frequency and gain, representing a system-level trade-off. In order to make this decision, it is necessary to evaluate the impact on the spacecraft's total mass, solar array size, system reliability, and antenna aperture size. TWT amplifiers offer lower technology risk with higher gains and greater efficiency.

TWTs for the W-band are essential due to their versatile slow-wave structures (SWS), which allow for different implementations. Among these, sheet beam configurations are generally preferred because they enhance efficiency. For these reasons we chose to study two different solutions as W-band SWS, focusing on enhancement given by the sheet beam configuration.

ANALYTIC MODEL AND SWS DESIGN

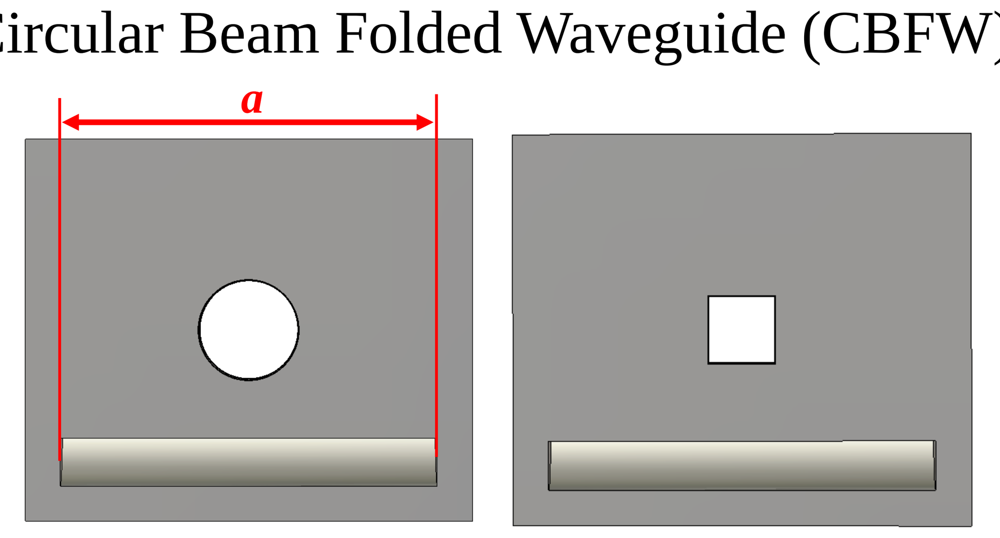
The important formulas to establish the period of the structure are the following: $eV_k = \frac{1}{2} m u_0^2\ ;\ \beta = \frac{\omega}{u_0}\ ;\ \frac{\beta L}{\pi} = 1.3$

In order to determine the interaction impedance of the folded waveguide (FW), we implemented an equivalent simplified analytic model in MATLAB. This mathematical model allows the prediction of the behavior of the waveguide, giving the possibility to spend less time in the optimization of the structure parameters. The code for the structures provided the result of 7.45 Ω.

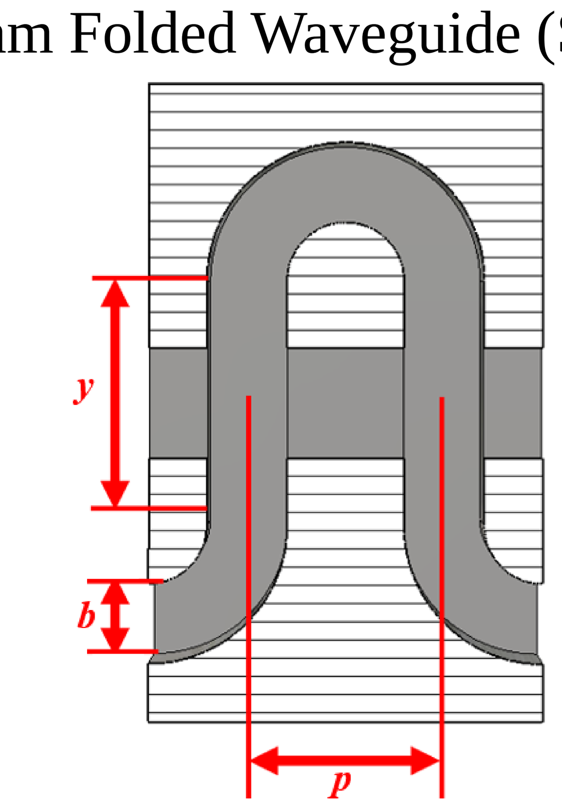
Table 1 shows final dimensions of the designed Circular Beam Folded Waveguide (CBFW) and Sheet Beam Folded Waveguide (SBFW).

