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DESIGN OF BEAM POSITION MONITORING SYSTEM FOR IPM LOW ENERGY ELECTRON LINAC

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Abstract

The Beam Position Monitors (BPM) are devices that can be used in every accelerator to provide information on the position of the beam. This paper reports the simulation and design of a re-entrant cavity BPM with its associated electronics to be used for IPM low energy electron Linac being developed at Institute for Research in Fundamental Sciences. The fabrication of some electronic components was also carried out.

INTRODUCTION

A Cavity Beam Position Monitor (CBPM) is a device composed of two pickup cavities and a detection circuit to read out the position of the beam. The cavity pickup will sense the mode strength generated by the passing beam of electrons. The working modes are TM110 (dipole) for the so called position cavity and TM010 (monopole) for the reference cavity. When the beam crosses the cavity gaps it induces signals proportional to charge and position offset in the position cavity, and to the charge only in the reference cavity. The position cavity has four rectangular waveguides that couple to the dipole mode while rejecting the monopole mode that would otherwise limit the resolution of the electronics [1].

This signal will be input to a detection circuit that is be used to calculate the signals detected by four antennas arranged. A 180 degree hybrid at the first stage reduce the monopole and a heterodyne receiver principle was used to down-convert the signal frequency in about MHz IF frequency. These signals can then be used to determine the beam's displacement from the centre [2].

The IPM low energy electron Linac is operating at a 7 µsec pulse duration and 250 Hz repetition rate with 2998 MHz bunching frequency and 4.5 MeV beam energy. A 8-MeV electron beam is available in the second phase of commissioning [3].

CAVITY SIMULATION

The reference and position cavity was simulated using the Eigenmode Solver of CST software at operation frequency of 2998 MHz. The reference cavity (see Fig. 1) is designed as a re-entrant construction and position cavity (see Fig. 2) with waveguide arrangements.

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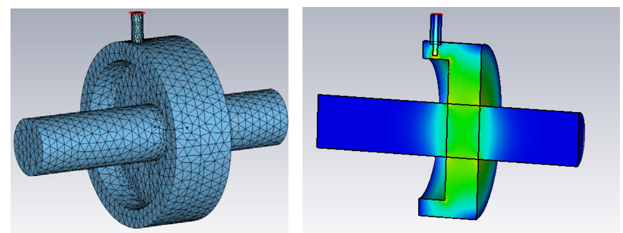
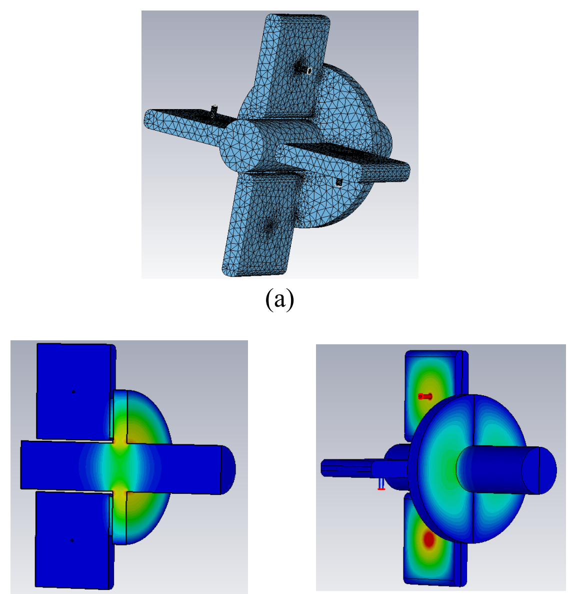


(a) (b)

Figure 1: Reference cavity: (a) mesh cell (b) monopole field.



(a)

(b) (c)

Figure 2: Position cavity: (a) mesh cell (b) monopole field (c) dipole mode.

ELECTRONICS

Simulations of the super heterodyne receiver were performed in ADS software (see Fig. 3) and the signal changes were investigated in each stages. The practical examples of several required elements including hybrid and high frequency passband filters with the Fr4 substrate for this receiver were designed, constructed and measured using ADS, CST and AWR software.

