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High Power Magnetron

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ABSTRACT: This paper presents electromagnetic arrangement of coaxial-cavity for high power X-band coaxial magnetron. The primary dimensions of cavity have been controlled by settling otherworldly condition using graphical procedure. The Eigen mode simulation has been finished by using CST MW Studio. It is found that TE011 mode occurs at 9.3 GHz. Yield coupler of cavity is planned to dispatch RF control into WR112. Proposed setup is examined similarly as execution parameters i.e., exhausted, stacked, and outside quality factors. Circuit profitability and coupling coefficient are analyzed by changing fundamental geometrical parameters. Unloaded Q factor of 13108 is cultivated for circuit efficiency of 93%. CAD design of millimeter wave magnetrons working in a non-7r mode calls for self-consistent numerical simulation of the electron dynamics. For a design examination of the opened roundabout coaxial depressions utilized in these magnetrons, complete arrangements of Eigen modes, thunderous just as irrational, must be figured. The Generalized Spectral Domain (GSD) strategy gives a quick and precise intend to compute the eigenvalues of these modes and to examine their modular field circulations. Results for a common millimeter wave magnetron depression are introduced

KEYWORDS*:* Coaxial Cavity, Coaxial Magnetron, Linear Accelerator, Output Coupler

I. INTRODUCTION

Magnetron, a vacuum tube microwave oscillator has been searched for after since World War II. Notwithstanding the way that, being one of the most youthful individual from microwave tube family, the transcendence of magnetron is immaculate as it has applications in different areas i.e., radars, stoves, present day warming, microwave sputtering, and direct restoring experts (LINACs). LINACs are exhaustively utilized in remedial, payload reviewing, and molecule research applications. LINACs produce high centrality X-columns, utilized in radiotherapy. High hugeness X-bars are fit for obliterating destructive improvement tumors. An enormous flood is found in the zone of hurtful advancement divulgence in making nations e.g., India, tolling around a million disease patients reliably[1].
For this situation, helpful LINACs are required to be insignificant and financially sharp. LINACs require microwave tube as a RF source to resuscitate electron shaft. Accordingly, magnetron is basic for remedial LINAC applications as it is famous for irrelevant effort, high productivity, and constrained structure. To and fro development take a gander at is proceeding to make X-band LINACs preservationist and light weight. This sort of LINAC system requires high force RF source at 9.3 GHz. However high force magnetrons in lower rehash social affairs (L-band, S-band) have been spoken to recorded as a printed copy and currently accessible (MG5125X e2v tech.), in X-band, magnetron giving essentially up to 1.5 MW top force is monetarily open (VMX3095 cpi). Taking everything into account, X-band magnetrons use WR90 or WR112 standard rectangular aides in yield partition. Nitrogen (N2) or sulfur hexafluoride (SF6) gases at high weight are utilized to improve the force overseeing purpose of restriction of waveguides for working in high pinnacle control (in MWs)[2].
Coaxial magnetrons are bolstered in high rehash goes when showed up distinctively according to standard magnetrons. Coaxial magnetron was made to beat the regulations of common magnetron to the degree execution, for example, yield control and working recurrent band. If there should arise an occurrence of standard pit magnetron, estimations, diminishing at high working frequencies acknowledges low quality factor (Q). In addition, tying manufactures RF mishaps correspondingly as breakdown at high rehash go in standard magnetrons. Coaxial magnetron doesn't require

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tying. External hole with high Q is in like manner comfortable coaxially with anode misery in coaxial magnetron. Beginning late, increase of X-band coaxial magnetron has been spoken to recorded as a printed copy[3].

II. DESIGN AND EIGENMODE SIMULATION OF CAVITY

A. Determination of Design Parameters of Cavity

Coaxial pit should essentially be expected for TE011 mode action as this mode has high essentialness accumulating. Azimuthally electric field is accessible in TE011 mode which gets generally outrageous in the inside and vanishes at the interior and outer dividers of coaxial sorrow. Anode pit structure lies inside the proposed coaxial sorrow. Course of the electric field will be same in coaxial gap as in the working π-technique for the substitute resonator of the anode hole. Disguise of the undesired strategies for the coaxial discouragement should be conceivable viably by putting attenuator. TE011 similarly makes mechanical tuning trustworthy.