Table 1:

$Hole\ Area:\ 0.09\ mm^2$
$p\ = 0.53\ mm$
$y =\ 0.66\ mm$
$b\ =\ 0.22\ mm$
$a = 1.7\ mm$

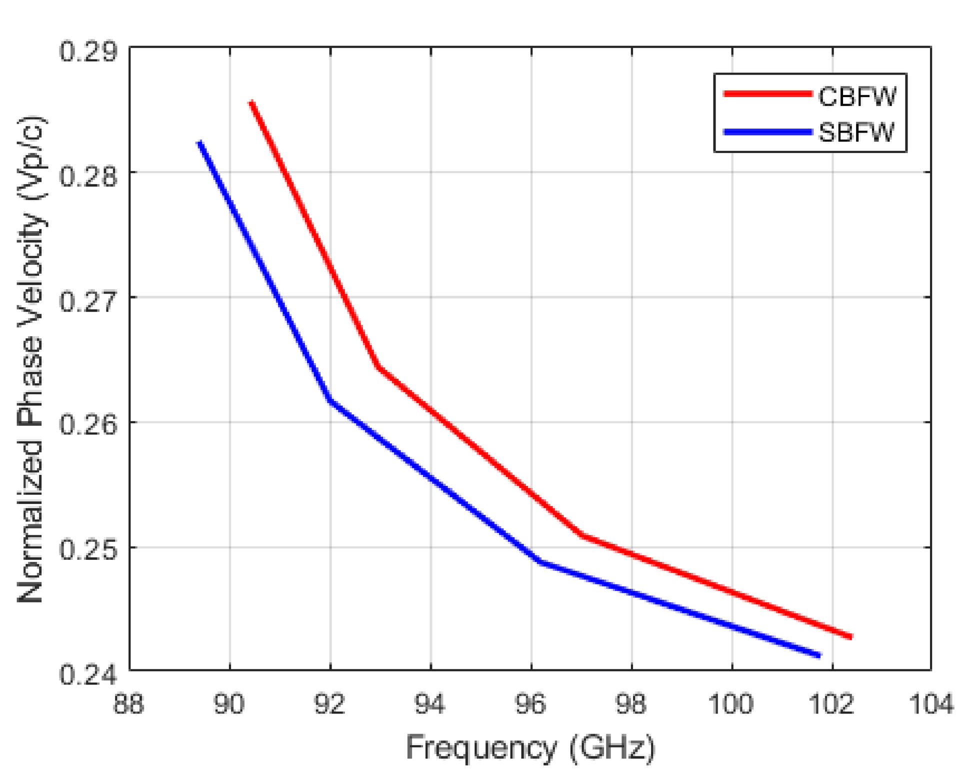


Side views of the SWSs for the CBFW (left) and SBFW (right)