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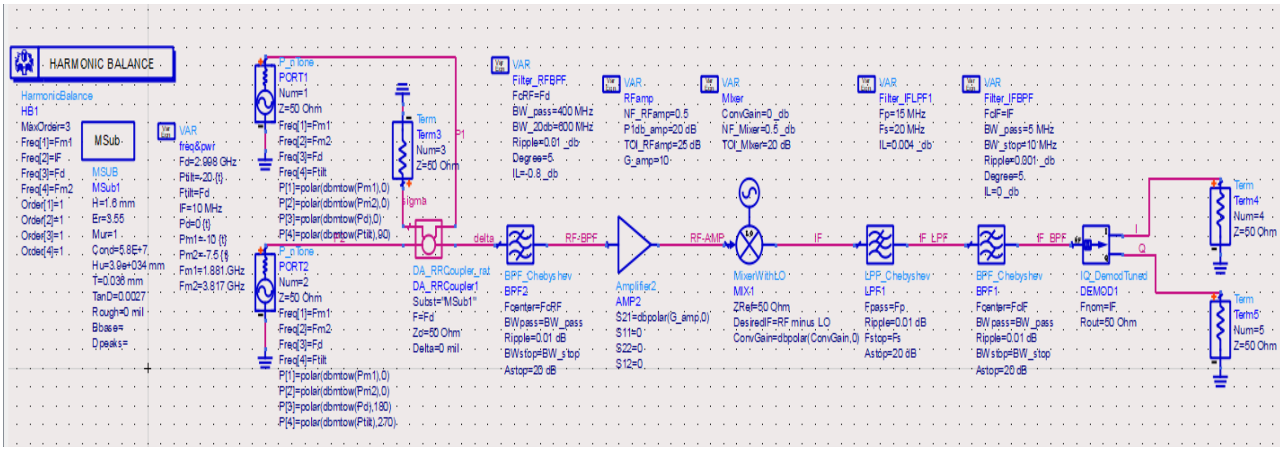

Figure 3: Super heterodyne simulation in ADS.

180 Degree Hybrid

A 180 degree hybrid, also known as Ratrace, is a four-port network that can be used as a microwave divider or combiner. In Fig. 4, the overall schema of this element and Eq. (1) its dispersion matrix has been shown [4]. The simulation of this element is carried out in ADS and CST software and simulated models are shown in Fig. 5, respectively. The prototype measurement fabricated on the fiberglass substrate, is shown in Fig. 6. Simulations and optimizations are at a frequency of 2998 MHz.

$$[S] = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & +1 & +1 & 0 \\ +1 & 0 & 0 & -1 \\ +1 & 0 & 0 & +1 \\ 0 & -1 & +1 & 0 \end{bmatrix} \quad (1)$$

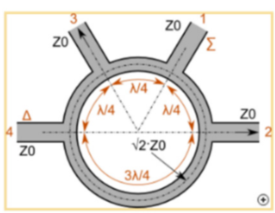

Figure 4: Constructional details of 180 degree hybrid.

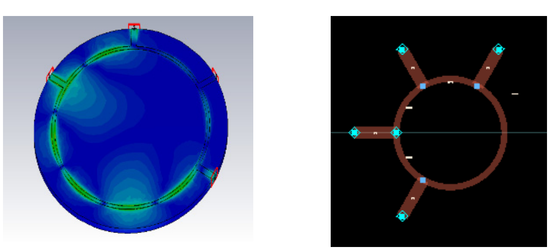
(a) (b)

Figure 5: Layout in (a) CST (b) ADS software.

Hybrid sensitivity to parameter changes was investigated. It can be seen that in given range, the loss tangent can affect the output severely. Therefore, in accurate and sensitive measurements, the use of a better substrate with more precise parameters such as Rogers, construction can have a better result. Phase imbalance will vary with a radius of a tenth of a millimetre. In the whole the states of isolation remain a good value.

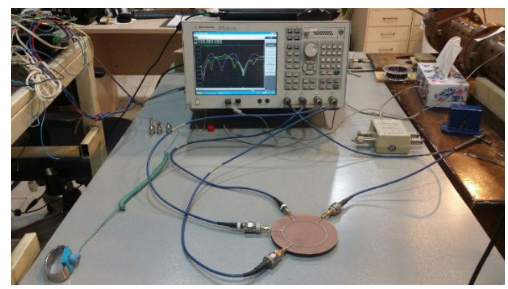
Figure 6: Parameter measurement of hybrid.

The values of the scattering parameter of the two output ports of the simulation and the measured values are shown in Table 1 and graphs are in Fig. 7.

Table 1: Simulation and Measured Parameter at 2998 MHz

S-param	simulation	measured
S_{11}	-42.95	-35.42
S_{12}	-36.66	-28.81
S_{13}	-4.03	-4.39
S_{14}	-3.78	-4.60

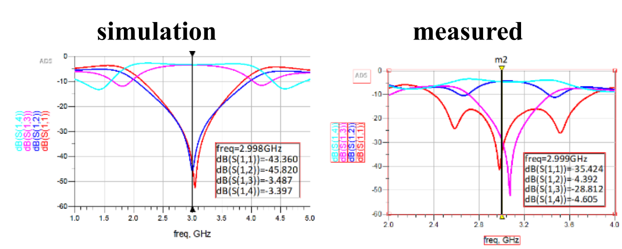

Figure 7: Characterization results of scattering parameter magnitudes.

