Design and Development of a Novel Stripline Fast Faraday Cup to Measure Ion Beam Profile

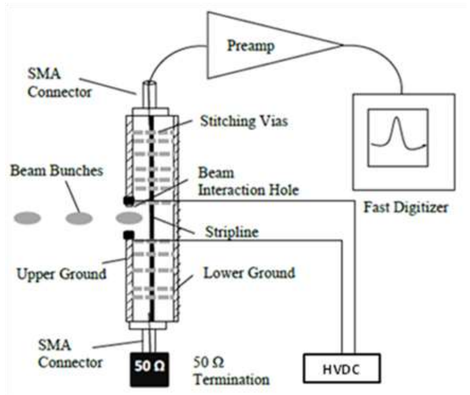
A. Sharma†*, R. K. Gangwar†, B. K. Sahu*

† Indian Institute of Technology (ISM), Dhanbad, India

** Inter-University Accelerator Centre, New Delhi, India*

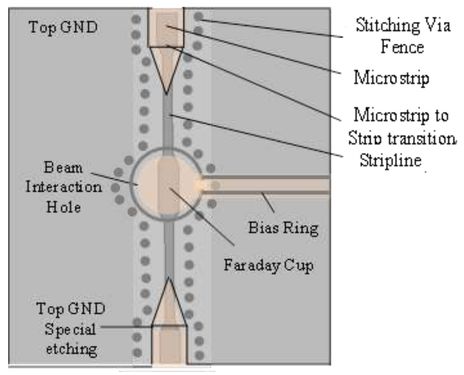
Introduction

- Determination of time structure and energy spread of a sub-nanosecond bunched beam.
- Interceptive pick-up devices: Faraday Cups.
- Fast rise time devices to capture smaller bunches : Fast Faraday Cups.
- Planar Stripline Faraday Cups : smallest yet highly broadband structures with BW > 6-10 GHz (resolve beam bunches 100-200 ps wide)
- Measurement of beam bunch widths of Pelletron or HCI accelerator of IUAC towards the Superconducting LINAC.
- Bunch widths of the order to 200 ps – 1 ns are required to be measured using the setup.

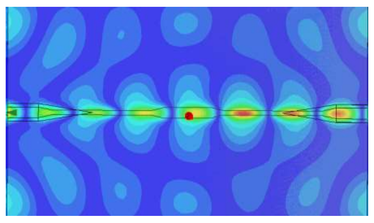


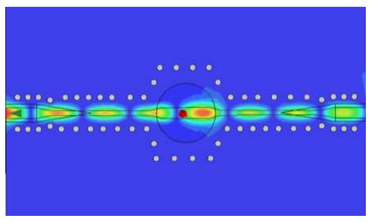
Design Details

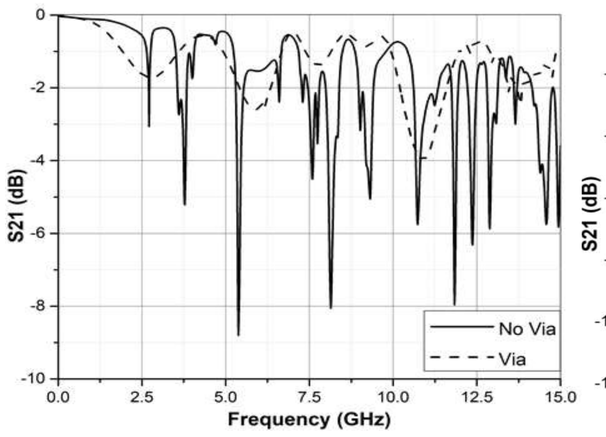
- Stacked multi-layer with 50Ω transmission line.
- *Bidirectional*, *broadband* and *50Ω* stripline structure with TEM mode of operation.
- Microstrip cut-outs at the edges for RF launch.
- Tapered transition at microstrip-to-stripline joints to provide smooth field and impedance variation.
- Bigger beam interaction hole for low current, low β beams.
- Negative Bias Ring around the hole.
- Via-fencing to suppress unwanted spurious modes and enhancing the 3 dB bandwidth.
- Standard Microstrip and Stripline Design equations used for 50Ω designs of λ/4 lengths.

