Investigation of a Sheet Beam RF Structure with Bragg Reflector for W band Amplifier

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***Abstract*— A W Band staggered double vane (SDV) loaded traveling wave tube amplifier (TWTA) with two sections separated by a lossy dielectric loaded rectangular wave guide is studied in this paper. The dispersion characteristics and transient analysis of the slow wave structure are analyzed in Computer Simulation Technology Microwave studio (CST MWS) and High Frequency Software Simulator (HFSS). In this amplifier, we propose to use Bragg reflectors on both sides of the slow wave structure (SWS), at the windows for the sheet beam at the electron gun and collector ends; this increases the impedance bandwidth of the RF structure. The attenuator section is comprised of a rectangular waveguide loaded on either side with single lossy dielectric material spanning over 5.5 pitches. The loss profile of the attenuator and loss magnitude is optimized to provide a 20dB loss in separating the input and output sections. A bandwidth of 15GHz ranging from 90-105GHz is obtained through the analysis. In the PIC simulations, a sheet beam of 50mA current is fed with an operating voltage of 18.3kV. The TWTA yields 20dB gain in the 90-105GHz range.**

Keywords—staggered double vane loading, traveling wave tube amplifier, slow wave structure, Bragg reflector, and attenuator.

I. INTRODUCTION

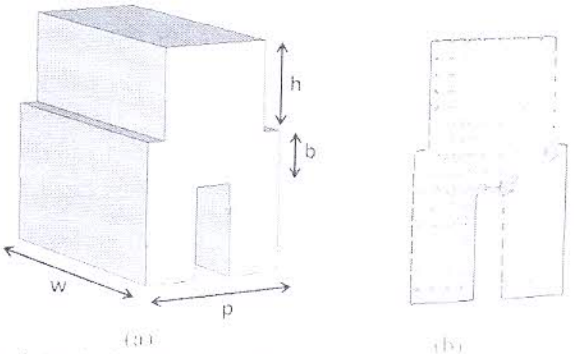
Sub-millimetre devices find its applications in high-data-rate communication, deep space research, high-resolution imaging, sensing and radars [1-3]. The conventional travelling wave tubes offer wide bandwidths at microwave frequencies. However, at millimetre frequencies, the operational bandwidth reduces due to their dispersive nature and the output power drops drastically [1]. The all-metal staggered vane loaded slow wave structure (SDVSWS) offers much wider bandwidth, higher gain, low loss and better heat dissipation. The frequency dependent dimensions reduce the space of beam tunnel and the interaction impedance reduces for increased beam tunnel, the use of sheet beam is preferred for optimal beam wave interaction [2-4]. A much wider beam reduces the space charge effects and requires minimal focussing to decrease the beam spread.

In this paper, a sheet beam supported SDVSWS is designed for W band applications. Section II discusses the dispersion characteristics of a unit-cell of the SWS. The transient analysis of the SWS is discussed in the section III, with the importance of Bragg reflector [5, 6] and single lossy dielectric loaded attenuator section. The plan towards the PIC simulations for yielding 20dB gain in the 90-105GHz bandwidth is subsequently discussed.

II. DISPERSION CHARACTERISTICS

Fig. 1(a) displays a unit-cell of the proposed SDV slow wave structure. The dimensions of the unit-cell are presented in the Table I. The axis along pitch, p, is aligned with z direction. The cutting plane view of the electric field distribution at 95GHz is displayed in Fig. 1(b).

The Eigen-mode analysis was computed using CST-MWS and HFSS on the unit cell by applying periodic conditions along axis and electric boundary conditions at the transverse planes. Fig. 2 plots the resultant dispersion characteristics of the proposed SDVSWS. A DC beam line with18.3kV passes through the dispersion curve along a bandwidth of 20GHz ranging from 85-105 GHz.



(a) (b)

Fig. 1.(a) Unit cell of Double staggered vane loaded SWS. (b) Cut view of the electric field distribution at 95GHz.

TABLE I. NORMALIZED DIMENSIONS OF PROPOSED UNIT CELL

Vane height, h/p	Vane width, w/p	Beam tunnel, b/p
0.6455	1.7273	0.2546

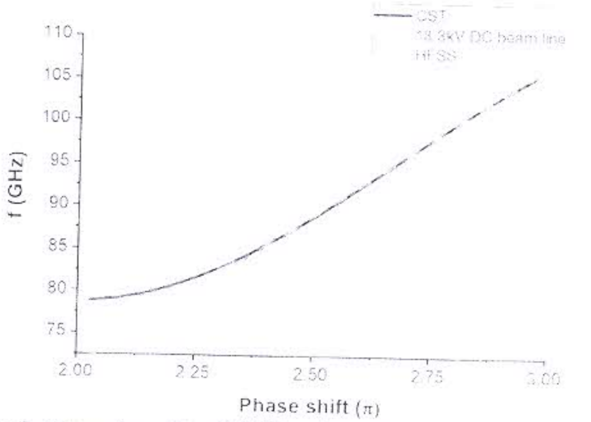


Fig. 2. Dispersion plot of SWS using CST Microwave studio and HFSS with synchronous 18.3kV DC Beam line