A cut point of view on coaxial pit is showed up in Fig. 1. A coaxial wretchedness has three estimations i.e., internal compass (an), outside range (b), and length (l). Coaxial despondency can be surrounded by shorting the two pieces of the deals line[4]–[6]. Length (l) of the cavity can be constrained by entire number several of half frequency of the guided wave as:

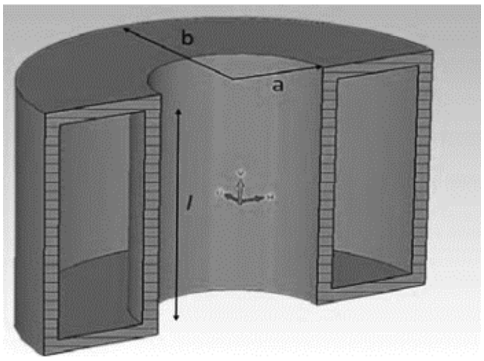

Fig. 1. Axial Cut View of the Proposed Coaxial Cavity

$$l = m\,(\lambda_g/2), \qquad (1)$$

Where m = 1, 2, 3... Additionally, λ_g is guided frequency as demonstrated by repeat at which magnetron is working and which is more significant than the cut-off repeat of coaxial line. In proposed structure, m is picked as 1 to help needed TE011 mode. Cut-off repeat and working repeat are picked as 8.6 GHz and 9.3 GHz, independently. For TE mode, azimuthal piece of electric field can be gotten from the wave condition conveyed in barrel molded sorts out as

$$E_\varphi = j\omega\mu/k_c\,(A\sin(n\varphi) + B\cos(n\varphi))(CJ'_n(k_c\rho) + DY'_n(k_c\rho))\exp(-j\,(2\pi/\lambda_g)\,z), \qquad (2)$$

where A, B, C, D are self-assertive constants. In the event of coaxial line, $a \le \rho \le b$. Subsequent to applying limit condition ($E_\varphi(\rho, \varphi, z)=0$ for $\rho = a, b$) in (2), after relations are gotten as

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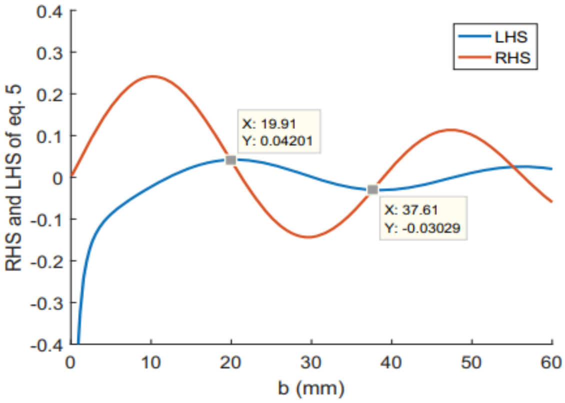

Fig. 2.Graphical Solution of Outer Radius (b) (mm) from.

CJ' n (kca) + DY' n(kca)=0, (3) CJ n(kcb) + DY n(kcb)=0. (4)

Here, n is an entire number and addresses mode number. Jn(.) and Yn(.) are nth-demand Bessel elements of the first and second kind, independently. J n(.) and Y n(.) are first auxiliaries of Bessel's ability. Solicitation of Bessel work is picked as 0 for TE011 mode. kc and λg address spread steady and guided frequency, independently. Non-negligible plan of (3) and (4) exists, specifically if J n(kca)Y n(kcb) = J n(kcb)Y n(kca). (5) Equation (5) is a powerful trademark condition for TE technique for coaxial line. Heavenly conditions can be handled by numerical systems which are extremely cumbersome. Right now, internal range (an) is considered as known parameter, since it is the outside breadth of the anode cell and simply cloud parameter is outer range (b). Internal range (an) is picked by anode melancholy and is taken as 19.91 mm for reference. Graphical approach is useful for this sort of course of action. Game plan can be directed by the intersection purpose of LHS and RHS plot of (5) as showed up in Fig. (2). First union point is the irrelevant plan when the two radii are same. Needed plan is settled as 37.61 mm (outer range) from the ensuing intersection point as depicted in Fig. 2. All the arrangement parameters of the downturn have been settled.

