

Mukesh Kumar Alaria and Sanjay Kumar Ghosh

# Design of Coaxial and Waveguide Couplers for Helix TWT

**Abstract:** In this paper, two types of coaxial coupler and waveguide coupler for different frequency helix TWTs are designed, fabricated and cold tested. The coaxial coupler includes of window ceramic and RF transformer section. At present multi-section impedance transformer design approach is used for wideband helix TWTs. In any helix TWT, impedance of the source is transformed to the characteristic impedance of helix. This is done by the quarter-wavelength ( $\lambda/4$ ) impedance transformation approach. The simulated results of different types of couplers are carried out by HFSS and CST microwave studio software and compare with experimental results. 3-D electromagnetic field simulators allowing the any geometry with port excitations it is possible to model the complex coaxial and waveguide type couplers with helix SWS assembly and predict its desired return loss performances.

**Keywords:** Traveling wave tube (TWT), Coaxial, Waveguide, Return loss, Wide bandwidth

## 1 Introduction

Helix travelling wave tubes (TWTs) are widely used as medium power microwave amplifier in the transponders of satellite communication and radars. There has been growing demand for wide bandwidth, high efficiency and high gain helix TWTs to meet the new emerging requirements of communication systems [1]. In TWT, small RF power, feed into TWT through input coupler, gets amplified through electron beam and taken out through output waveguide coupler. Hence, for efficient power transmission, proper impedance transformation from helix to external connector or waveguide through couplers is required.

The coaxial couplers are very important components for efficient coupling the microwave power in and out from the helix slow wave structure (SWS) of TWT with minimum reflection and transmission loss. In this paper, authors have presented modelling of SMA type input coupling system and door knob type waveguide structure at output for handling of high average power. Normally coaxial type of couplers is extensively used for moderate output power because of their large bandwidth and small size. The waveguide type output coupler was designed for transmitting the output power more than 300 Watts with minimum absorption and reflection, over wide frequency band [2]. For efficient power transfer coaxial couplers are suitably modelled and design to multi-section coaxial coupler for proper impedance transformation of helix to standard connector [3]. It is required to have a coupler with  $VSWR < 1.20$  for entire frequency band of operation. The coaxial couplers are extensively used in helix TWTs of moderate output power up to 200 watts because of their large bandwidth and small size. The coaxial couplers consist of coaxial RF window and RF transformer multi section assembly. The RF transformer assembly is connected to a standard connector at the input while the transformer is terminated with a helix SWS through laser welding the inner conductor of the coaxial line [4]. The coaxial couplers have been modelled with slow wave structure with tip loss on support rods. The helix is supported inside the metallic barrel assembly using three proper sized and shaped dielectric rods at 120 degrees. Material properties, disc thickness, etc., of the window plays an important role in designing of the coaxial couplers. In any TWT, impedance of a coupler should have a good match with the interaction circuit for maximum power transfer and minimum reflection from both input and output ends. To demonstrate the novel approach and geometrical model of helix TWT with coaxial and waveguide coupler is shown in Fig.1 [5]. In this design, both the RF connector with window ceramic and the helix SWS were simulated in their real situations with the coupler assembly for TWT. The C-band helix TWT and Ku-band were designed by CSIR-CEERI, India and developed jointly with BEL, India. In C-band space TWT TNC connector was used and Ku-band a special coaxial-to-wave guide adapter has been designed for coupling power to standard rectangular waveguide WR-75 through the window assembly was used. A novel approach developed for the efficient design and analysis of the coaxial and waveguide couplers have been validated with the software HFSS [6].

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All of these couplers were originally optimized using either the conventional technique or through repetitive experimental evaluation. The novelty of this simulation approach is that RF coupler matching to helix SWS at the other end lossy resistive thin film coating on the three support rods [7]. The electrical design of the coaxial coupler assembly can be divided into three sections as shown in the Fig. 2.

