Roadability Test & Field Data Analysis of Radar Sensor Vehicle

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Abstract:

Radar Sensor Vehicle (RSV) of is a mobile radar system mounted on wheeled vehicle. The radar is used for automatic first-round location of artillery weapons, it is specified for all weather and all terrain operations. For the evaluation of the radar at different conditions, the various environmental conditions are simulated and the performance checks are carried out after every test.

The paper discuss in details about ground field data analysis of shock and vibration of the recorded data by making the radar sensor vehicle to run on the selected track which simulates actual test track for conducting the roadability test. Paper also discuss about fatigue life analysis of the recorded shock and vibration data of RSV running on these tracks, thus ensuring that the system is capable to withstand vibration and other dynamic stresses normally induced during transportation and it represent more severe condition of deployment and are more realistic than laboratory test, as they reproduce the combination of various environmental/dynamic stresses that occur in the field.

Key Words: Grms, g-ms, FFT, QTP, ATP

I INTRODUCTION

RSV is mounted on a wheeled vehicle on single vehicle configuration for high mobility. The radar is used for automatic first-round location of artillery weapons. The radar is specified for all weather and all terrain operations. The phased array antenna is mounted on a platform, which is resting on the twelve inflated air springs mounts. The whole platform including the Control cabin can be slewable for positioning the Radar. The radar is specified for all weather all terrain operation.

Roadability test is conducted to evaluate radar sensor vehicle for its mobility. The paper discuss in details about selection of test track, capturing of ground shock and vibration during transportation and field data analysis by making the vehicle to run on these test tracks. Thus summarizing the effect of ground shock and vibration, and comparing with the actual permissible limit. Fatigue life analysis of the Radar Sensor Vehicle is carried out based on the recorded data / results and ensured that the system is capable to withstand ground shock, vibration and other dynamic stresses normally induced during transportation

II. Test Description

The Radar electronics (Phased Array Antenna, Transmitter, SDP, Communication Equipment, Display console etc.,) is placed inside the shelter which is mounted on the platform and is supported on mounts to control shock and vibration level.

The Pneumatic system of air mount assembly is provided for safety of the sensitive phase controller modules, which are sandwiched between two metallic plates in the array lens. During transportation these air springs fitted between base frame and antenna shelter top act as cushion for isolating the antenna system from shock and vibration. All these Air mounts are inflated and the total antenna system remains floating on these air mounts to avoid any ground shock and vibration. During operation of the system, the air mounts are deflated. The Pneumatic system air tank is filled from the Vehicle compressor. The regulated air supply to all the air mounts is through the air tank fitted inside the antenna shelter. During operation of the Antenna system, the air mounts are required to be deflated [1].

2.1 Pneumatic lay out for Air mounts

The following describes the operational requirements of this unit. Pneumatic Panel which comprises of pneumatic circuit is used to inflate mounts (14 no's) for total antenna system to float in air during transportation mode to avoid shock and vibration and deflate air mounts during operating mode.

In all there are three pneumatic panel circuit viz. Pneumatic Panel-1, Pneumatic Panel-2 and Pneumatic Panel-3. All pneumatic panel circuits are required to maintain different pressure according to load distribution of total antenna and base frame. Refer figure 1.0 below for block diagram of pneumatic system.

Pneumatic Panel- 1---------60 psi (6 air mounts)
Pneumatic Panel- 2---------50 psi (4 air mounts)
Pneumatic Panel- 3---------40 psi (4 air mounts)