B. Eigenmode Simulation of Cavity:

Considering the estimations got in past measurement, reenactment model is exhibited as showed up in Fig. 1 using CST MWS. Copper is picked as the material thing. Eigenmode solver is used to deliver Eigenmode of any full structure from lower resonation repeat to higher resonation repeat. Needed mode can be settled reliant on electric field and appealing field structures. Electric field vector plot of TE011 mode has been showed up in Fig. 3. It shows electric fields are azimuthally present and which is generally outrageous at the inside and vanishes at the metallic surfaces as needed TE011 mode occurs at 9.3011 GHz[7]–[9].

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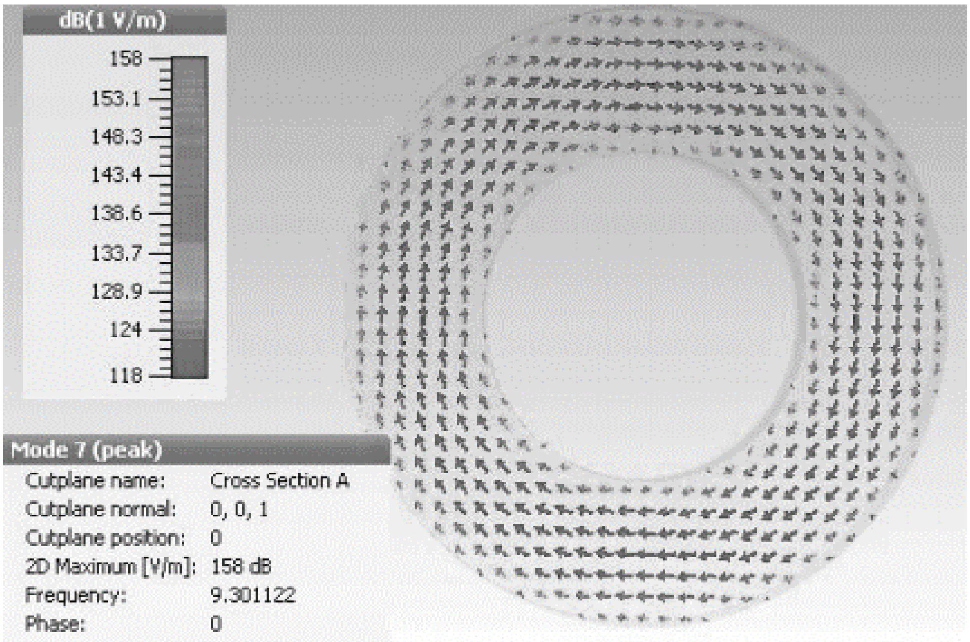