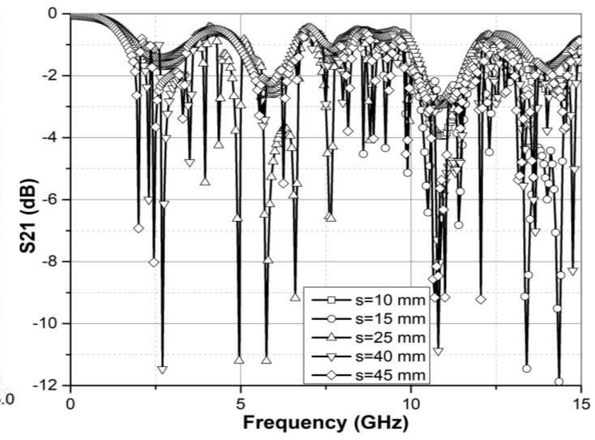


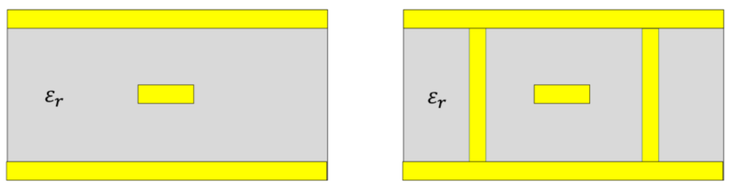
Mode Suppression: BW Enhancement







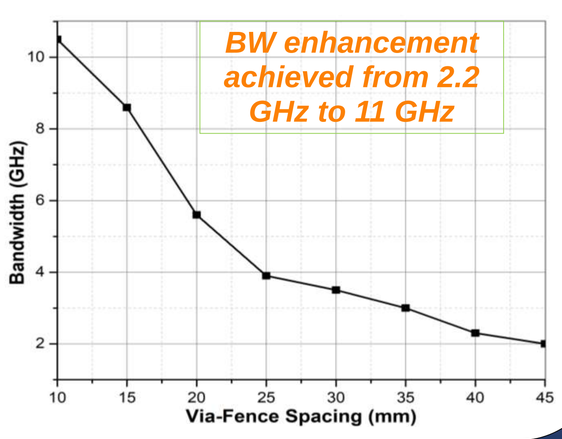




- Higher order spurious modes exists in without via.
- Scattered field plot is visible. Modes shown by |S21| > 3 dB.
- These modes behave as rectangular cavity modes governed by Eq. shown.
- Higher order modes are shifted to higher frequency with introduction of VIA.

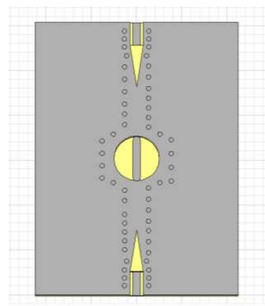
$$f_{rmn0} = \frac{c}{2\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W_g}\right)^2}$$

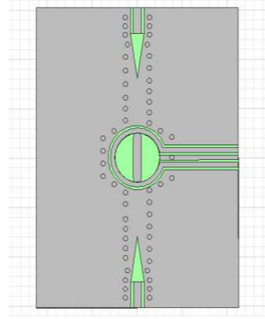
Mode	f_{rmn0}	HFSS
f_{r110}	2.2	2.66
f_{r210}	3.16	3.55
f_{r120}	3.73	3.75
f_{r310}	4.3	4.02
f_{r130}	5.29	5.365