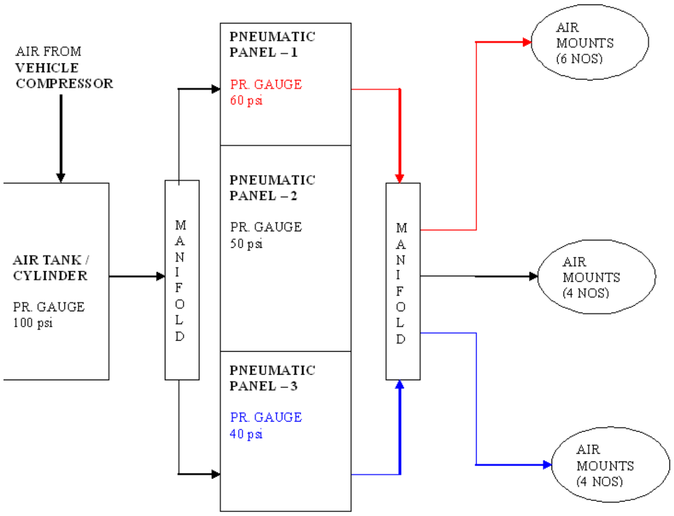

Fig 1.0 Block Diagram of Pneumatic System

2.2 Layout of Air mounts on the frame

Figure 2.0 shows layout of air mount on the assembly frame which is prepared based on the volume and weight of the system. These mounts provide safety for the sensitive phase controller modules, and other electronics in the array during transportation

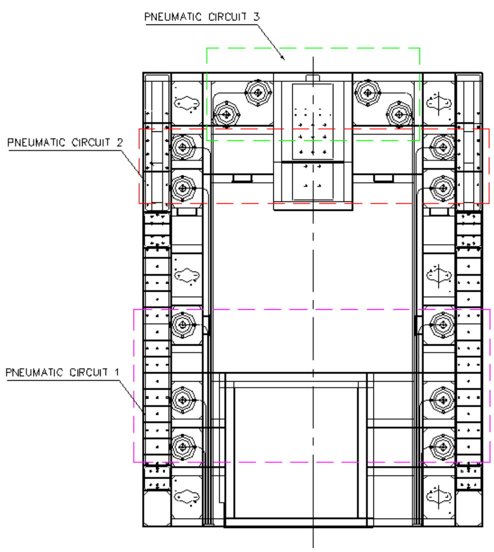

Fig 2.0 Layout of Air mounts

2.3 Radar in Transportation mode

Figure3.0 shows RSV in transportation mode during roadabilty test.

Fig 3.0 Layout of Air mounts

2.4 Test Procedure and Test Setup

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Being defence equipment the vehicle has to travel through different terrain class including smooth roads as well as cross country terrain with bumps and undulations in the forward areas. The vehicle contains a number of sophisticated equipment like Phased array antenna populated with PCMs, Transmitter, Receiver Signal processor etc. It is mandatory to reduce the levels of vibration and shock to a minimum for functioning of these sensitive equipments reliably at various field environments.

As the vibration levels has a direct impact on the life of the equipments it is decided to measure the vibration level of the equipment on the actual road conditions at different locations.

Step 1 -Connect the 8 accelerometers to the Data acquisition system as shown in figure 4.0 below. Switch on the analyzer and set the software calibration to the following:

- Sampling rate: 1.25 KS/s
- Unit of Measurement: g
- FFT resolution & bandwidth: 1.0 Hz, 1600 lines
- FFT overlap: 30%

Fig 4.0 Hardware OR36 Test Setup

Step 2- Switch on the engine and run it at different rpm and record the data

Step 3- With the test item in 'switched off' and transportable mode, drive the vehicle for 50 km on normal cross country / rough road comprising different types of road surfaces like tarmac & gravel at an average speed of 20 km/hr and max speed of 30 km/hr.

Step 4- Apply service brakes 10 times to bring the system to rest. The system shall be checked for effectiveness of braking and coming to stop within the specified distance moving on different terrains at specified speeds.

Step5- After completing the roadability test, conduct performance check of the test item and document the results in the Table

2.5 Accelerometer Position

OR36-Eight channel data acquisition system is used to capture ground shock and vibration. Eight points been identified critical in RSV for radar electronics performance and sensors / accelerometers is mounted on those points as shown in fig 5.0

