Evaluation & Reliability Enhancement of Digital Beam Former (DBF) for Active Phased Array Radar

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Abstract:
Digital Beam Former (DBF) is one of the critical subsystem of Active Phased Array Radar. DBF is used to generate multiple beams from the complex video digital signals received from multiple receiver modules. This paper prescribes about the evaluation methodology and various challenges encountered during qualification process. It also brings out the reliability analysis carried out for DBF unit by addressing its quality and reliability issues. An unique approach followed in the design by providing redundancy in critical functional unit of DBF. It also covers methodology used for mitigating the failures occurred during qualification tests.

Key Words: DBF, QTP, ATP, Reliability, MTBF, Failure rate

I Introduction

DBF is one of the critical subsystems of an Active Phased Array Radar. Digital Beam Former (DBF) does the function of beam formation from the received Inphase, (I), Quadrature (Q) components from the receiver modules and sent these mutli beams to Signal processing units (SPU) for further processing.

Qualification of DBF is carried out to ensure that the system is capable of operating to specified performance throughout the range of environment of its service application. It also provides reasonable assurance for meeting the life requirements of the unit. If the system is exposed to these conditions and continuously to operate in a satisfactory manner, a high degree of confidence will be established that the item could survive the field environment during its expected operational and storage life.

Reliability is the probability that the system will perform its required function under stated conditions, for a stated period of time. $R = e^{-\lambda t}$ [1].

As the complexity of the system increases reliability decreases, unless some compensatory design measures have taken else alternative way to increase the reliability is by providing redundancy in a part / system [2].

Thus the paper discusses about the test methodology and various challenges faced during qualification process. It also describes reliability analysis performed for the system by considering various quality and reliability requirements.

2.0 Qualification Process

Qualification begins with the idea of identifying all the failure modes and their potential effects on its operation. It requires evaluation of each element such as hardware components, software algorithms and the software for implementing these algorithms independently. Then the system as whole will be qualified to ensure that all these elements are working together effectively [4].

The following tests are conducted as per JSS 55555 standard for the evaluation of DBF unit.

Sl. No.	Quality Tests Plan (JSS 55555 – 2000)
1	Vibration Test {Refer Table 4.28.2 Sl.1 b) & Table 4.28.3}
2	High Temperature (Test #17, Procedure 6, Test Condition M)
3	Damp Heat (Test # 10)
4	Low Temperature (Test # 20, Procedure 4, Test Condition J & K)
5	Altitude Test (Test #3)
6	Rapid temperature cycling (Test # 22) - Thermal Shock
9	Tropical Exposure (test #27)
10	Mould Growth (Representative samples will be used for the test) Test #21,
11	Salt Corrosion (Representative sub-systems will be used for the test)-Test #9, Procedure 2
18	Shock (Test # 24, Procedure 2)

2.1 DBF Qualification Test Setup

DBF hardware is realized based on a hierarchical configuration. It consists of two cards for the formation of partial beams and another card for the formation of final beam. This hardware mentioned is capable of forming twelve multiple beams from approximately 200 complex video channels. In addition, the unit is supported with a power supply card to cater necessary power requirements for DBF.

DBF hardware is also provided with an Automated Test Equipment (ATE) system which emulates various functionalities of DBF interfaces with other subsystems like receiver modules, scheduler and dwell manager unit, SPU and Built In Test (BIT). ATE generates different signals with same interfaces as that of a real Radar system. It has got various interfaces for differential (RS422), optical and electrical signals.DBF test setup as shown in Figure 1.

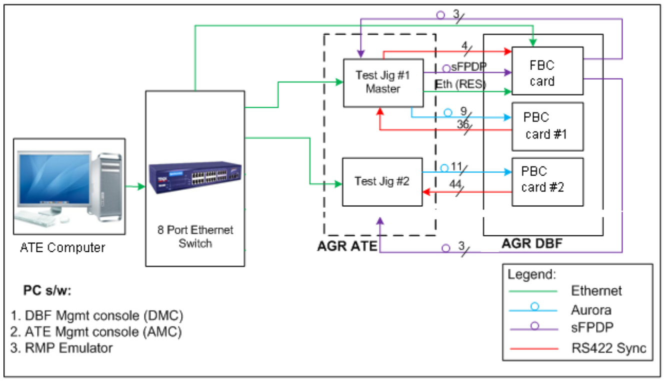

Figure1. DBF Test Setup

In the above configuration setup, ATE emulates all test inputs and feed to DBF unit. The output of DBF is again fed back to ATE computer for evaluation purpose.ATE computer is provided with a dedicated graphical user interface (GUI) which can generate different types of test inputs to DBF unit.

