# FT Guardband: A Structural Solution Control in Screening Lots for Test

**Myra C. Bagadiong**
**Shiela Marie M. Ocampo**
**Aristeo L. Dela Fuente**

RF Power Test Engineering
AMPLEON Philippines Inc., Philips Ave. LISP1 Bo. Diezmo Pulo, Cabuyao Laguna
myra.bagadiong@ampleon.com, shiela.ocampo@ampleon.com, aristeo.dela.fuente@ampleon.com

## ABSTRACT

Production delay is observed in Final Test (FT) due to high occurrence of hold lots for GaN Z devices. Queuing lots for assessment at FT due to Resonance Frequency (Fres) failure in the Statistical Yield Limit and Statistical Bin Limit (SYL/SBL) resulted in the high production throughput time (TPT).

Resonance Frequency (Fres) parameter simply refers to the balancing of the capacitor reactance through the inductors. It is the effect of wire bond loop heights and tip-offsets on matching and coupling of RF power amplifier.

The lot assessment and disposition took an average of seven (7) days to release. The challenge is how to identify controls in the Assembly to ensure that lots performance in Final Test is compliant with the SYL/ SBL limit.

The implementation of FT Guard band limit control in Spar Wire calibration test will safeguard the out-of-control performance during machine optimization and proactively prevents test verifications from the Failure Analysis Team, thus improving the overall Test efficiency in the process.

## 1. 0 INTRODUCTION

One factor that negatively affects the throughput time (TPT) is the duration it takes for a hold lot due to test rejects to be analyzed and released.

GaN Z products sensitivity is simply demonstrated in wireband calibration where qualification is performed frequently per lot. Spar wirecal test is used at assembly for wire bond process control during wire bond calibration. This is critical as its function is to qualify and maintain products performance to its desired design specification.

Spar Wire Calibration test uses tight specification limit from Final Test but Fres parameter failure is chronic. The expectation is that units rejected in Spar Wire calibration can be recovered in Final Test limit. However, this is not always the case; in most instances, low yield is discovered when it is already too late. The Final limit is concealed at Spar Wire calibration test.

Consolidating all low yields lots, majority of findings were failed at Spar wire calibration.

We use Problem Definition Tree to drill down all the factors. See figure 1.0 Problem Definition Tree.

We arrived in red X of "High holding lots at Final Test caused by the samples known failed at Spar Wirecal are included in the mother lot that occurs in any of work shifts.

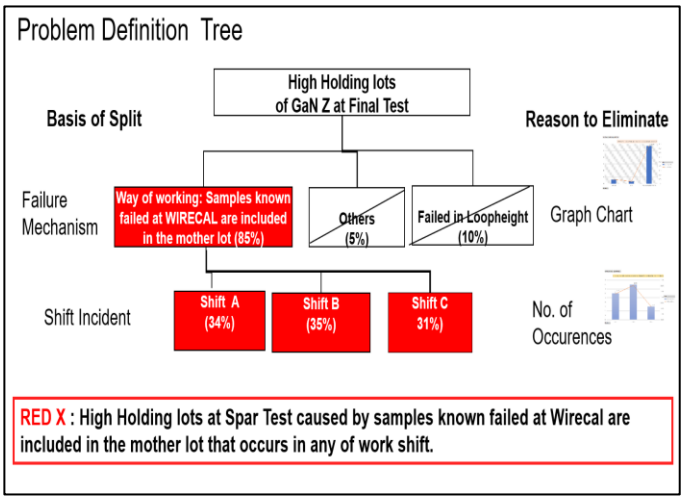
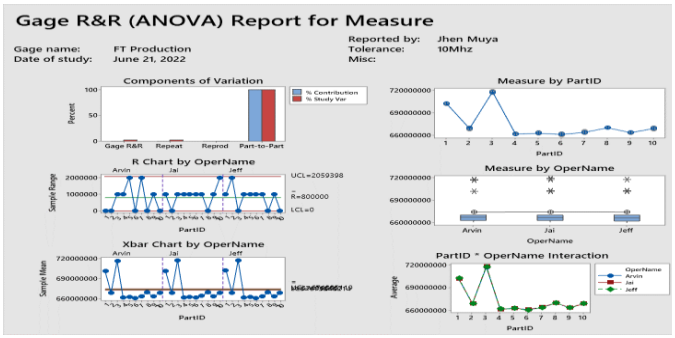



Figure 1.0 Problem Definition Tree.