Fig. 3. Electric Field Vector Plot of TE011 Mode of Proposed Coaxial Cavity

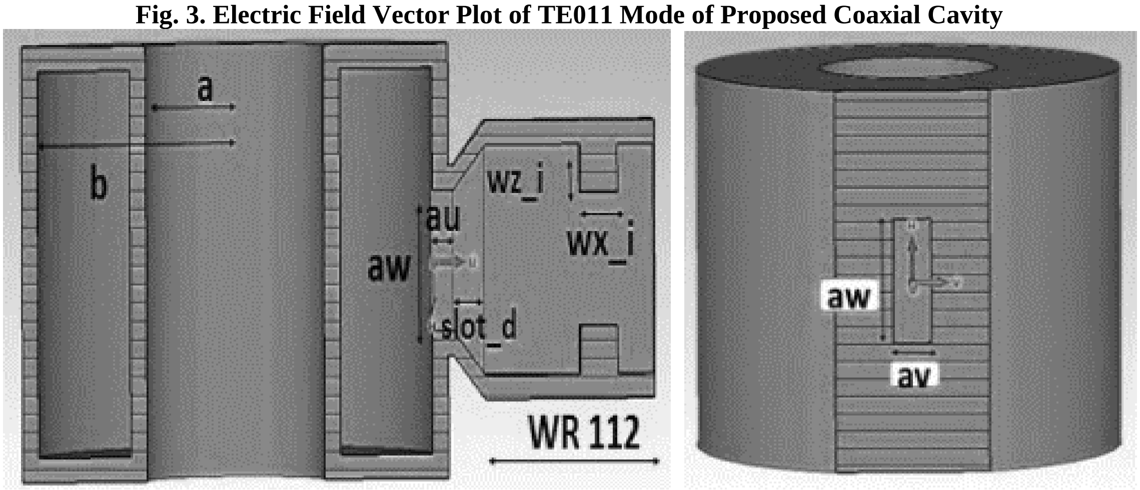

Fig. 4. Design of Output Section of Coaxial Cavity

III. DESIGN OF OUTPUT COUPLING SECTION

Coaxial gap is used to store RF control, created from anode resonators of the magnetron. This force is moreover taken out from the coaxial misery through standard transmission line for needed applications. Right now, is taken from the coaxial pit through rectangular space into the standard WR112 rectangular waveguide. Waveguide is joined with the coaxial discouragement by methods for rectangular space as depicted in Fig. 4. aw and av are the length and width of the opening, exclusively. Yield coupling ought to be arranged in such a plan right now, it can invigorate winning TE011 mode in WR112 from TE011 technique for coaxial melancholy. In order to facilitate impedance, diminishing is familiar with partner opening and waveguide. Diminishing length is given by opening d parameter. In proposed structure, electric coupling is used. Opening coupling is introduced as opposed to circle coupling which is used in customary magnetrons. The electric field quality is higher than the alluring field near the yield opening in TE011 mode.

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Thusly, electric coupling gives capable coupling. Further, excitation of needed mode in circle coupling is difficult to make sense of it.

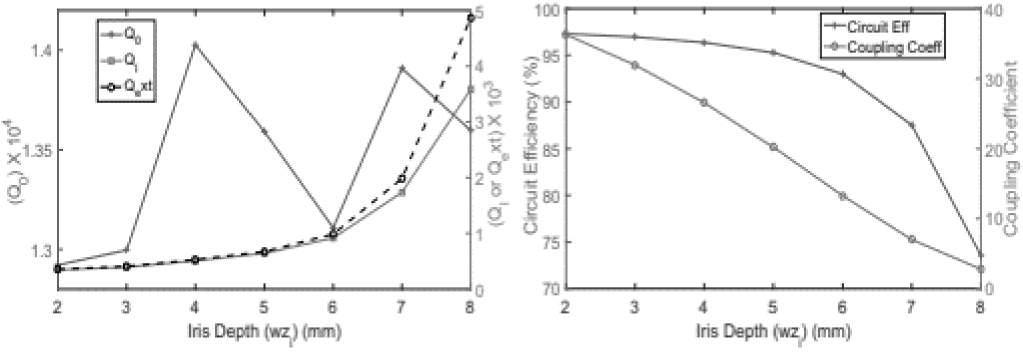

Fig. 5.Performance Analysis with Iris Depth (wzi) Variation.