2.2 Challenges

I. **Vibration Test:**

Vibration testing is performed to determine the resistance of the unit to withstand vibrational stresses expected in its shipment and application environments. The DBF unit is mounted in a rigid vibration fixture which is light in weight and is made out of aluminum alloy, the test is conducted in the same orientation which simulates the actual mounting configuration. Refer Figure 2 for vibration test setup, were DBF unit is undergoing vibration test and the test is conducted in all the three direction (X,Y,Z-axis).

Figure2. DBF Vibration Test Setup

A failure has been observed with the system during POST PC check. Based on the failure analysis carried out it is found that voltage regulator for one of the Final Beam Card(FBC) has misplace from the board due to dry solder joint. This was re-soldered with a new component in place of broken solder joint component in FBC card as shown in Figure.3.

Figure 3. Component failure & Replacement of Component

In addition to this, various corrective actions have been taken to address the quality issues faced during vibration test.

a. Changed all SMD modules to through hole modules in all the cards.

b. Increased stiffener across the length of the card and added extra stiffener for the weak area of PCB.

c. Apply Room Temperature Vulcanizing (RTV) **-** glue for all tall components to take care of shock and vibration issues [5].

II. **Thermal Cycling Test:**

Low temperature chamber tests are performed to determine if the unit can be stored and operated under pertinent low-temperature conditions without experiencing physical damage or deterioration in performance. This test is mainly carried out to check the unit stability in cold laden environment by soaking at -20°C for 16 hours inside a chamber as shown in figure 3. Later the unit will be powered ON and PC check is carried out.

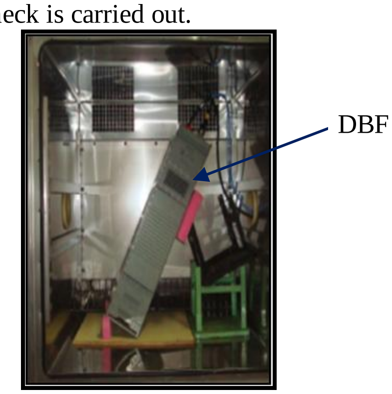

Figure 3. DBF-Chamber Test Setup

The unit failed during PC run check because of condensation. Due to the condensation effect, one of the Partial Beam Card (PBC) was observed a failure during PC check. After detail analysis it was found that the card was burnt below the associated optical connector. The water deposit below the connector lead to the short circuit between digital and chassis ground. In this regard, following corrective and preventive measures were taken [6]:

- Replacement of PBC card
- Usage of metal washer in place of leather washer for the connectors
- Usage of hemi seal material for conformal coating
- Conversion of Non Plated through Hole (NTPH) to Plated through Hole for mechanical mounting.

3.0 Reliability Analysis

The aim of this analysis is to estimate the reliability of DBF system using a recognized method based on MIL-HDBK-217F. This analysis highlights information on the few vital components whose failure rates are very high and helps designers on selection of right components. It identifies the weak components in the system and helps in the computation of Mean Time Between failures (MTBF) figures.

Reliability analysis is performed based on the assumption listed as follows:

- The prediction model assumes that failure of any component is assumed to lead to a system failure.
- Failure rate of components/sub-assemblies assumed to be constant for time period considered
- Component failure are independent
- Based on reliability handbook MIL-HDBK-217F
- No distinction is made between complete failure and drift failure
- Components are faultless and are used within their specifications
- Design and manufacturing process of the item under consideration are faultless
- Process weaknesses have been eliminated, or if not, screened by burn-in

The following conditions were considered for the analysis purpose such as environment as ground benign controlled and temperature as 55°C. The reliability computations are performed based on Parts Stress Method as per MIL-HDBK-217FN2.

3.1 Reliability Block Diagram (RBD)

RBD is an event diagram which tells about the sequence of elements / item under consideration for the fulfillment of the required function [3].

