# Design Of A Transverse Focusing Structure For Mm Wave TWT For Radars

Mita Jana, Latha Christie, Deepu Augustin
Microwave Tube Research & Development Centre, Bangalore 560013, India
Tel: +91-080-28388151, Fax: 91-080-28381750
Email:mita@mtrdc.drdo.in, christie@mtrdc.drdo.in

***Abstract:***

*This paper presents a novel magnetic focusing structure using magnets in the direction transverse to the TWT axis. This helps in achieving an uniform magnetic field over a relatively longer length for focusing the high density electron beam used in TWTs for mm-wave radars. Two different types of transverse magnetic focusing structure is presented and the results obtained for these two structures using CST simulation is compared.*

***Keywords:*** *Magnetic focusing, mm-wave radar, simulation, transverse polarization, Traveling Wave Tube.*

## I INTRODUCTION

Latest advances in millimeter wave (mm wave) technology have led to the development of radars above 30 GHz for remote sensing, atmospheric studies like cloud and precipitation, for space exploration and for active radar seekers. Mm wave radars offer better range resolution than low frequency radars and can detect targets more accurately and is more resistant to fog, smoke and snow. They are also used in advanced driver assistance systems to improve safety amidst dust, fog and darkness where image based systems lack robustness. Though vacuum electronic devices are potentially the right devices for providing reasonable power and bandwidth in a compact package for mm wave radars, it is challenging to realize them in millimeter wave frequencies. The circuit dimensions decrease with the frequency and the conventional fabrication schemes fail [1]. As the beam tunnel dimensions scale down with frequency, a very high current density electron beam have to be focused throughout the structure from the electron gun to the collector. Hence, the design and development of Periodic Permanent magnet (PPM) focusing structure becomes a challenging issue as fabrication, charging and measuring of individual magnets becomes difficult. This difficulty can be circumvent by using multi-period PPM structure [2] or by single permanent magnet, but achieving uniform focusing field for avoiding beam interception is difficult with multi period PPM or by single permanent magnet. For a high gain TWT, uniform magnetic field is required over a greater interaction length.

In this paper, two different approaches of transverse focusing structure [3] has been described, where uniform magnetic field is achieved over a longer interaction length by shifting the corresponding magnets in the direction transverse to the beam axis, which we call as transverse focusing structure. This way of aligning the magnets helps in correcting the dip in the shape of the axial magnetic field that arises when using multi period PPM or single permanent magnet. Also the results obtained from simulation carried out using CST Studio for the two transverse magnetic field approaches are compared.

## II THE DESIGN METHODOLOGY

The beam optics design has been carried out for a 40W TWT operating at 94 GHz and a bandwidth of 2 GHz, with a beam voltage of 9-10 kV, beam current of 30-50 mA, beam diameter of 0.35 mm and a Brillouin field of ~1000 Gauss. The magnetic focusing design was carried out for a shielded electron gun, with no magnetic field threading into the gun region. The total length of the interaction structure for this design is 14λ at 94 GHz. In a conventional single permanent magnet focusing structure, the magnets are axially magnetized as shown in Fig 1(a).

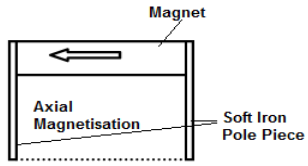

Fig. 1(a) Axial magnetization

Maintaining uniform magnetic field over the complete interaction structure is a challenging task as the structure of the magnet circuit become bulky. In order to avoid the problem, two different focusing structure designs have been proposed. Focusing structure I consist of linearly charged bar magnets, with transverse polarization as shown in Fig. 1(b) [3].

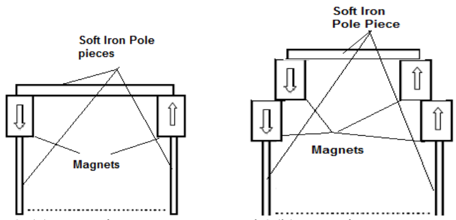

Fig. 2 (a) Focusing structure-I and 2(b)Focusing structure-II

Simulation has been carried out using commercially available CST-EM studio software which is based on finite integration method. The Retentivity ($B_r$) and Coercivity ($H_c$) values for Samarium Cobalt, $SmCO_5$ are given as 9000 G and 8500 Oe. The axial magnetic field obtained from simulation had a dip in the center of the interaction length and uniform magnetic field was not achieved even with different combinations of charging levels and dimensions of the magnets. This problem is corrected using the focusing structure II, and in this approach, transversely polarized $SmCO_5$ magnet blocks are used as shown in Figure I (c).

Simulation has been carried out, which shows that due to the extra magnets introduced within the interaction length in the focusing structure II, the axial magnetic field becomes uniform over the required interaction length. The dimensions of the bar magnets are 25 mm x 25 mm x 8 mm. The magnetic flux density within the soft iron pole piece is 1.4 T (max), which is well below the saturation limit of soft iron material (2 T).

## III Results & Discussion

Figure 3 gives the comparison of the axial magnetic field over the full interaction length of 14λ for both the focusing structure I and II. The axial magnetic field obtained using focusing structure I is uniform as compared to that obtained using focusing structure II. The dip in the axial magnetic field seen in the figure for the focusing structure I is eliminated by introducing the extra magnets as per focusing structure II. The design of focusing structure II has been found to be the optimum design and hence it is adopted.

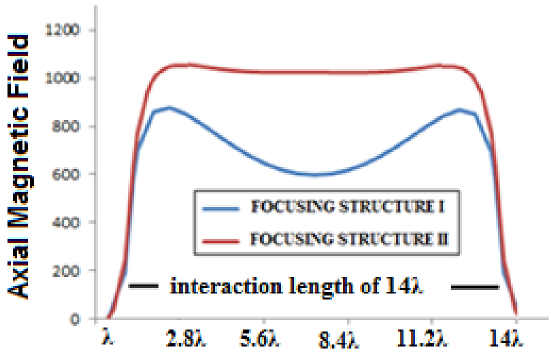


**Fig 3** Axial magnetic field for focusing structure I & II

## IV Conclusion

In this paper, two different types of focusing structure using transverse magnetic focusing are presented. The axial magnetic field obtained from simulation for the two structures are compared and the results are analysed.

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## Bio Data of Authors

Mita Jana received her B.E. degree from REC Durgapur in CSE in 2000 and received her M.Tech. degree from IIT Madras in 2008 in CSE. She is presently working as Scientist ‘D’ in Microwave Tube R & D Centre. Her area of work includes design of PPM focusing for Helix, Coupled Cavity. And Millimetric wave TWTs, design of depressed Collector for efficiency enhancement of TWT. Her present area of interest include computational Electromagnetics

Latha Christie is presently Scientist ‘G’ & Associate Director in Microwave Tubes R & D Centre. She received her Ph.D. (Engg) and MSc (Engg.) from Indian Institute of Science, Bangalore in 2007 and 2001 respectively and BE (Hons) from GCE, Tamilnadu in 1986. She has a technical book and around 40 publications in International journals and conferences. Her research interests are in the field of Microwave Engineering, Traveling wave Tubes and Computational Electromagnetics.

Deepu Augustin is presently working as TO ‘B in MTRDC. He graduated in Electronics and Communication from the Institute of Engineers, India, 2007. His area of interest includes high power TWTs, high voltage power supply maintenance and solid modeling of various sub assemblies of TWT.