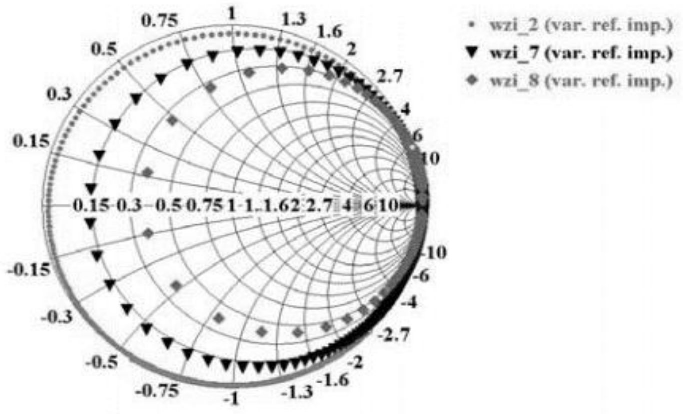

Fig. 6. Variation of S11 Iris Depth on Impedance Smith Chart

Coupling can be requested into under coupling, essential coupling, and over coupling reliant on the advantage of coupling coefficient (β). Coupling coefficient (β) can be portrayed with respect to purged and outside Q factors (Q0, Qext) as: β = Q0 Qext . Further, β is related to V SWR as seeks after from (6)

$$VSWR = \begin{cases} 1/\beta & \text{for under coupling} \\ 1 & \text{for critical coupling} \\ \beta & \text{for over coupling.} \end{cases} \quad (6)$$

Over coupling (β > 1) is needed for magnetron applications as high β prompts incredible factor (Q). To obtain needed impedance planning among wretchedness and waveguide, inductive sort iris is introduced in WR112 as showed up in Fig. 4. Significance of the iris is wz I and width of the iris is wx I as showed up in Fig. 4.

A. Performance Analysis

Execution of coaxial hole is bankrupt down in regards to Q factors (e.g., Q0, Ql, and Qext), circuit profitability (ηc), and β. Effects of the assortments of essential geometrical parameters for instance iris significance (wz I), space width

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(av), opening length (aw), opening thickness (au), and abatement length (space d) are considered. Execution parameters are dictated by S-parameter (S11) and using (7) and (8) as

$Q_l = Q_0/(1 + \beta)$, (7)

$Q_l = f_r/(f_+ - f_-)$, (8)

where β = Q0 Qext and fr is thunderous recurrence of TE011 mode. f+ and f− are upper and lower 3 dB frequencies, individually.

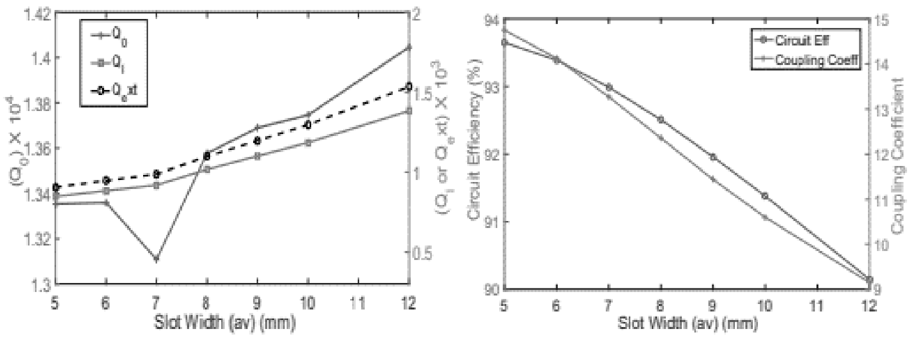

Fig. 7.Performance Analysis with Slot Width (av) Variation.

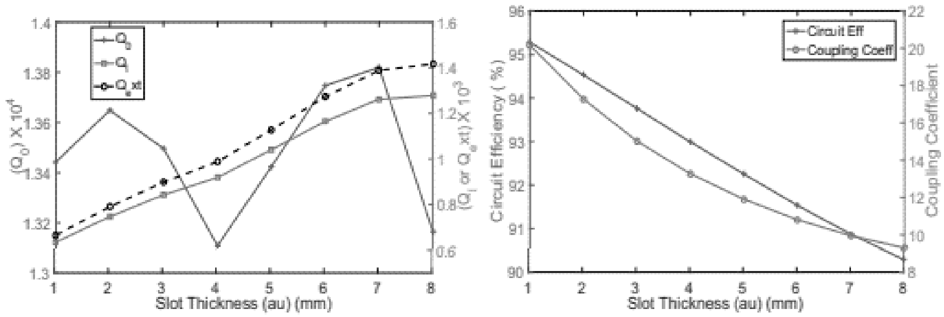

Fig. 8.Performance Analysis with Slot Thickness (au) Variation.