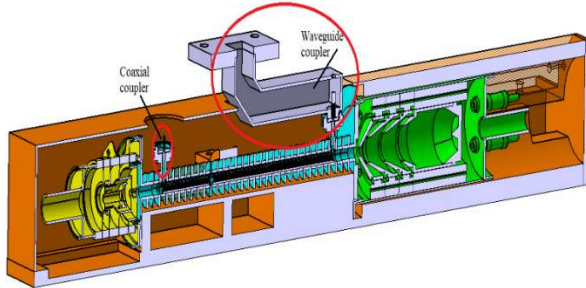


Fig. 1: Geometrical model of TWT with couplers

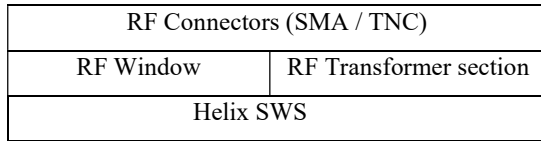


Fig. 2: Block diagram of coaxial coupler assembly model

## 2 Coaxial and Waveguide Couplers

In TWTs, couplers are used to feed and extract RF power and which are derived from transmission line by changing  $b/a$  ratio and their respective heights, where 'b' is the inner radius of outer conductor and 'a' is the radius of inner conductor. Coaxial couplers are suitably modelled to multi-section coaxial coupler (MSCC) for proper impedance transformation of helix to standard connector such that adequate S-parameters can be achieved [8]. For very high gain application, reflection of RF signal must be negligible from each sections of multiple sub-quarter wave transformer. Reflection of RF signal causes back-and-fourth oscillations in the TWT which generates heat at the helix to coupler joint and finally leads the TWT to destruction [9]. Coupling systems, namely, input coupler and output coupler are designed to transform high characteristic impedance ( $Z_s$ ) of helix to standard load impedance ( $Z_L$ ) of connectors through quarter wave transformers to minimize reflection of RF signal which is further quantified by S-parameters. At output in TWTs, source impedance ( $Z_s$ ) of helix needs to be matched with load impedance ( $Z_L$ ) of the dominant mode of the

respective waveguides [10]. Hence, for suitable impedance matching between  $Z_s$  and  $Z_L$  at input radii of coaxial system ( $b/a$  ratio) is suitable modelled to achieve return loss ( $S_{11}$ ) less than 15.0 dB and at output additional waveguide to co-axial transition is modelled to achieve return loss ( $S_{11}$ ) less than 15.0 dB. The input and output couplers characteristic impedances of Ku-band TWT are shown in Fig. 3 and transformed to  $35 \Omega$  at input and dominant waveguide mode impedance at output through quarter wave transformers to achieve  $VSWR < 1.5$ . A standard rectangular waveguide has been used for output coupler at different operating frequency. In waveguide coupler, door knob structure has been used for coupling with optimized short position from waveguide end, diameter and height of center pin. Coaxial coupler assembly is treated as a coaxial transmission line and modelled with port I at the source end and port II at the load end as shown in Fig. 4. At the load end sever loss is attached in terms of the resistive material with helix SWS. Total number of turns of the helix is taken as 11 and loss is attached up to 4 turns of the helix. The coaxial coupler of C-band helix TWT with SMA connector was modelled and shown in Fig.4. The simulated results are compared with experimental test results shown in Fig.5.