Driven by focus on process improvement, the author initiated to develop structural control solution at Spar Wire Calibration.

Prior to the actions, MSA (Measurement System Analysis) was performed on the measuring equipment used in the Spar Wire calibration and Final Test in terms of GR&R and both testers had satisfactory result. See figure shown below.

**GR&R of FT Production setup:**
The FT production setup has an acceptable result with total gauge of 2.81%. See figure 2.0



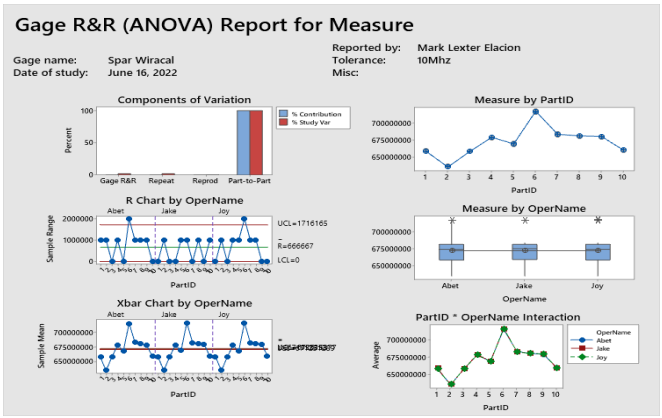

**Gage Evaluation**

| Source | StdDev (SD) | Study Var (6 × SD) | %Study Var (%SV) |
|---|---|---|---|
| Total Gage R&R | 551265 | 3307593 | 2.81 |
| Repeatability | 547202 | 3283213 | 2.79 |
| Reproducibility | 66809 | 400854 | 0.34 |
| OperName | 66809 | 400854 | 0.34 |
| Part-To-Part | 19616912 | 117701473 | 99.96 |
| Total Variation | 19624656 | 117747938 | 100.00 |

Figure 2.0 GR&R of FT Production Setup

**GR&R of Spar Wire Calibration Setup:**

The Spar Wire Calibration setup also has an acceptable result with total gauge R&R of 2.38%. See figure 3.0



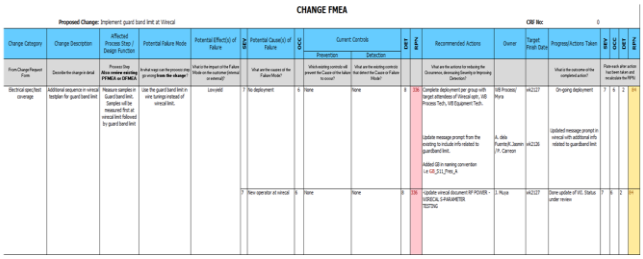

**Gage Evaluation**

| Source | StdDev (SD) | Study Var (6 × SD) | %Study Var (%SV) |
|---|---|---|---|
| Total Gage R&R | 512151 | 3072903 | 2.38 |
| Repeatability | 507494 | 3044962 | 2.36 |
| Reproducibility | 68908 | 413449 | 0.32 |
| OperName | 68908 | 413449 | 0.32 |
| Part-To-Part | 21514392 | 129086350 | 99.97 |
| Total Variation | 21520487 | 129122920 | 100.00 |

Figure 3.0 GR&R of Spar Wire Calibration Setup

Complete risk assessment of FT Guardband concept was also carried out to pinpoint potential risk and specify corrective measures. This is shown in Figure 3.0

**Risk Assessment of FT Guard band Concept**




See figure 3.0 Risk Assessment of FT Guardband Concept.

Prior to changing to VEEpower (VEEpower is a program used at Spar Wire Calibration), a risk assessment of the current program was also performed. See figure 4.0.