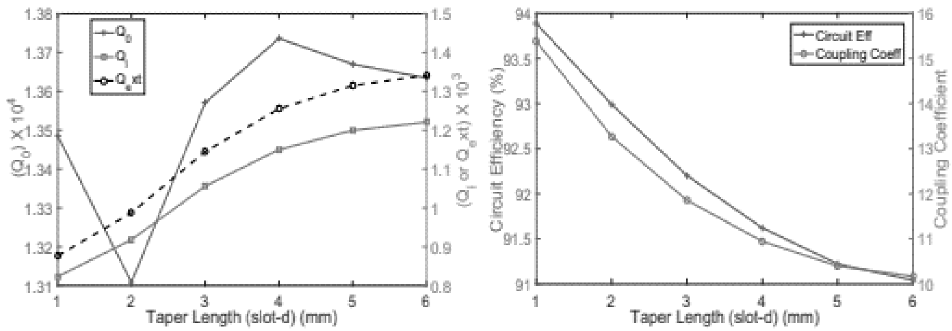

Fig. 9. Performance Analysis with Taper Length (slot d) Variation

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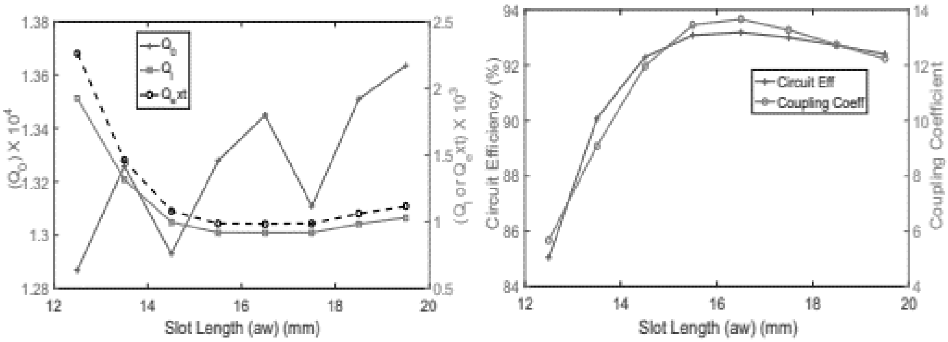

Fig. 10. Performance Analysis with Slot Length (aw) Variation

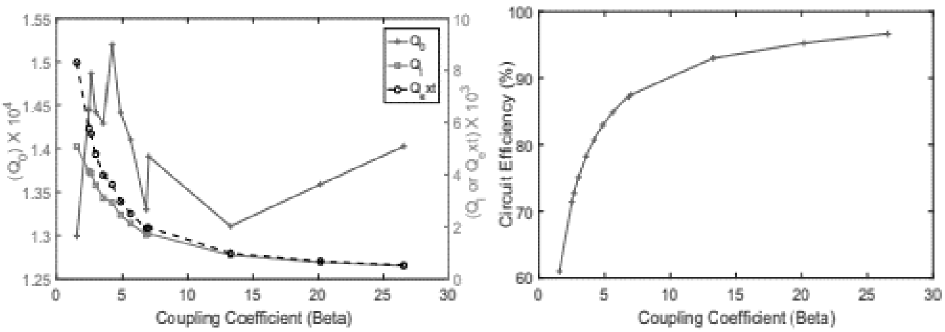

Fig. 11. Performance Analysis with Coupling Coefficient (β) Variation

In Fig. 5, it is shown that iris significance increases with reducing circuit capability as coupling lessens. This is in like manner evident from smith diagram in Fig. 6, as wz I assembles plot shifts from over coupling towards fundamental coupling (experiences point of convergence of layout in essential coupling). Iris significance also impacts Q-factors. Stacked Q factor (Ql) and external Q factor (Qext) increases with the significance of iris.