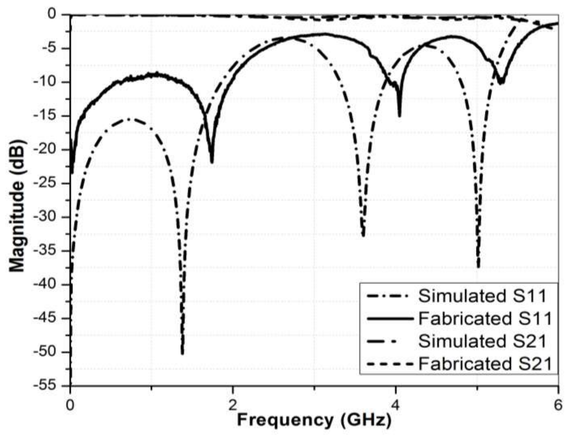
Experimental Results

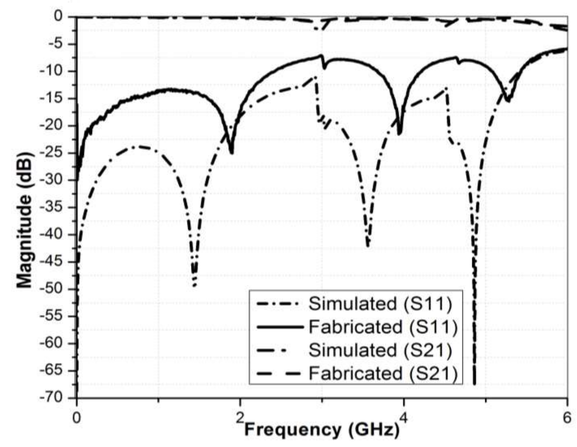
Parameter	Value
Substrate	RO4003C
Substrate 1 Dimension ***(w × l × h)***	45 mm × 60.8 mm × 0.8 mm
Substrate 2 Dimension ***(w × l × h)***	45 mm × 60.8 mm × 0.8 mm
Dielectric constant ε_r	3.55
Strip Width	0.7753 mm [50Ω]
Microstrip width	1.804 mm [50Ω]
Via Size (dia.)	1 mm
Via Pitch (< λ/8)	1 mm (variable)
Via fence spacing	5.3 mm
Beam Interaction Hole (dia.)	10 mm (upper substrate)

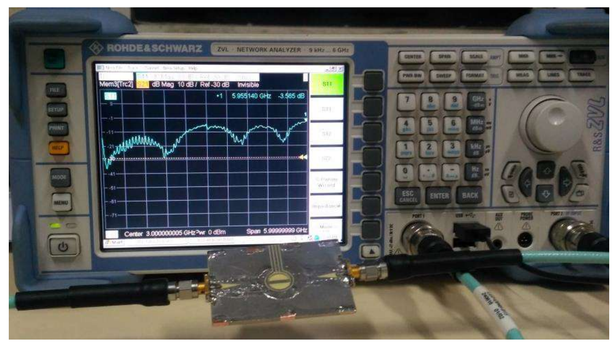




HFSS Design Parameters and Models







Conclusions

- Simulation and Measured results useful for a bandwidth of ~ 6 GHz (due to VNA bandwidth limitation)
- |S21| < ~3 dB throughout the bandwidth.
- The device can handle beam bunches with a rise time of <~60 ps. However, simulations have shown the bandwidth > 10 GHz.
- Abrupt discontinuities are observed due to co-placement of bias ring.
- The devices are ready to be mounted on the beam line to perform the measurement of 200 ps – 1 ns ion beams of IUAC SC-LINAC.

References

1. A Designer's Guide to Stripline Circuits, Microwaves, January 1978, pp. 90–96.
2. C. E. Deibele, "Fast Faraday Cup with High Bandwidth", US Patent no. 7012419B2, March 26, 2004.
3. G. Zhu et al., "Development of bunch shape monitor for high-intensity beam on the China ADS proton LINAC Injector II", Review of Scientific Instruments, vol. 89, p. 053303, 2018.
4. E. Holzman, Essentials of RF and Microwave Grounding, Artech House.
5. J. Gipprich and D. Stevens, "A New Via Fence Structure for Crosstalk Reduction in High Density Stripline Packages", IEEE MTT-S IMS Digest, vol. 3, pp 1719-1722, 2001
6. G.E. Ponchak, D. Chen, J-G Yook, L.P.B. Katehi, "Characterization of Plated Via Hole Fences for Isolation Between Stripline Circuits in LTCC Packages", IEEE MTT-S IMS Digest, vol. 3, 1998.
7. A. Sain, K.L. Melde, "Impact of Ground via Placement in Grounded Coplanar Waveguide Interconnects", IEEE Tran. On Components, Packaging And Manufacturing Technology, vol. 6, no. 1, pp. 136-144, January 2016.
8. T. Maleszka, G. Jaworski, "Broadband stripline to microstripline transition with constant impedance field matching section for applications in multilayer planar technologies," 18th Int. Conf. on Microwaves, Radar and Wireless Comm., Vilinius, 2010, pp 1-4.