**Risk Assessment of FT Guard band for VEEPOWER updates**

Change FMEA

| Potential Failure Mode | Potential Effect(s) of Failure | Potential Cause(s) of Failure | Prevention | Detection | Recommended Actions | Progress/Actions Taken |
|---|---|---|---|---|---|---|
| Failure to tune using correct reference | Low yield | Incorrect Information in message prompt | None | Visual Inspection | Proper validation | |
| Failure to follow correct disposition | Low yield | 1. Not following instructions 2. New operator at Wirecal | None | Visual Inspection | 1. Update Work Instruction 2. Deployment | |
| Incorrect disposition provided by the program | Low yield | Incorrect guard band limit reference in the program | None | Test plan review prior release | Proper validation prior release | |
| No guardband Disposition even though testplan has indicated Guardband parameters | prolonged downtime | Testplan is not in AutoWirecal | Convert testplan to Autowirecal. | GuardBand Prompt indicates "NA" | Proper deployment prior release. | |

Figure 4.0 Risk Assessment of FT Guard band for VEE power updates.

We aim to streamline disposition of Spar wirecal samples prior modification in VEE power program. See figure 5.0.

**Guard band limit disposition of samples:**

| | Wirecal Limit | Guard band limit | Unit Disposition | Description |
|---|---|---|---|---|
| 1 | Reject | Reject | Reject | Reject qty should deduct at Wirebond camstar transact. Note: Use "Qual reject" call out at Wirebond. |
| 2 | Reject | Good | Good | Sample to include in the mother lot |
| 3 | Good | Good | Good | Sample to include in the mother lot |

Figure 5.0 Guardband Disposition for Wirecal Samples.

Project scope is for Spar Wirecal only and no changes on the product test specification. Improvement in product performance is being handled by a separate team.

## 2. 0 REVIEW OF RELATED WORK

Test already uses the Guardband technique. We used different approaches in this instance, based on the Spar wirecal process control requirement and capability.

This significantly promotes and enhances the way of working at Spar Wirecal to resolve persistent issues, increase yield and improve product quality.

## 3.0 METHODOLOGY

FT Guardband limit was introduced. This technique was defined to have structural control over the assembling procedure.

This is how the FT Guardband limit works. See Figure 6.0. The green color represents the Final Test limit. This is the limit defined from Device Test Specification (DTS). The Spar Wirecal limit shown in red, is tighter than the Final Test limit by +/-30Mhz. This is the limit defined in the Assembly Wirebond Diagram. Additionally, between Wirecal and the FT Final limit is the FT Guardband limit. The limit defined in FT Guardband was based on the GaN Z product and process capability.


Figure 6.0 FT Guard band Limit Concept.

Here are the steps to define FT Guardband limit:

1. Prepare samples. These are the combination of good and reject samples. 20pcs of good and 20pcs of rejects.
2. Measures all the samples in serialize at FT Limit using production setup.
3. Measures all the samples in serialize at Spar Wirecal using wirecal setup.
   Note: For item 2 and 3, the purpose is to check the variation of tester.
4. Decap all samples.
5. Measures the samples without cap in serialize. This is to check the variation response of with caps (sealed) and no caps (unsealed).
6. Compare the result and check the delta.
7. Delta will be used for FT Guardband limit against the FT limit.
8. This procedure will be done per device level.

Wirecal Testplan was updated with Guardband limit and Veepower program was modified for FT Guardband. See figure 7.0. Included in the modification is the automatic disposition of wirecal samples.

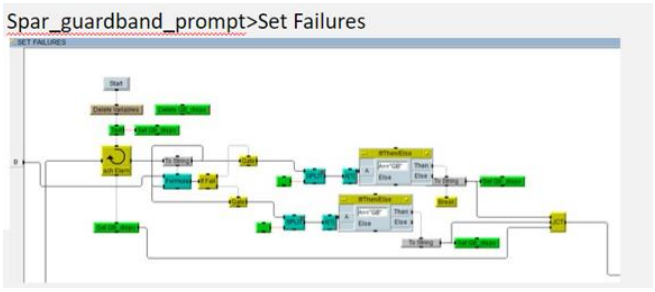



Figure 7.0 Modification on VEEpower program

FT Guardband concept was presented and approved in Ampleon Global Change Control Board (GCCB).

