

Transmission line matching simulation for 350 MHz RF driver for 400 KeV (deuterium) RFQ based 14 MeV neutron source

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Introduction

A 60 KW, 350 MHz tetrode based high power RF system is being developed for 400 KeV RFQ based 14 MeV neutron generator in BARC to study physics of coupled neutron sources and subcritical assembly. This RF system requires a 2.5 kW RF driver which is being designed by using tetrode TH-393[1]. At such high frequency i.e. 350 MHz, lumped components are not practically useful due to radiation losses. Therefore, techniques such as coaxial line with stub tuning [2] are preferred, which minimizes these losses. Simulation of two such stub tuning based matched coaxial lines at the input and output of the tube has been done by using CST studio [4]. CST STUDIO is a special tool for the 3D EM simulation of high frequency components.

Coaxial transmission line with stub tuning

For a coaxial transmission line with outer diameter ‘b’ and inner diameter ‘a’ the characteristic impedance [2] is given as

$$Z_0 = 138 \log_{10} (b/a) \text{ ----- (i)}$$

A stub [2] consists of a side section of line attached in series or shunt with the main coaxial line, at a point where it cancels the reactance part of the line to match it to 50 Ω load. This is shown in Fig 1. Here coaxial shunt shorted stub is used for matching.

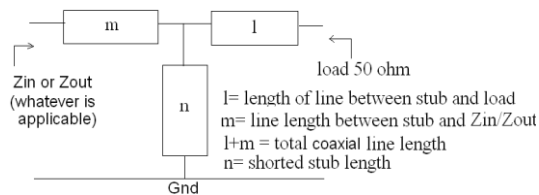


Fig 1. Coaxial line with shunt shorted stub

Calculations of input and output impedances of TH 393 tube

The datasheet of TH 393[1] shows that C_{in} of tube is 117 pF. Considering the effect of stray capacitance (say, 5 pF) effective $C_{in} = 117 + 5 = 122$ pF. Similarly, effective $C_{out} = 10$ pF.

The tube is assumed to operate in class B. From constant current graph of TH 393 [1] and Eimac computer calculations [3], peak anode current $i_p = 4.8$ A, instantaneous anode voltage $E_a = 4$ kV, instantaneous grid voltage $E_g = -140$ V, fundamental anode current $I_a = 1.91$ A, input resistance $R_{in} = 73.298 \Omega$ and output resistance $R_{out} = 2.094$ kΩ. The equivalent input and output impedances of the tube are:

$$Z_{in} = 73.298 \Omega // 122 \text{ pF} = 0.18 - j 3.723 \Omega \text{ ---- (ii)}$$

$$Z_{out} = 2.094 \text{ k}\Omega // 10 \text{ pF} = 0.86 - j 45.46 \Omega \text{ ---- (iii)}$$

These impedances are to be matched to 50 Ω each to get the maximum power transfer.

Simulation of input matching line

To avoid voltage break down between coaxial conductors and provide better cooling, Z_0 of the matching line is chosen to be 20 Ω [5]. From eq (i) $b/a = 1.4$. Accordingly, ‘a’ and ‘b’ are chosen as 80 mm and 112 mm respectively for input coaxial line.

Using these values, the simulation was done in MIMP and CST studio [4] softwares. Comparison of the resultant parameters ‘l’, ‘m’, ‘n’ (defined in Fig 1) found by using both the softwares is given in Table 1.

Table 1

Parameters (mm)		l	m	n
Input	CST	257.8	468.4	449.3
	MIMP	434.6	433.3	447.6
Output	CST	454.6	535.4	512.2
	MIMP	454.3	569.6	446.6

The resultant values of these parameters were not practically feasible to fabricate, so a length of $\lambda/2$ was added to get practical values. According to microwave theory [2], addition of $\lambda/2$ doesn't affect the impedance of the line. For 350 MHz, $\lambda/2$ is 428.57 mm.

