Benefits of Reduced Insertion Loss for mmW Over Temperature Wafer Test

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Conventional arrangement for waveguide over temperature wafer probing

- Large heavier extenders warrant large positioners
- Probe tips at the thermal chuck and inside microchamber enclosure
- Positioners are tall meaning we used tall probes and tall waveguide S bends









Why shorten path to the probe?

- Raw directivity of system is degraded by up to 2x Insertion loss between test port and probe tip
- For T geometry probe at 330 GHz insertion loss is 2.9 dB and guide insertion loss approx. 5.8 dB (approximately double probe dB loss)
- Reflected signal from ISS Short will be attenuated by 11.6 dB compared to a directly connected probe assuming 8" path length
- Degraded directivity = Increased drift





Image shown is with T-Wave "T" geometry probe





Why is system stability important?

- Vector network analysers have systemic errors
- Calibration routines regardless of method aim to characterise these errors to produce accurate corrected data
- If systemic error changes, corrected data is no longer valid and corrected data will now have a difference between what it would have been when calibration was new.
- Reduced directivity and increase path length make instrument more sensitive to small changes in system due to environment, predominantly temperature and vibration driven
- Reduction of loss and path length should improve directivity and changes due material expansion
- The less sensitive a system is to environmental changes the less time wasted in frequent recalibration and less tendency to except data that is "reasonably" good
- Calibration standards will last much longer as less cal cycles needed







Semi-automatic – raised chuck solution



- Highest Frequency supported by our probes
- Allows probes to connect directly to extender which gives best performance
- Raising probes limits usable chuck diameter and no access to thermal chuck







Virginia Diodes Mini Modules







- ¼ Volume of standard
- Overall length varies with band slightly but cross section is the same
- No fans below 110 GHz
- Attenuator is removable if desired



Standard-Size to Mini Module size comparison



Semi-automatic, thermal – manual positioner bands from 50-330GHz





- This arrangement makes use of Tall geometry probes and small form factor of the Virginia diodes **mini modules**
- Probes connected directly to extender
- Reliant on shallow 14mm Chuck to platen height of Summit 12000
- Other stations in our ranges are deeper to improve thermal stability but which prevents use of this approach





Angled extender allows minimal path length



- Allows over temperature test with minimal loss
- Angled extender used new RF tophat designed originally to allow for short 120 GHz coaxial cables
- S Geometry probe for minimal insertion loss and very short waveguides to change angle
- Same RF tophat as used with N5291A (125 GHz coaxial)





Angled extender allows minimal path length



- Non chambered (left) and Chambered versions (right) available
- Non chambered version still capable of hot thermal measurements but has even shorter waveguide extension
- T-Wave / ACP and Infinity all supported for all implementations





Experimental performance comparison – path loss



- Setup on left has angled extenders, S Geometry T-Wave probes and Short waveguide extensions
- Setup on right has conventional Large area positioners, T Geometry T-Wave wave probes and typical extensions
- Response cal done (not full as wg shim can't be used on extender without port saver section in place)





Path loss flange to flange – using response cal



- Low frequency is around -7.5 dB insertion loss compared to -15 approx.
- Improvement of around -7.5 dB at cutoff





Load compared to short- raw absolute



COMP/SS

- The larger the separation from Load w.r.t Short the better
- Top is conventional Bottom is Angled



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Load normalised by short



GHz

- ADVANCED RAW SHORT --- ADVANCED RAW LOAD

COMP/SS

- Worst case for LAP load actually have +3.87 dB w.r.t Short
- Angled case worst case -2.53 dB
- In general around 5 dB better off



Error set repeatability – LAP left / Angled right



- 10 Calibrations done one after the other without probe movements (hence LRRM)
- In general error set resulting from LRRM has comparable differences other than outlier seen on 10th cycles



Drift improvements





- Experiment done to see if drift is better for reduce path case
- First case is Long path setup left using Tall geometry and Angled Right short geometry
- Second case is with sides swapped Angled left, Long path right
- Calibrated Open measurements taken every five minutes and normalised to first





Drift comparison - magnitude



- Heavy drift characteristics clearly follows the setup
- Both setups left overnight





Max drift at single frequency – scratch and sequence combined

by Function Editor - ScratchPad

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Expressions

1. item_name = GetString("Item_to_plot"