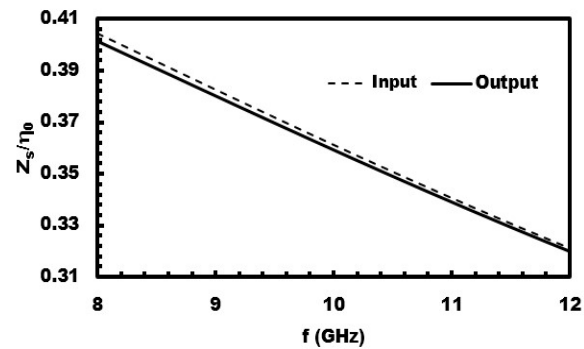


Fig. 3: Normalized characteristic impedance for Ku band TWT

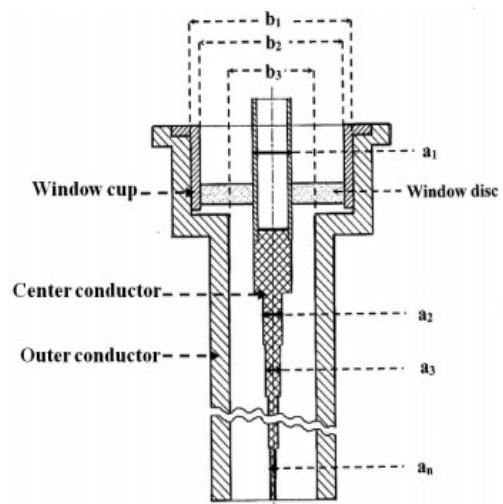


Fig. 4: Schematic view of coaxial coupler for C-band TWT

The coaxial couplers of Ku-band helix TWT with an SMA connector are modeled with same approach and the simulated result is compared with the experimental test results shown in Fig.6 shows the HFSS model of coaxial coupler for Ku-band helix TWT. Fig.7 shows the simulated and experimental results of coaxial coupler for Ku-band TWT.

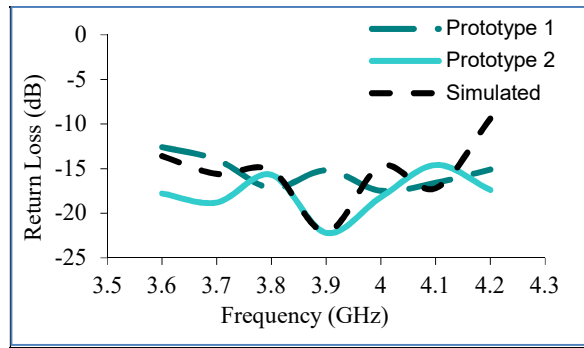


Fig. 5: Measured and simulated results of C-band coaxial coupler

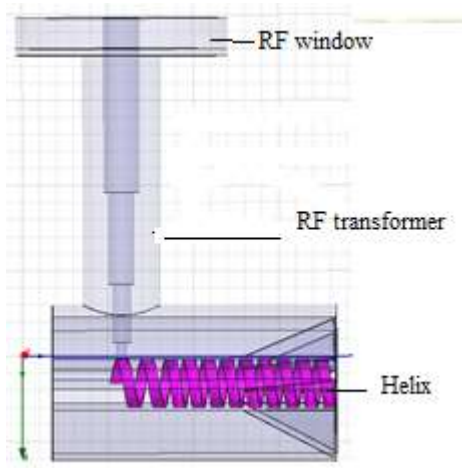


Fig. 6: HFSS model of coaxial coupler for Ku-band TWT

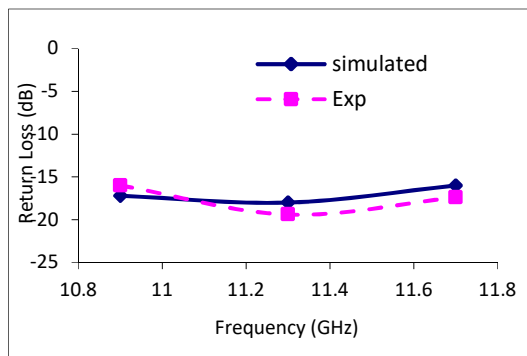


Fig. 7: Measured and simulated results of Ku-band coaxial coupler

A standard rectangular waveguide WR-75 has been used for output coupler for Ku-band. As in Ku-band output power is 200 W, a special coaxial-to-wave guide adapter has been designed for coupling RF power to the standard wave guide WR-75 through the window assembly as was presented. The center conductor of the coaxial line extends into the waveguide to form an electric probe. As the present design approach gives better confidence and thus design approach is more reliable. The output coupler is used to extract the RF power from the TWT. As this power is high, a coaxial to waveguide transition will be designed to couple the power out of the tube. A door knob type structure has been used for coupling with optimized short position from waveguide end and height of center pin. The cone shape structure has been modelled on the center pin for efficient heat dissipation. In this design center pin is supported from cone for taking out the heat from the window assembly. Fig.8 shows the output coupler with WR-75 waveguide assembly. Fig. 9 shows the comparison of simulated and experimental results of Ku-band output waveguide coupler.

