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Design of helix slow wave structure for X band helix TWT using multi-dispersion

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Abstract

In this paper, a compact, multi dispersive helix slow-wave structure (SWS) with coaxial input coupler for a high efficiency X-band helix TWT has been proposed. Design of SWS has been carried out using in-house developed analytical code GANGA, SUNRAY-1D and commercial software ANSYS Electronics Desktop. The helix SWS has been modelled in three sections each having different dispersion characteristics — realized by different loading scheme to each section to achieve desired output characteristics. Due to different dispersion characteristics, coupling system has also been suitable modelled to exchange RF power from SWS.

1. Introduction

Helix travelling wave tubes (HTWTs) are possibly the most complex power amplifiers and have drawn significant attention when it is to be used for satellite communication due to high linearity, flat power and gain frequency response, high efficiency, high reliability, etc [1–4]. Such HTWTs are essentially required for satellite communication systems as a high power and high gain microwave amplifier. Therefore, performance of any such HTWT depends on optimised designed slow wave structure and coupling system.Thehelix SWS which supports the propagation of the RF signal and controls the interaction of the modulated electron beam with the RF signal, primarily determines the overall performance of a TWT [1]. A well designed helix SWS enhances tube efficiency with reduction in circuit dissipation.Earlier, it was reported that performance of the TWT can be improved if the helix SWS exhibits flat to negative dispersion [2]. However, achieving negative dispersion using isotropic inhomogeneous loading is very difficult and can be realized by anisotropic inhomogeneous loading. Further, for narrow band TWT, anisotropic loading is not appreciated by the designer due to several constrains. In view of limitations of anisotropic loading, and to improve the performance of the TWT, multi-dispersion has been adopted and presented in this paper. Recently, a multi-dispersive helix SWS structure with positive taper in output section has been reported in [3]. However, the

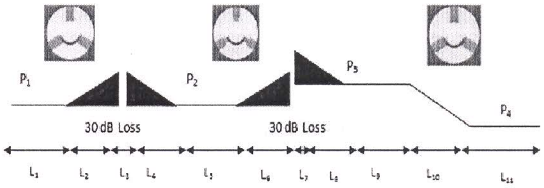

Figure 1. Schematic of HSWS profile. (Input and output section have rectangular shape APBN supports rods placed symmetrically 120° apart, middle section has T shape APBN supports rods placed symmetrically 120° apart).

large signal gain (LSG) variation is more than 2 dBm over the 1 GHz band of interest [3].

Therefore, to reduce ripples in both output power and gain over the band an improved three section multi dispersive helix SWS structure has beenproposed in this paper, which gives flat power and gain frequency response and corresponding helix pitch profile is depicted in fig 1.

Multi-dispersion has been realized by loading the helix SWSin two different ways, namely, using T shaped and rectangular shaped APBN helix supports. Keeping remaining structure dimensions constant, helix pitches have been varied and the normalized helix pitches are Pitch 1 (P_1) = 1, Pitch 2 (P_2) = 1, Pitch 3 (P_3) = 1.02 , Pitch 4 (P_4) = 0.79. The normalized lengths of different helix sub-sections are Length 1 (L_1) = 1 , Length 2 (L_2) = 0.43 , Length 3 (L_3) = 0.057 , Length 4 (L_4) =0.43, Length 5 (L_5) = 0.43, Length 6 (L_6) = 0.43, Length 7 (L_7) = 0.057, Length 8 (L_8) = 0.43, Length 9 (L_9) = 1.143, Length 10 (L_{10}) = 0.34, Length 11 (L_{11}) = 0.14, Length 12 (L_{12}) = 0.17.

After estimation of cold structure parameters, namely, propagation constant, interaction impedance, the structure is optimized for hot performances, namely, power, gain, etc, using large signal analysis code [4]. Due to multi-dispersive structure and or multiple helix pitches, proper matching of helix characteristic impedance with the coupling system have been carried out for efficient power transmission. Due to very high variation of helix characteristic impedance Z_S, quarter wave transformers have been suitable modelled to properly match with the

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standard Z_L of connector impedance to minimize reflection of RF signal.