Parameters av, au, and space d are impacting execution along these lines as the iris significance, as showed up in Fig. 7, 8, 9. The lead of room length differs this example. Circuit efficiency increases and gets submerged as space length (aw) increases, as depicted in Fig. 10. Stacked and outside Q initially lessens and a while later gets steady with the expansion in opening length as in TE011 mode, there exists only a solitary half frequency assortment of electric field along the cavity length. Most extraordinary electric field quality occurs at the focal point of opening where rectangular space has been cut as showed up in y-z find in Fig. 4(b). This electric field a tiny bit at a time reduces and vanishes at the top and base dividers of the cavity. Electric field quality gets decayed with the ultimate objective that it doesn't impact coupling and β gets drenched past a particular length[10].

Execution assessment is furthermore finished with the assortment of β as showed up in Fig. 11. ηc increases with β considering the way that coupling gets more grounded. Stacked and external Q in like manner diminishes with the development in β. Propositions results furthermore seek after relations yielded (7), checking the reenactment results.

Purged Q factor (Q0) shows self-assertive lead with the 1.25 1.3 1.35 1.4 1.45 1.5 1.55 (Q0) X 104 0 2 4 6 8 10 (Ql or Qext) X 103 Q0 QlQext 0 5 10 15 20 25 30 Coupling Coefficient (Beta) 60 70 80 90 100 Circuit Efficiency (%) 0 5 10 15 20 25 30 Coupling Coefficient (Beta) Fig. 11. Execution examination with coupling coefficient (β) assortment. Assortment of structure parameters, moving from 12000 to 14000 which is valuable for a coaxial opening oscillator. Circuit efficiency (ηc = QlQext) cannot be acknowledged astoundingly high as in coaxial magnetron some proportion of power is in like manner required for proceeding with movements. For magnetrons, ordinary ηc is 86% [5]. Nevertheless, since anode subsystem isn't considered here, the system is progressed for higher ηc to save stipend for the reduction of ηc in view of joining of anode. Yield coupling zone has been arranged reliant on the show assessment.

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Propelled execution is picked as: Q0 as 13108, Ql as 918, Qext as 987, ηc as 93%, β as 13.27 for plan parameters as au is considered as 4 mm, av as 7 mm, aw as 17.5 mm, space d as 2 mm, and wz I as 6 mm.

It may be seen that right now, fundamental system for improving a coaxial gap is shown and the perfect characteristics reported here are without considering the anode get together. To improving the whole magnetron system including anode, fitting alteration in plan parameters may be basic.

IV. CONCLUSION

In this examination, electromagnetic structure method of coaxial hole for high power X-band coaxial magnetron has been proposed. Eigen mode recreation of coaxial cavity is done utilizing CST MW studio. Full recurrence of wanted TE011 mode is seen as 9.3 GHz. TE011 mode is perceived by its azimuthal electric field design which is most extreme e at the center of the cavity. Yield RF control is propelled in TE011 method of the standard rectangular waveguide WR112 through rectangular opening in the coaxial hole. Decreasing and inductive sort iris are presented for impedance coordinating among depression and waveguide. Execution examination as far as Q factors, circuit effectiveness and coupling coefficient has been completed with the variety of basic geometrical parameters. Streamlined estimations of the Q0, Ql, and Qext for 93% circuit proficiency are acquired as 13108, 918, and 987, separately. Coupling coefficient is acquired as 13.27 which affirms the over coupling and is same as the V SWR at full recurrence. The ideal plan of the magnetron including the rest of the subsystems is being completed. Specifically, enhancement of the hole with anode subsystem present are being considered.

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