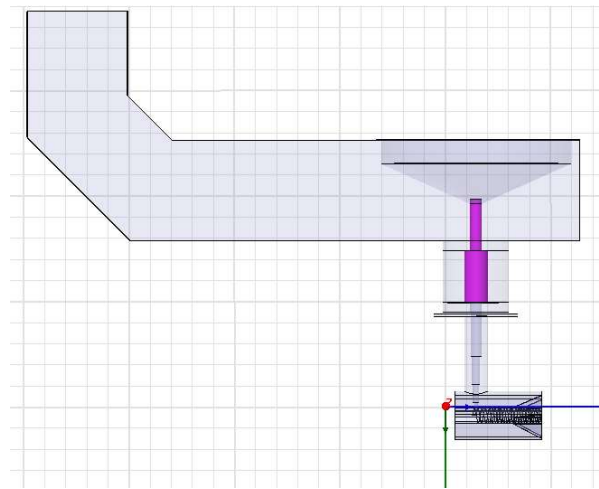


Fig. 8: Simulated HFSS model of waveguide coupler for Ku-band

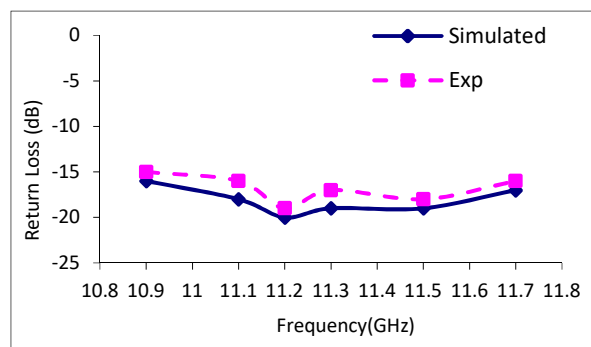


Fig. 9: Measured and simulated results of waveguide coupler

Table 1 shows the design parameters of Ku-band helix TWT. Fig. 10 shows the model of Ka-band output coupler with WR-51 waveguide. Fig. 11 shows the return loss performance of output waveguide coupler. In HFSS software the mesh is adaptively refined, until the difference between two consecutive passes.

Table 1. Design Parameters of Ku-band Helix TWT

| RF Parameters     | Values        |
|-------------------|---------------|
| Frequency         | 10.7-11.7 GHz |
| Output power      | 140 W         |
| Window            | Alumina       |
| Ceramic thickness | 0.9 mm        |
| Input coupler     | SMA           |
| Output coupler    | Waveguide     |

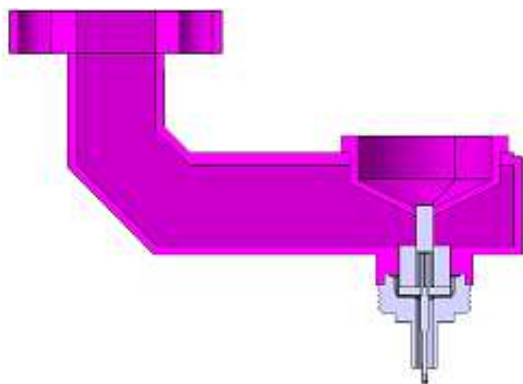


Fig. 10: HFSS model of WR-51 waveguide coupler for Ka-band TWT

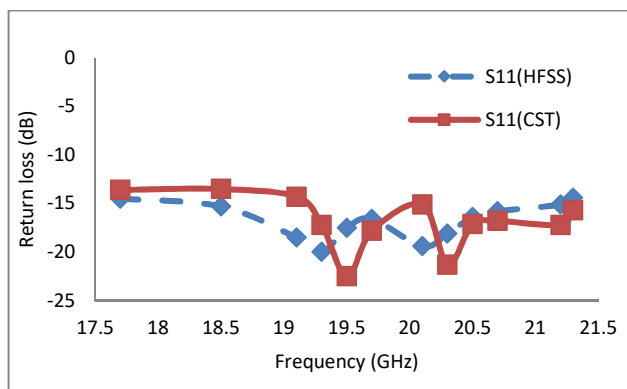


Fig. 11: Simulated return loss performance of Ka-band waveguide coupler

### 3 Conclusion

The modelling and designing of coaxial and waveguide couplers have been described and validated by experimental results for C-band, Ku-band and Ka-band helix TWTs in this article. The coaxial and waveguide type couplers have been extensively used in helix TWTs for high output power because of their large bandwidth. The return loss of the coaxial and waveguide coupler has been obtained throughout operating frequency band. The novelty of work is door knob structure has been used for high power handling capability with optimized short position from waveguide end. The proposed methodology can be used as a fast and accurate modelling.

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