Modeling of Multi-Octave Coaxial Couplers for Helix Traveling-Wave Tubes

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Abstract:-

This paper presents an efficient design of broad band coaxial coupler using Ceramic bid, for space TWTs. An approach has been developed for the efficient design and analysis of the coaxial couplers in the practical situation. Normally multi-section impedance transformer approach is used for any wide band coupler. For a space helix TWT, coupler should be wide bandwidth and small size. In this case coupler is matched with helix slow wave structure and the standard 50-ohm connectors. The simulated return loss (dB) profile for different type of couplers is obtained by using CST microwave studio.

I. INTRODUCTION

Space helix TWT is a vacuum microwave device that is used as high power microwave amplifier in communication satellites [1]. The input and output couplers play an important role in efficiently coupling the microwave power in and out from the helical SWS of a TWT with minimum reflection and transmission loss. It is required to have a coupler with VSWR < 1.20 (return loss < -15 dB, without electron beam) for full frequency band of operation. Coaxial couplers are extensively used in space TWTs of moderate output power up to 300 Watts because of their large bandwidth and small size. In Ku-band space TWT output power is 140 W, TNC connector was used [2]. For a broad band helix traveling-wave tube (TWT), the design of Input and output couplers become one of biggest handicap in obtaining such a wide band. The facility of fabrication technology, which is important for successful design, also should be taken much concern.

The design of coupler is very critical as one end of it is attached with helix SWS and other end with the rf connector (impedance 50 ohm). Earlier, the design of coupler consisting of window assembly and transformer section has been done without considering the rf connector and helix SWS in their real situations. Each of these components is simulated by its characteristic impedance and the design is performed by CST Microwave Studio. In the present approach, both the rf connector and the helix SWS were simulated in their real situations.
Coaxial window of material 96% Alumina has been preferred because of its low RF loss, high mechanical strength and non toxicity. The thickness of the Alumina window was chosen minimum possible (0.9mm) for low RF loss and radial dimensions are chosen for its impedance of nearly 50 Ohms.

II. DESIGN

The whole coupler assembly has been considered as a cascade of multi-section transmission line of arbitrary lengths. The input coaxial coupler, as shown in Fig.1, Fig.2, consists of RF window assembly and an impedance RF transformer assembly for Ku-short and Ka-band respectively. Window assembly is also accounted as a section of this cascaded line having different dielectric medium. Design expressions have been derived based on (a)Impedance Transformation, (b) ABCD Matrix and (c) Small Reflection methods by extending these methods discussed for either one section transformer or multi- section 3L/4 transformer in microwave engineering books[3]. Tiny size of ceramic window disc results insubstantial rise of window temperatures and need to be cared. Therefore, the thermal considerations in the design of couplers become necessary especially for space TWTs to ensure reliability. The RF transformer assembly is a multi-section coaxial transmission line. The radial dimensions of the Ceramic window and the RF transformer were chosen for its impedance of nearly 50ohms (same window and RF transformer for output also). A compensation capacitance between RF window and coaxial transmission line was introduced to compensate the mismatch between them.

A ceramic bid of Alumina 96% same as of the window ceramic is introduced inside the coupler so as to make the coupler broad band. An experiment has performed on the ku-short and ka-band helix TWTs, using the same dimension coupler with and without ceramic bid. Due to reduced dimensions of the interaction structure in Ka-band, the characteristic impedance is different from Ku-band TWT and the mismatch of the impedance is compensated by suitable positioning the ceramic bid.

The coaxial coupler, made of three sections, is modeled using CST Microwave studio. The coupler is suitable modeled in three sections and developed for Ka-band TWT to achieve return loss value less than -15 dB (Fig. 2(a)). The same coupler is used in Ka-band TWT and very good impedance mach is achieved by inserting the ceramic bid (Fig. 2(b)). Thus, this multi-octave coupler finds its suitable potential application at higher frequencies when the structure dimensions became tinny. Moreover, at higher frequencies, due to reduced structure dimensions, coaxial couplers suffer from thermal management issues and which can be minimized by using coaxial couplers of larger transverse dimensions.

Whole experiment is performed without taking losses into consideration and the simulated results are observed and shown in Fig 3 & 4 respectively.