DBF system consists of two PBCs cards, one FBC card and one Power Supply card. The Reliability block diagram of unit shown in Figureure 4.

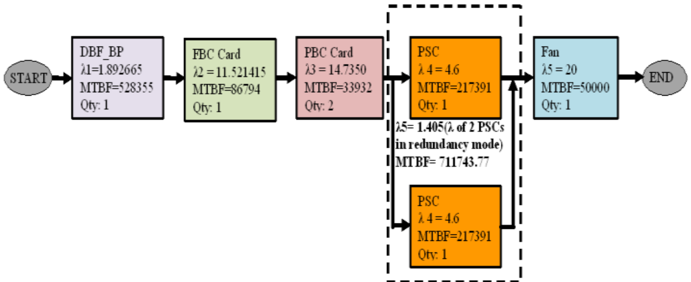

Figure 4.Reliablity Block Diagram-DBF

As per normal convention system failure rate is computed as $\lambda_{system} = \lambda1+\lambda2+ (\lambda4) \times 2+\lambda5+\lambda6$;

Where $\lambda1$= failure rate of DBF back plane

$\lambda2$ = failure rate of Final beam former card

$\lambda3$ = failure rate of Partial beam former card

$\lambda4$ = failure rate of Power supply card

In this case DBF system was resulted with a failure rate of 64.28 failure per million hour (fpmh) and a overall System mean time Between failure (MTBF) as 15554 Hrs.

3.2 MTBF Results

MTBF values were computed for various conditions with variation in temperature and variation in platform. Table 1.0 shows MTBF values with Temperature ranging from -20°C to +70°C for ground benign controlled condition.

Table 1. MTBF V/S Temperature

Temperature (°C)	MTBF(Hours)
-20	20937
-10	20519
0	20027
10	19450
20	18776
30	17995
40	17102
50	16097
55	15554
60	14988
65	14399
70	13792

From the above table it can be seen that system MTBF is directly depending on temperature and environmental factors. System MTBF increases at low temperature and reduces at high temperature.

MTBF with respect to different platform condition is shown in table 2. It shows MTBF increases if the environment changes from Ground benign controlled to a movable platform.

Environment	MTBF(Hours)
Ground Benign, Controlled (GB,GC)	15554
Ground Mobile (GM)	2615
Missile Flight (MF)	1533
Missile Launch (ML)	670

Table 2. MTBF V/S Different Platform

4.0 Conclusion

Qualification Test is conducted to ensure that the system is capable of operating to specified performance throughout the range of (Thermal & Dynamic) environment of its service application. Generally all electronic system fails because of 40% thermal and 25% dynamic influence these failures are Thermo-mechanical in nature, typical thermal failures are soft failures and this soft failure is converted to hard failures in dynamic environment. Hard failures are crack solder joint, broken wires, cracked circuit, cracked PTH, broken pins, cracked component and cracked hermitical sealed.

Exposing DBF system to these environmental test and if the system operate in a satisfactory manner a high degree of confidence will be established that the item could survive the field environment(Thermal & Dynamic) during its expected operational and storage life[7].

Reliability of the system is also carried to ensure that system will perform its required function under stated conditions, for a stated period of time. Reliability of the system increases if the reliability of the component increases. An alternative to increase the component reliability is by providing redundancy in the system. Standby or backup redundant systems are widely applied type of redundancy in fault-tolerant systems. In addition repair of the standby system / components significantly increases the system reliability.

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REFERENCES

[1] Ross ,S.M .Stochastic Processes, New York, John Weilly & Son,1983

[2] A. Biroloni , Reliability Engineering Theory & practice SIE Edition

[3] Ebeling, CE., An Introduction to Reliability & Maintainability Engineering, New York, John Weily & Son,1994

[4] M Pecht and A Dasgupta, "Physics of failure: An approach to reliable product development." IEEE Integr. Reliability workshop

[5] D. Steinberg, "Vibration Analysis for Electronics Equipment",New York: Wiley 2000.

[6] R.A Amy GS Aglietti and G Richardson, "Reliability analysis of electronic equipment subjected to shock & Vibration", Shock & Vibration, Vol.16.

[7] MIL-STD-810F "Environmental Engineering consideration and laboratory test"- DOD America

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