Filter

In the design of the band pass filter, two types of hairpin and edge-couple were performed (see Fig. 8). A 0.001 dB ripple Chebyshev with centre frequency of 2998 MHz were

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chosen for both. A third order 300 MHz BW for edge-couple and a seventh order 500 MHz BW for hairpin type [5].

The hairpin type is better for its band stop attenuation and the edge couple types are better for their insertion loss or noise factor.

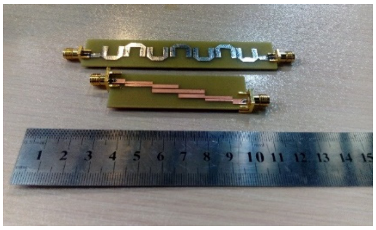

Figure 8: Fabricated filters on 1.6 mm FR4 substrate.

Table 2 shows return loss and insertion loss results at 2998 MHz for edge-coupled filter in ADS, AWR and CST software, and its measured value. The frequency spectrum also shown in Fig. 9.

Table 2: Results for Edge-Coupled Filter at 2998 MHz

	Return loss	Insertion loss
ADS	-25.86	-2.14
AWR	-25.04	-1.93
CST	-18.43	-3.03
measured	-23.78	-2.24

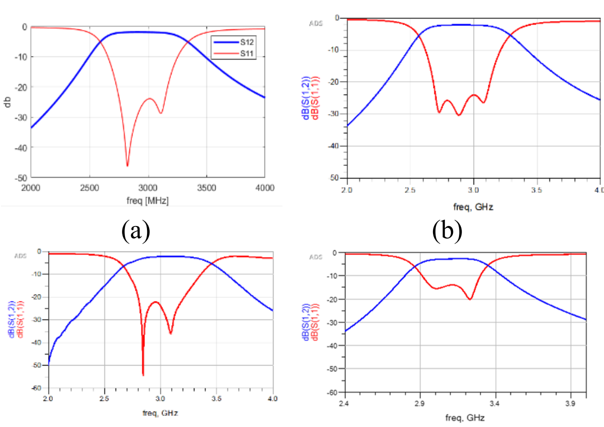

Figure 9: S-parameter results: (a) AWR (b) ADS (c) CST (d) measured.

Due to better compliance of AWR software measurement spectrum, outputs for hairpin type are shown in this software. Table 3 shows return loss and insertion loss results at 2998 MHz, and the measured value. The frequency spectrums are shown in Fig. 10.

Table 3: Results for Hairpin Filter at 2.998 MHz

	Return loss	Insertion loss
AWR	-19.35	-3.9
measured	-17.83	-5.77

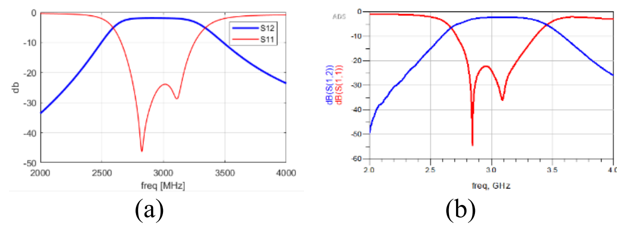

Figure 10: S-parameter results: (a) AWR (b) measured.

CONCLUSION

The IPM low energy electron Linac is operating at a 7 µsec pulse duration and 250 Hz repetition rate with 2998 MHz bunching frequency, so the designs in cavity and electronic section have been done in this frequency.

The reference and position cavity was simulated in CST software and the front end electronic in ADS.

The prototypes of some section of electronic were fabricated. Due to hybrid and waveguide filters to remove unwanted harmonic, and the importance of reducing the number of noise factor before the first amplifier in electronic stage, also due to the lack of restrictions on the physical size of the filter, the edge-coupled type was a better choice to continue the electronic implementation.

ACKNOWLEDGEMENTS

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REFERENCES

[1] P. Forck, “Lecture Notes on Beam Instrumentation and Diagnostics”, presented at Joint University Accelerator School (JUAS), ESI, Archamps, France, Jan.-Mar. 2017.

[2] S. Trummer, “Beam position monitor for electron linear accelerator”. United States Patent and No. US 2012/0262333 A1, Oct. 18 2012.

[3] H. Shaker, “Introduction to linear accelerator”, presented at Institute for Research in Fundamental Sciences School, Tehran, Iran, 2017.

[4] D. Pozar, *Microwave Engineering*, 4 Ed., New York, NY, USA: Wiley, 2011

[5] National Instruments, `https://awrcorp.com/download/faq/english/docs/Users_Guide/iFilter.htm`