## 4.0 RESULTS AND DISCUSSION

Here is the result of GaN Z device:

1. With and without cap after measures in serialize

| DeviceID | Average of S2_S11_Fres_A(Hz)2 | Average of S2_S11_Fres_B(Hz)2 |
|---|---|---|
| No caps | 2.544764706 | 2.581705882 |
| with caps | 2.559058824 | 2.586823529 |
| Delta | 0.014294118 | 0.005117647 |

- Result shows that Fres performance of unsealed and sealed devices are different. Note, that assembly process control samples are measured unsealed vs. sealed production units at FT. Fres of sealed units is around 20 MHz higher vs unsealed units.

2. For Tester variation checking using FT limit production setup vs Wirecal setup.

| | Production vs Wirecal Setup delta | |
|---|---|---|
| | S2_S11_Fres_A | S2_S11_Fres_B(Hz) |
| Average | -0.001642857 | 0.003857143 |

- Result shows very minimal tester variation

3. For Guardband limit.

| Device | Specs Limit | FT_S2_S11_A(GHz) | |
|---|---|---|---|
| | | LSL | USL |
| FT Limit | >2.44G <2.56G | 2.44 | 2.56 |
| Wirecal Limit | >2.47G <2.53G | 2.47 | 2.53 |
| Guardband Limit (Proposal) | >2.46G <2.54G | 2.46 | 2.54 |

- Therefore use 0.02 delta (from with caps and no caps/ after sealed) against FT limit.

Complete deployment was also done across all groups for way of working at Spar wirecal was changed.

**Current Practice at Spar Wirecal**

1. Wirecal limit is use
2. Wirecal limit is use for wirebond tuning
3. Samples rejected at wirecal is included in the mother lot for simple reason that reject will turn good at Spar production
4. Sample is measured with plastic cap.
5. Number of samples and frequency of wirecal

**New Practice at Spar Wirecal**

1. Wire calibration limit + Guard band limit are used. Wirecal limit will be measured first followed by Guardband limit.
2. Wire calibration limit is used for wire bond tuning. No changes.
3. Guardband limit will be used for disposition of samples:

| Wirecal Limit | Guard band limit | Disposition | Remarks |
|---|---|---|---|
| Reject | Reject | Reject | Reject qty should deduct at wirebond camstar transact. Note: Use "qual reject" call out at wirebond |
| Reject | Good | Good | Sample to include in the mother lot |
| Good | Good | Good | Sample to include in the mother lot |

4. Sample is measured with plastic cap. No changes.
5. No changes on the number of samples and frequency of wire calibration

After measurement of samples, disposition for wire calibration is automatic display for user reference as shown below. Message prompt number 2 is for FT Guard band wire calibration disposition either to include or remove from the mother lot.

a.) Wire calibration limit is fail, guard band limit is fail. Expected output is red prompt with auto wire calibration adjustment and guard band disposition.


- Number 1 is related to wirecal /wirebond tuning. This is existing.
- **Number 2 is for FT Guardband limit. Disposition of sample is to remove from the mother lot.**

b.) Wire calibration limit is fail, guard band limit is passed, and expected output is orange prompt with auto wire calibration adjustment and guard band disposition of PASS.


- Number 1 is related to wire calibration /wire bond tuning. This is existing.
- **Number 2 is for FT Guard band limit. Disposition of sample is to include in the mother lot.**

c.) Wire calibration limit is pass, guard band limit is pass then expected output is green prompt with auto wire calibration pass and guard band disposition of pass.


- Number 1 is related to wirecal /wirebond tuning. This is existing. Sample passed, indicating that the parameter settings are valid to use and wire bond machine can be released to production.
- **Number 2 is for FT Guardband limit. Disposition of sample is to include in the mother lot.**

d.) Wire calibration limit is failed, Guard band limit is "NA" then expected output is red prompt with auto wire calibration adjustment and guard band disposition of "NA".