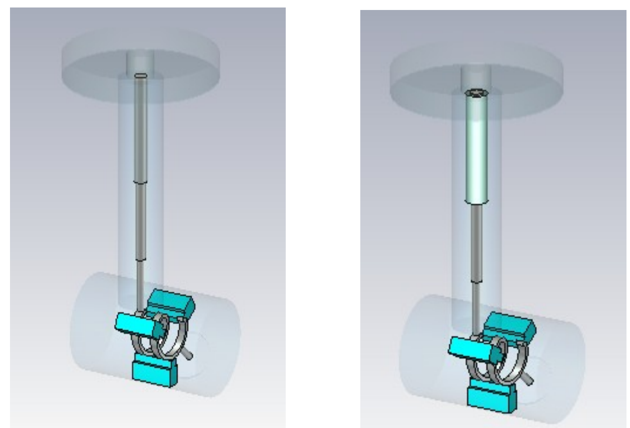

Fig. 1(a) Fig. 1 (b)

Fig. 1 Input coupler of Ku-band short length 140 W helix TWT (a) without ceramic bid (b) with ceramic bid.

The dimensions of both ku-band short length and ka-band couplers remain to be same, only the ceramic bid is so adjusted in its axial direction so as to achieve minimum return loss over the desired frequency band.

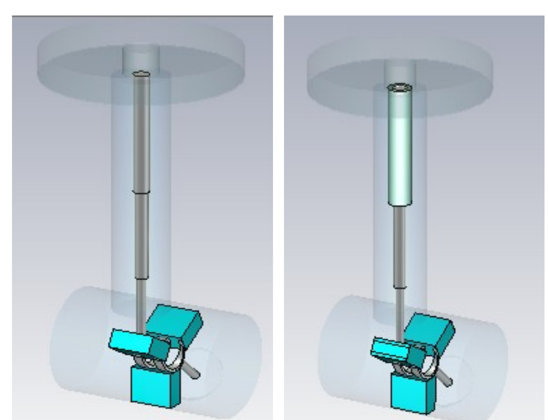

Fig.2 (a) Fig.2 (b)

Fig. 2 Input coupler of Ka-band 40 W helix TWT (a) without ceramic bid (b) with ceramic bid.

III. RESULT AND CONCLUSION

The CST Microwave Studio was used to simulate the couplers. The Return loss of the input coupler is shown in Fig.3 & 4. For the respective couplers, it was observed that over 10.9-11.7 GHz & 20.6-21.2 GHz band the return loss is found to be ≤10dB without changing any parameters of the coupler. This is done up to the simulation process only. The successful design will be a great help for the development of the TWT.

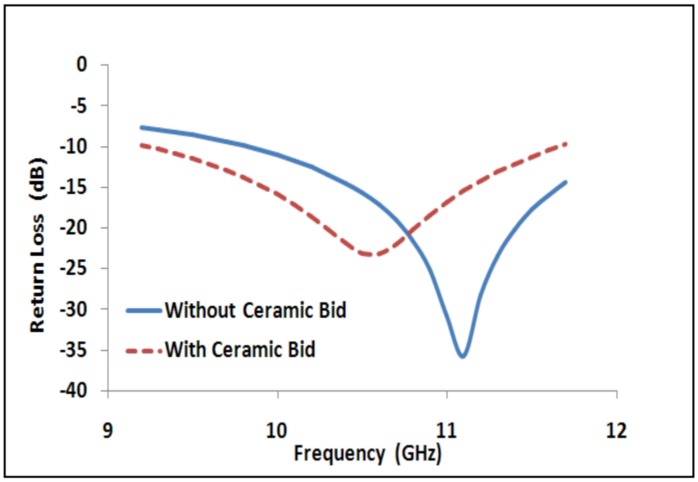

Fig. 3 Return loss performance of coupler with and without Ceramic Bid for Ku-Short band 140w space helix TWT.

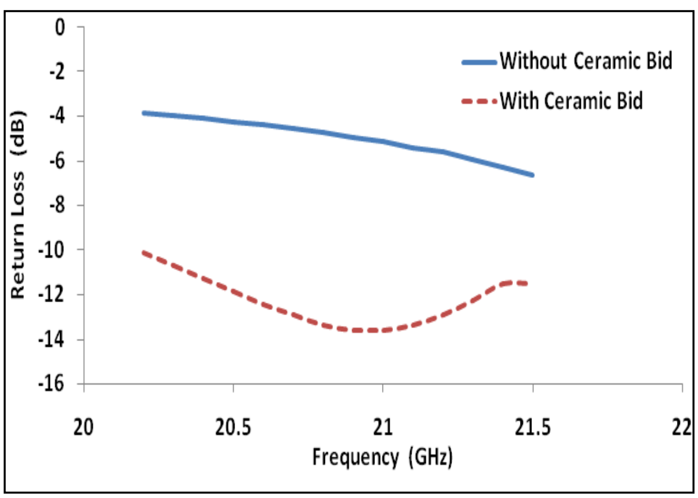

Fig. 4 Return loss performance of coupler with and without Ceramic Bid for Ka-band 40w space helix TWT.

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