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III. TRANSIENT ANALYSIS

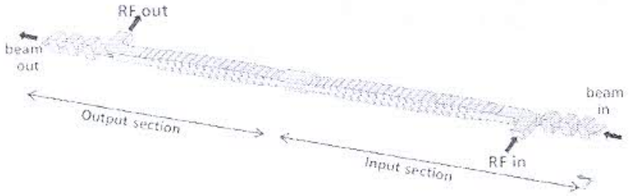

Fig. 3. Proposed two section double staggered vane loaded SWS separated by attenuator section.

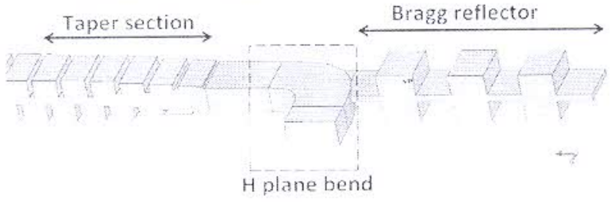

Fig. 4. Input section of the proposed structure

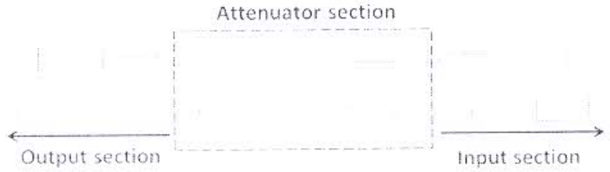

Fig. 5. Attenuator section separating input and output sections

The SDVSWS comprises of two sections – input and output sections separated by attenuator section as shown in Fig. 3. The ports at both the input and output sections are identical, but reversed for their ease of access to the respective external circuitries.

Bragg reflectors are conventionally used in optical systems and in backward wave oscillators where the signal is prevented from leaking on either ends of the circuit. A three section Bragg reflector is used for impedance matching at the input port, which also prevents the RF signal leaking into the beam tunnel. The input section presented in Fig. 4 comprises of an H plane bend through which the RF input signal is fed. The taper section adjacent to the H plane bend improves the impedance matching between the SWS and the bend, and also provides the necessary phase velocity taper at the SWS to waveguide transitions. A sheet electron beam of 50mA current driven by a dc voltage of 18.3kV is intended to be guided through the Bragg reflectors and the SWS with a magnetic focussing system of 0.15T at the axis of the beam.

The conventional attenuator sections generally are comprised of tapered SWS filling each cavity with lossy materials [1-2]. The cutting of such lossy materials into precise small pieces and its usage increases the length of the SWS and its cost. In order to provide sufficient loss to the RF signal, the conventional attenuator sections would span a minimum of 7-8 pitches axially [1]. Fig. 5 displays the attenuator section separating the input and output sections. In this paper, we present a rectangular waveguide loaded with single lossy material of 5.5 pitches, which is optimised to provide an attenuation of 20dB to the RF signal. On both sides of the attenuator, a taper is provided in the input and output sections for velocity tapering.

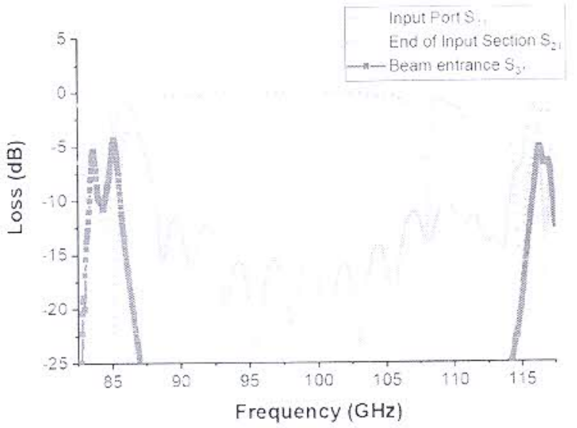

Fig. 6. Reflection loss at Input port S11, Insertion loss at end of input section S21, coupling at Beam entrance S31.

The transient analysis results of the input section are presented in Fig. 6. The -12dB bandwidth ranges from 88-108 GHz for the SWS. The signal lost in the beam tunnel at the electron gun end is minimal due to the use of Bragg reflector. With minimal attenuation at the input port (and the output port), the SWS would successfully operate in the intended 90-105 GHz range.

Initial investigation of SDVSWS with Bragg reflector on both the ends, collector as well as electron gun, has revealed encouraging results in terms of bandwidth (>15GHz), gain (>20dB) and efficiency. The final optimized results will be reported in the conference.

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