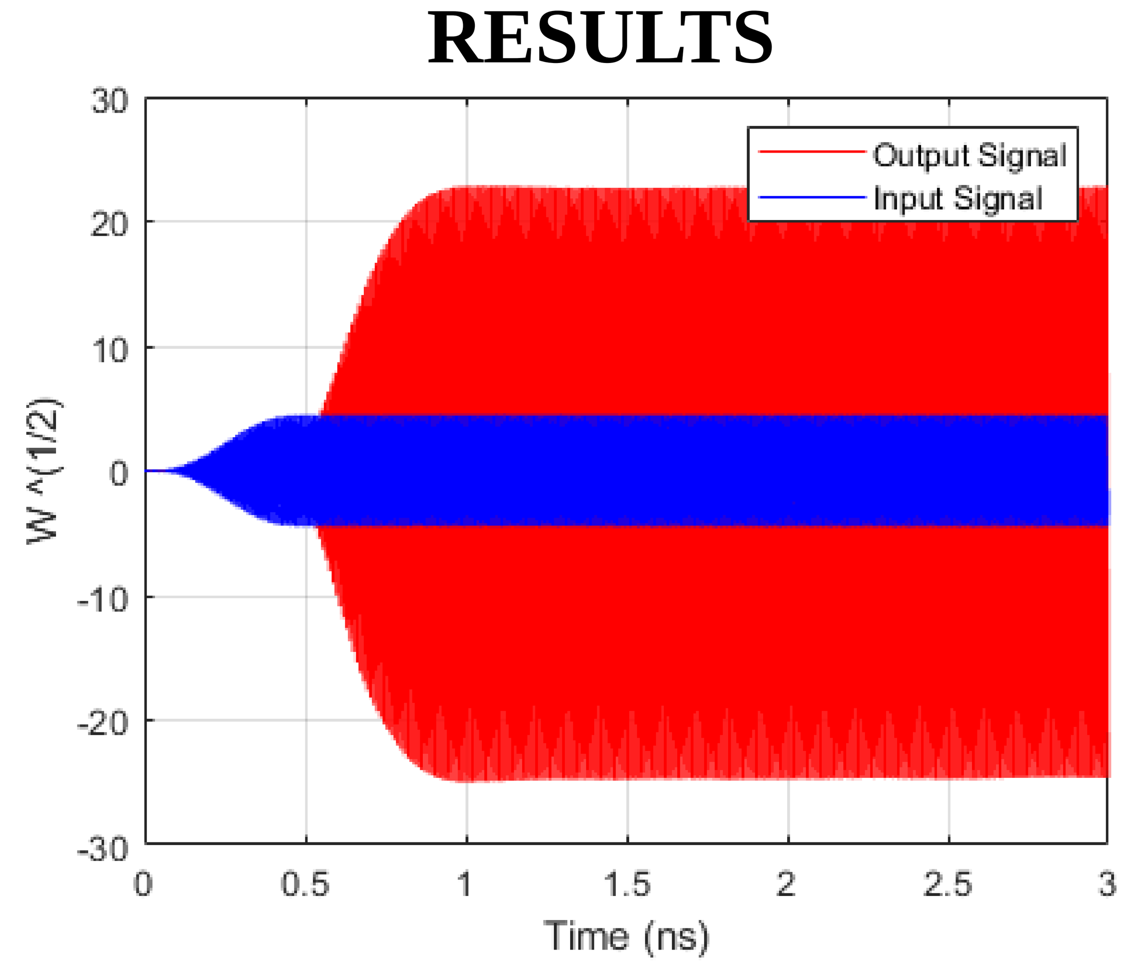


View of the section of the SWS

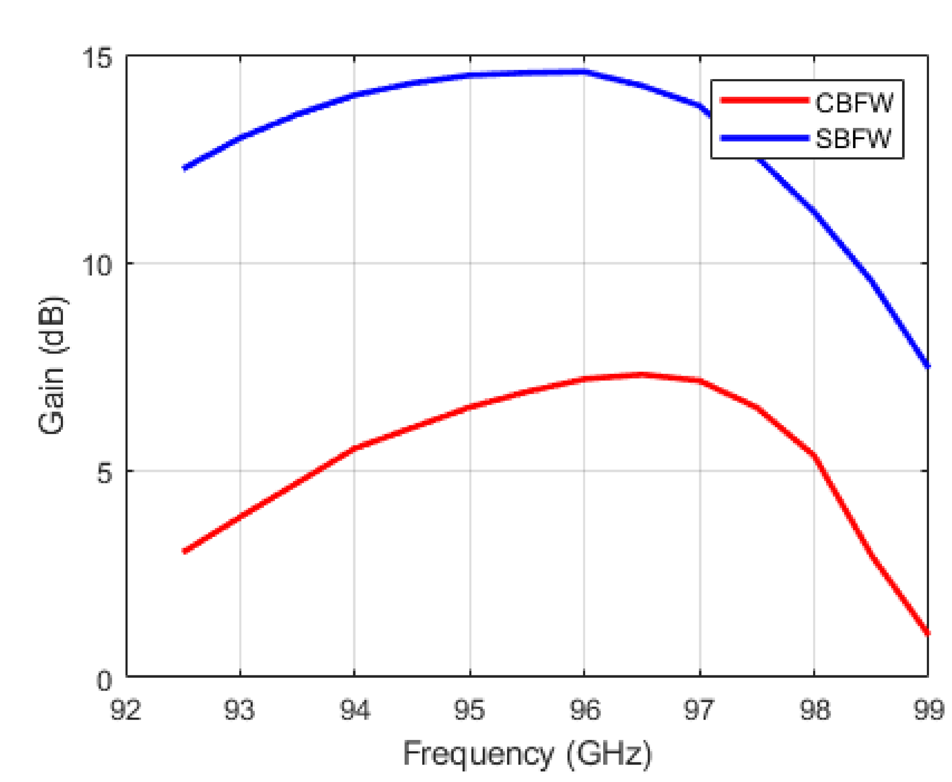
RESULTS



Normalized Phase Velocity for CBFW and SBFW



Input and Output signal in time of the SBFW at 96 GHz



Frequency vs Gain for CBFW and SBFW

CONCLUSIONS AND FUTURE WORK

The results obtained are preliminary at this stage but provide a solid base for further advancement for a W-band TWT.

Some consideration on novel FW-SWS configurations will be made to improve efficiency, considering the feasibility and advantages of using a sheet beam cathode.

It is essential to proceed with the design of the electron gun, which represents a critical component for the efficient operation of TWTs and the development and implementation of a code that incorporates the equivalent circuit model of the folded waveguide.