Study of the impact of variation in number of trajectories on the collector performance

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***Abstract*— Generally, the multi-stage depressed collector simulations have been done with the beam starting conditions of 96 electron trajectories obtained from the large signal beam-wave interaction code – SUNRAY-3D. But, the authors had been curious to check if the performance of the collector remains the same with increased or decreased number of electron trajectories, which has been the motivation for carrying out this study. With this study, it has been evident that from the large signal code point of view, an optimum of 96 electron trajectories have been taken since the power, gain and electronic efficiency gets saturated beyond 96 electron trajectories. However, the performance of the collector varies highly with the increase in number of electron trajectories even beyond 96 electron trajectories.**

***Keywords*— Multistage depressed collector, Collector Efficiency, Electronic Efficiency**

I. Introduction

In a traveling wave tube, after interaction of electron beam with the RF signal, the spent electron beam is collected by the collector. In order to simulate the performance of a collector, the beam starting conditions are generally taken from the beam-wave interaction large signal code. In large signal analysis using SUNRAY-3D [1] code, 96 electron trajectories are used for the simulation of interaction between beam and RF. Twenty four discs with each disc having four electrons have been assumed in the SUNRAY-3D [2]. The choice of 96 electron trajectories has been optimized with compromise between the accuracy and computational time.

Hence, generally the simulation of the collector has been done with the spent beam data of the 96 electrons. However, the impact of either increase or decrease in the number of electrons entering the collector has always been a concern, which has been ignored. Here, the authors have made an attempt to study the effect of increase or decrease in the number of electron trajectories in the performance of the collector.

Further, it has been realized that increase or decrease in the trajectory data will cause change in electronic efficiency, gain, power etc of the tube, as simulated by SUNRAY-3D. Beyond 96 electron trajectories, the gain, power and electronic efficiency of the tube doesn’t show much variation due to variation in number of trajectories and they almost remain constant. But, however, below 96 electron trajectories, the power, gain and electronic efficiency varies much with number of electron trajectories. And hence, from large signal code point of view, an optimum of 96 electron trajectories had been choosen.

Correspondingly, their impact on the collector efficiency has also been investigated using particle tracking code EGUN [3]. Changes in back streaming current and body current of the collector have also been observed. It has been noticed that though beyond 96 electron trajectories the collector efficiency shows greater variations (almost 6% from 96 trajectories to 160 trajectories).

II. Simulation Results

A. Large Signal Code

The beam-wave interaction simulation of the slow-wave structure is done using large signal code – SUNRAY-3D. The general convection followed while running SUNRAY-3D is the choice of 96 electrons trajectories. This choice of 96 electron trajectories has come from extensive optimization studies done to compromise between the accuracy of the results and the computational time. As number of electron trajectories used for running the large signal code is increased, the accuracy increases but at the cost of increase in the running time. Hence, an optimum value for the number of electron trajectories to be taken for running large signal code has resulted in 96.

The effect of variation of output power of the tube with the increase in the number of electron trajectories has been shown in figure 1. It could be observed that the power varies from 51.2W to 52.5W with simulation using 16 electron trajectories to 48 electron trajectories. Beyond 48 electron trajectories, the power remains almost constant.

The effect of variation of gain of the tube with the increase in the number of electron trajectories has been shown in figure 2. It could be observed that the power varies from 25.2 dB to 26.5 dB with simulation using 16 electron trajectories to 48 electron trajectories. Beyond 48 electron trajectories, the gain remains almost constant.

The effect of electronic efficiency of the tube with the increase in the number of electron trajectories has been shown in figure 3. It could be observed that the electronic efficiency varies from 26.5% to 30.5% with simulation using 16 electron trajectories to 96 electron trajectories. Beyond 96 electron trajectories, the gain remains almost constant.

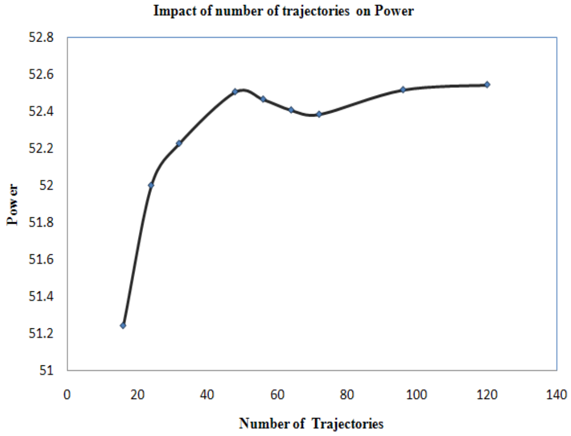

Fig. 1: Impact of variation in number of electron trajectories on output power of the tube