The designed matching network in CST studio is shown in Fig 2. Initially the line model was designed in Microwave studio and then with the help of Design studio final simulation was done. For perfect matching, it is desirable to get a return loss [2] of at least -30 dB. To achieve this, 'optimization' [4] tool of the CST software was used.

As shown in Fig 2, at port 1 of the line Z_{in} (eq (ii)) is taken and port 2 is terminated by 50 Ω . The line section of length 'n' represents the shorted stub.

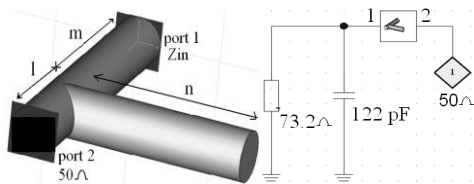


Fig 2. Input matching line using CST studio

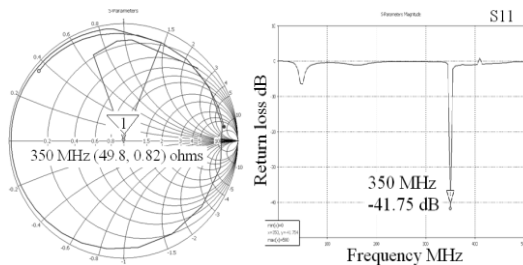


Fig 3. Smith chart

Fig 4. Return loss

The result of the simulation is shown in Fig 3 and Fig 4. Fig 3 gives the smith chart [2], which shows that perfect matching of nearly 50 Ω ($49.8 + j0.82$) has been achieved at 350 MHz. The return loss for the matching network comes out to be -41 dB (as seen in fig 4).

Simulation of output matching line

For output matching, 'a' and 'b' of the line are taken as 100mm and 140 mm respectively (from eq (i), for $Z_o = 20 \Omega$). The simulated

values in MIMP and CST studio are given in Table 1. Simulation of output matching in CST [4] is done in a similar manner as input matching described previously. Its schematic is shown in fig 5. Here, at port 2 Z_{out} (eq (ii)) is used and port 1 is terminated in 50 Ω . Fig 6 shows the smith chart with matching of $47.25 - j0.32 \Omega$ and Fig 7 shows the return loss of -29.25 dB at 350 MHz, obtained as a result of simulation.

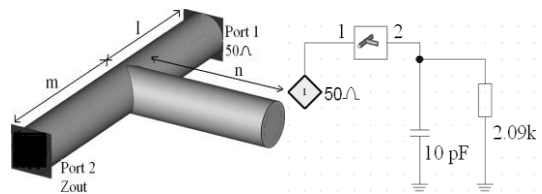


Fig 5. Output matching line using CST studio

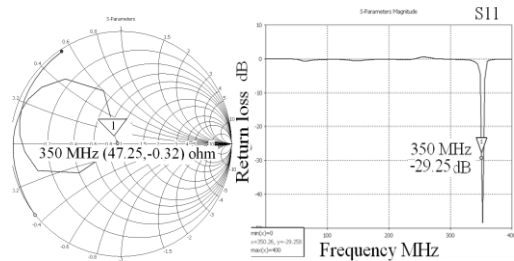


Fig 6. Smith chart

Fig 7. Return loss

Conclusion

Simulation for input and output matching network using coaxial line with stub matching has been carried out successfully with expected satisfactory results. The design is under consideration for its practical implementation.

References

- [1] "TH 393" datasheet provided by Thomson tube electronics.
- [2] "Microwave Engineering", by David Pozar.
- [3] Section 2 & 3, Care and Feeding of power grid tubes, 5th edition, CPI, EIMAC division
- [4] CST studio suite 2006, examples of Microwave studio and design studio.
- [5] "Design and testing of 200 kW/91.2 MHz RF amplifier" by Raghuraj singh, *et al.* in Science Direct, fusion Engineering and Design 82 (2007), pages 853-859.