- Number 1 is related to wirecal /wirebond tuning. This existing.
- **Number 2 is for FT Guardband limit. "NA" will prompt for parameter that is not included in FT Guard band limit. This is known defect and not part of tuning in wire bond.**

Test time validation was also check and the result shows no significant change or increase in the test time. See Figure 8.0

| Method | Wirecal Ttime ave. (s) |
|---|---|
| Without Guardband | 2.990905135 |
| With Guardband | 2.990544596 |

Figure 8.0 Test Time Validation

Additionally, this project produces measurable advantages such as:

- Significantly improved holding lots from an average of 7 days to <2 days as shown in figure 9.0.

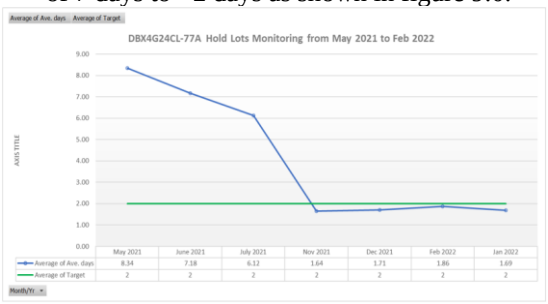



Figure 9.0 GaN Z Hold lots Monitoring

- 2.46% - hold lots and unit verification improvement / Tester efficiency improvement.

| | no. of first test lots | no. of ver lot | % of ver test | 1st Test Qty | Ver Qty | % |
|---|---|---|---|---|---|---|
| Before GuardBand | 1366 | 46 | 3.36749634 | 413450 | 4576 | 1.106784 |
| After GuardBand | 2766 | 25 | 0.903832249 | 237494 | 823 | 0.346535 |
| | | Improved | 2.463664091 | | | 0.760249 |

- **$45,662** - savings from Tester Efficiency equivalent of 0.76%.

## 5.0 CONCLUSION

FT Guard band helped provided proper disposition on sample units at Spar Wire calibration Test. Structural way of working by implementing Guard band limit thus improved product performance in Final Test to ensure compliance in SYL/SBL.

This enhanced TPT and added control for auto recovery within the Spar Wire calibration, potential low yield, and holding lots at FT. Disposition is simple to manage because this is automated. It proactively scrapped units due to Spar Wire calibration rejection. Tester efficiency was also improved by minimizing test verifications from the Failure Analysis team.

## 6.0 RECOMMENDATIONS

This project comes highly recommended, especially for those devices with recurring issues from various package types. On-going assessment for the ff. devices.

- Devices VT – High Priority
- Devices PV

## 7.0 ACKNOWLEDGMENT

The authors would like to thank the whole Test Engineering family. Special thanks to our Manager– Ma. Lourdes T. Paraiso for the entire support to make this project possible.

**To God be all the Glory**

## 8.0 REFERENCES

1. E. Del Rosario and P. Cheng, RF Optimization Through Wirebonding.
2. S-Parameter Techniques, for Faster, More Accurate Network Design,

## 9.0 ABOUT THE AUTHORS

**Myra C. Bagadiong** is a Sr. Test Process Engineer handling Test Process and Test Product Line Sustaining for GaN devices. She has led several yield improvement activities and has authored several papers presented in ASEMEP.

**Shiela Marie M. Ocampo** is a graduate of BS Electronics Engineering. She started her career as a technician in Ampleon Philippine Inc., then later promoted as Test Software Engineer from 2021 to present.

**Aristeo L. dela Fuente** is a graduate of B.S. Electronics and Communications Engineering at Manuel S Enverga University Foundation (MSEUF). He was previously affiliated with NXP Semiconductors Cabuyao Inc. in June 2011-December 2015 before joining the AMPLEON Philippines Company which was a divestment from NXP Company on its RF Power Products. His works are primarily focused on test system and process control development under test process engineering. He is working for Ampleon Philippines for almost 8 years and currently holding a position of Sr Test System Technician.