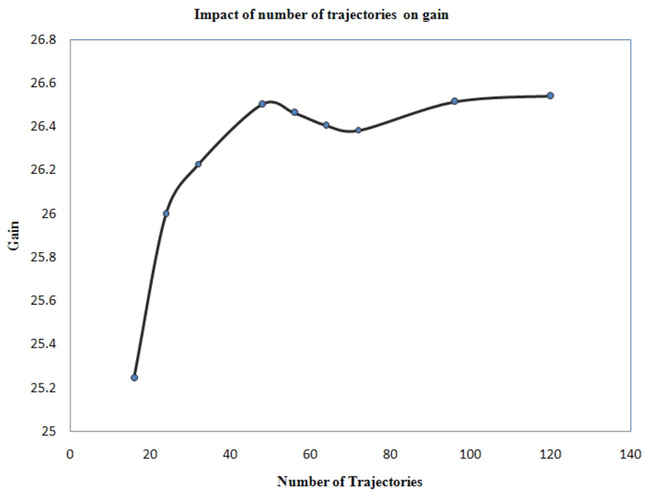

Fig. 2: Impact of variation in number of electron trajectories on tube gain

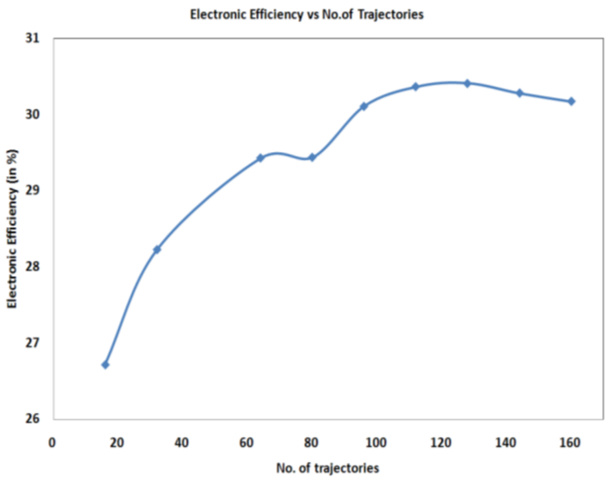

Fig. 3: Impact of variation in number of electron trajectories on electronic efficiency of the tube

Hence, based on these results, it has been concluded to choose 96 electrons as the optimum choice for the beam-wave interaction studies, as beyond that, all parameters remain almost constant. Increasing the number of electron trajectories beyond 96 just increases only the computational time but doesn't change the parameters of the tube much.

B. Collector Simulation

The simulation of the collector has been done with different number of trajectories using particle tracking code EGUN. Fig. 4 shows the effect of variation of number of electron trajectories on the collector efficiency (both with and without the effect of secondary electrons).

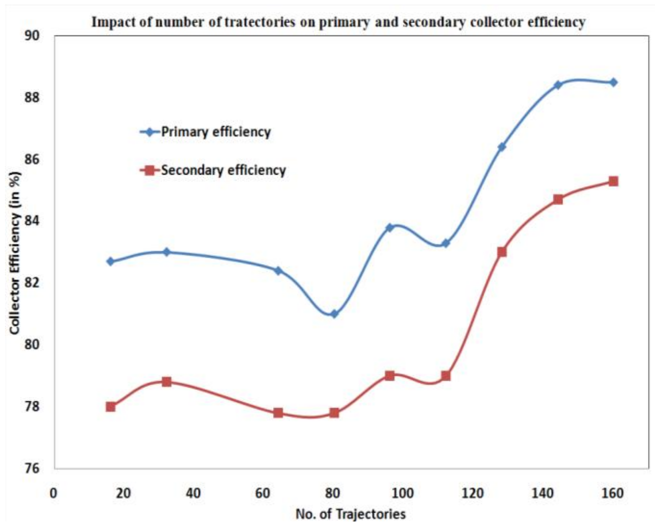

Fig. 4: Impact of variation in number of electron trajectories on collector efficiency of the tube

TABLE I
SUMMARY OF VARIATION OF BACK-STREAMING AND BODY CURRENT WITH THE NUMBER OF TRAJECTORIES FOR RF CONDITION
(EXCLUDING THE EFFECT OF SECONDARY ELECTRONS)

S.No.	Number of Trajectories	Back streaming current (mA)	Body Current (mA)
1	16	0.0	0.0
2	24	0.0	0.0
3	32	0.0	0.0
4	48	0.0	0.0
5	56	0.0	0.0
6	64	0.0	0.0
7	72	0.0	0.0
8	96	0.0	0.0
9	120	0.83	0.0
10	144	0.9	0.0
11	160	1.0	0.0

TABLE III
SUMMARY OF VARIATION OF BACK-STREAMING AND BODY CURRENT WITH

THE NUMBER OF TRAJECTORIES FOR RF CONDITION
(INCLUDING THE EFFECT OF SECONDARY ELECTRONS)

S.No.	Number of Trajectories	Back streaming current (mA)	Body Current (mA)
1	16	0.70	0.0
2	24	1.26	0.0
3	32	3.70	0.0
4	48	1.23	0.2
5	56	2.80	0.5
6	64	0.80	0.1
7	72	0.50	0.8
8	96	1.00	0.3
9	120	1.00	0.7
10	144	1.02	0.5
11	160	2.63	0.8

The back-streaming current and body current of the tube also varies with the number of electron trajectories. The following table I summarizes the effect of variation of number of electron trajectories on the back-streaming current and body current for the RF condition excluding the effect of secondary electrons (with just primary electrons). It could be observed that the back-streaming current remains 0mA till 96 electron trajectories. When increased beyond 96 electron trajectories, the back-streaming current increases.

The following table II summarizes the effect of variation of number of electron trajectories on the back-streaming and body current for the RF condition including the effect of secondary electrons. It could be observed that the variation of back-streaming current and body current appears highly non-linear with the variation in the number of trajectories.

The study of variation of number of electron trajectories on the collector performance reveals that the performance of the collector varies greatly with the number of electron trajectories and doesn’t saturate beyond 96 electron trajectories.

III. CONCLUSIONS

Based on the results presented, it has been concluded that though for the beam wave interaction large signal analysis code, optimum of 96 electron trajectories have generally been used, the collector simulation results doesn’t saturate beyond 96 electron trajectories. Hence, simulations done with optimum of 96 electron trajectories can’t be sufficient to simulate the collector performance.

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