- 2. **This Scratchpad is here to put normalised numerical drift values into strings and ultimately create traces of drift w.r 3. **The strings are displayed on the dash of the report.
- 4. **The item to plot string contains the name of the current string to be normalised.
- 5. **This is all driven by a sequence that moves through all the named items in a drift test.
- 6. **For each position the sequence will append to a long string that has the normalised response at a single frequency.
- 7. **Once that big string has been built a new trace is generated from that string and the trace is output to the report.
- 8. **The idea is to look at phase or mag as a function of time and temperature also.
- 9. current item = GetDataset(item name) 10. **This pulls in the named trace for normalisation 11. first item = GetDataset("0 minutes") 12. **This does the normalisation of all 4 S Par 13. division[-,Matrix,Row,Column] = current item[-,Matrix,Row,Column] / first item[-,Matrix,Row,Column] 14. SaveToDataItem(division, "last divison") 15. **This outputs the normalised values only for P1 and P2 at a point. User would vary that for max drift and min drift. 16. **The value needed to vary would be the second column in the division part 17. point real imag = GetValue(division[-,240,1,1]) SaveToDataItem(point real_imag, "pl_normalised_min") 19. point real imag = GetValue(division[-,258,2,2]) SaveToDataItem(point real_imag, "p2_normalised_min") 21. point real imag = GetValue(division[-,5,1,1]) SaveToDataItem(point real_imag, "p1_normalised_max")
- 23. point real_imag = GetValue(division[-,17,2,2]) 24. SaveToDataItem(point real_imag, " normalised 25. 26. *Everything below here disable when the sequence runs. 27. *In additoin all S par trace should be disabled so update is

28. *Enable after sequence to generate S par trace

37. SaveToDataItem(drift at single, "Drift Min P1")

39. SaveToDataItem(drift at single, "Drift Min P2")

41. SaveToDataItem(drift at single, "Drift Max P1")

43. SaveToDataItem(drift at single, "Drift Max P2")

35. **New traces are saved to the report

- alues only for P1 and e the second colu bn[-,240,1,1]) зi of normalised min" sion[-,258,2,2]) 29. drift_string_min_p1 = GetString("drift_string_min_p1") 30. drift_string_min_p2 = GetString("drift_string_min_p2") 31. drift_string_max_p1 = GetString("drift_string_max_p1") b2 normalised min" 32. drift_string_max_p2 = GetString("drift_string_max_p2") 33. **This gets enabled at the end to improve speed but can be le 34. **This part creates new traces based on the drift strings bn[-.5.1.1]) 36. drift at single = TraceNewFromString(drift string min p1) normalised mak" 38. drift at single = TraceNewFromString(drift string min p2) .17.2.2]) 31 bn [-40. drift at single = TraceNewFromString(drift string max p1) 42. drift at single = TraceNewFromString(drift string max p2) · · · 🏂 📆 | 🌫 🔚 🚛 | % 📄 🖺 | 🌫 | 🔳 憎 | Show Line Numbers OK Cancel Apply Help
- Scratchpad is used to normalise a given point (240,258,5,17) from trace selected by the name in the report toolbar variable w.r.t start point. This is done for max and min of S11 and S22
- Sequence takes normalised point and adds it along with the Time value to a single string in the form of Time, Real, Imag, Time, Real, Imag.....
- Long String is used to create a new trace. Once for S11 Min, S22 Min, S11 Max, S22 Max
- Sequence is used to iterated toolbar variable to all the times



Drift as a function of temperature



- Thermometer batteries fail after five hours
- Previous graph used to assess point of maximum drift
- Red trace advanced angled, blue trace conventional, green temperature
- Drift characteristics follow room temperature





Drift comparison – time to recalibration



- Zooming into the data
- If a tight 0.2 Db window is selected this is 90 minutes in comparison to just four







Autonomous RF – Now tested to 325 GHz

- True Automatic, hands free calibration
- Setup of Calibration for MLTRL requires no expert placement, all automatic including all lines
- Monitors calibration drift, re-calibrates automatically
- Full management of system expansion and RF stability
- Full thermal automatic calibration
- Save time & increase data accuracy
- Corrects "thermally induced" probe electrical errors







Autonomous RF System training with MLTRL Video







Autonomous MLTRL measurement repeatability



• 27 PS Lines corrected from their own MLTRL calibrations x5 using angled frequency extenders





Conclusion

- Mini modules from Virginia diodes allow a paradigm shift for on wafer probing
- Angled approach allows for vastly reduced insertion loss and still allows for on wafer probing throughout the temperature range
- Reduced loss demonstrably improves system drift
- Use of motorised angled arrangement in conjunction with Autonomous RF software allows for fully autonomous MLTRL testing in the WR3 band