2. Design Approach

In this section, design approach of helix SWS and input coupler has been discussed. The cold parameters (propagation constant, interaction impedance) have been

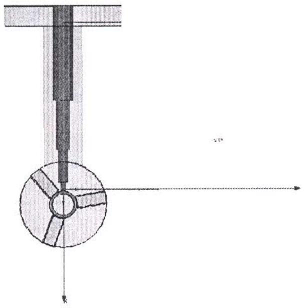

Figure 2. Simulation [5] model of input coupler with helix SWS

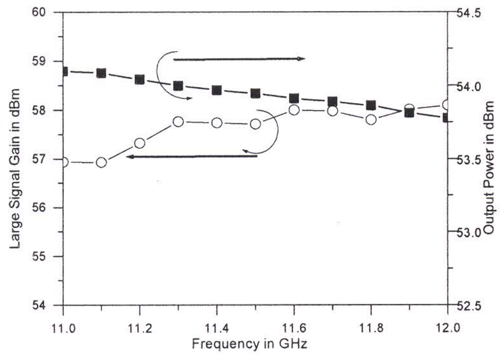

Figure 3. Simulated [4] output power and large signal gain (LSG) of the proposed HSWS.

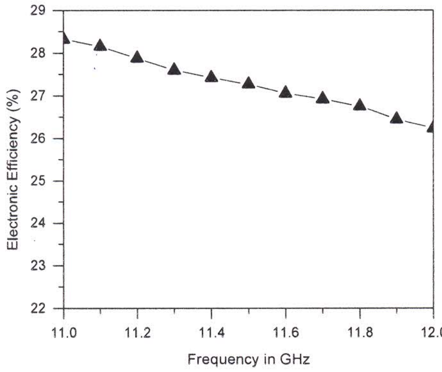

Figure 4. Simulated [4] electronic efficiency of the proposed HSWS.

evaluated using in-house code GANGA [3].Also, the same has been predicted using commercially available software ANSYS Electronic Desktop 18 [5]. A single turn approach of helix and Azimuthally Periodic boundary conditions (with master and slave boundaries) has been used in [5]for obtaining the cold parameters.

Subsequently, these parameters have been used in LSA [4] model to optimize TWT performance by suitable adjusting length, helix pitch of the sections to make a trade-off among maximum bunching current, maximum efficiency, and maximum power and gain. Care has also been taken such that TWT does not oscillate due to length and does not exceed start current and the optimised helix SWS has been shown in figure 1. The input coupler to the helix SWS has been designed using [5] for proper coupling of rf signal. The simulation model has been shown in figure 2, however, output coupling system, coaxial to WR-75, has been skipped here.

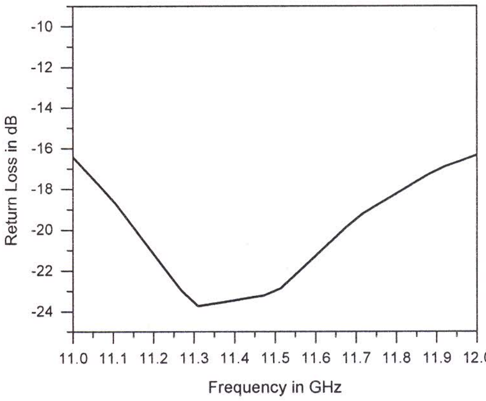

Figure 5. Simulated [5] return loss profile for the input Coupler to the proposed HSWS.

3. Results and Discussions

It can be observed from figure 3 that the proposed SWS exhibits almost linear output powerof ~ 240 W with ~ 1 dB gain variation without using linearizer. Moreover, it can be seen from figure4 that the electronic efficiency is more than 25% . The return loss profile of the input coupler is shown in figure 5. It can be observed that the coupler is well matched with the SWS over the entire operating band.

4. References

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