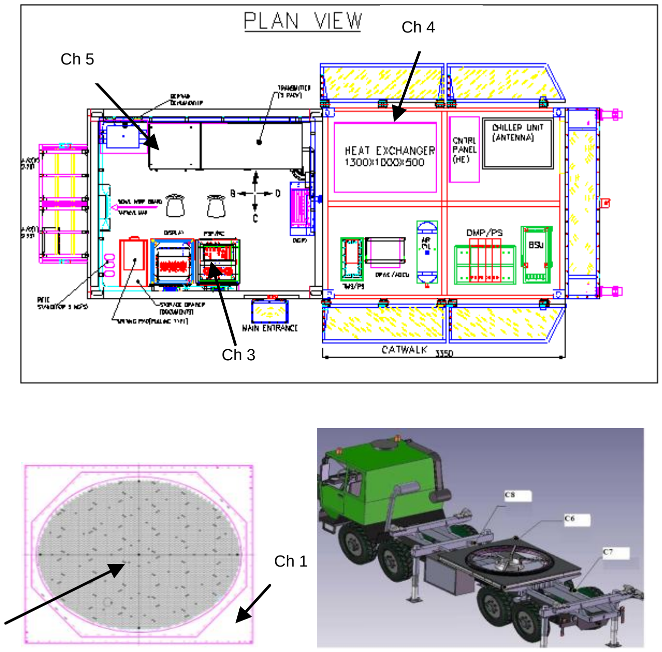


Fig 5.0 Accelerometer Position on RSV

C1: On top of antenna frame – right front corner

C2: On center of antenna frame – Radiating Plate

C3: Inside Antenna shelter, in ADCU compartment after the shock mount

C4: Inside Antenna shelter, in Chiller Unit compartment after the shock mount

C5: On top of the racks inside the Electronics shelter

C6: On bottom plate structure – right front corner

C7: On the sub frame in front of bottom plate structure

C8: On the sub frame (near Hydraulic Oil tank

2.6 Vibration and Shock Levels Monitored

The Radar sensor vehicle has been made to run on different track shown in fig 6.0 from Asphalt road to cross country track of natural and slushy terrain, for a distance of 50Kms with a speed ranging from 15-40Kmph.The photographs of different terrain is shown below

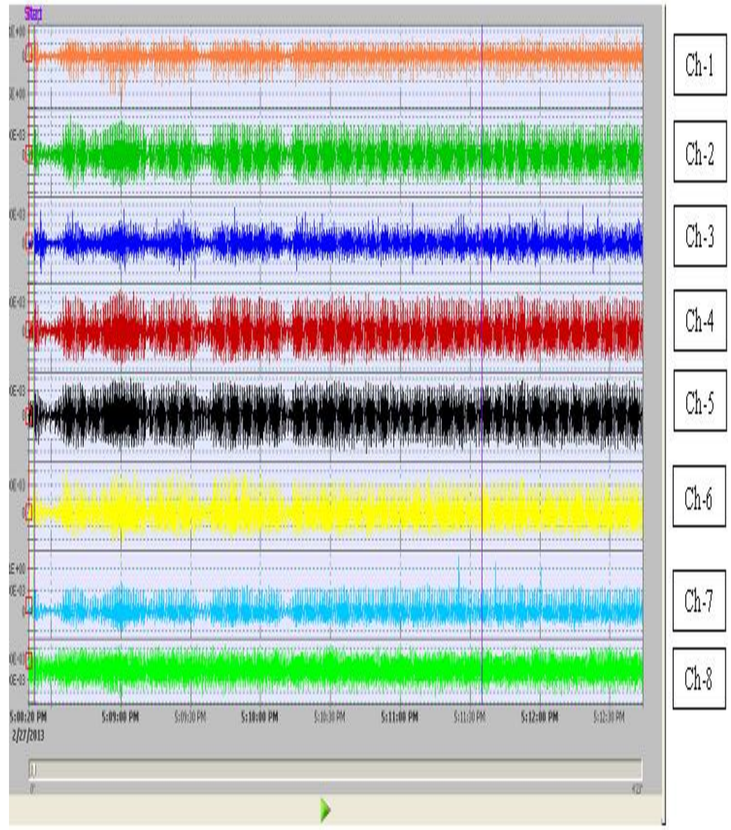
Asphalt Road

Cross Country Track

Fig 6.0 Asphalt & Cross country track

2.7 Data Measured in Time Domain during Roadability

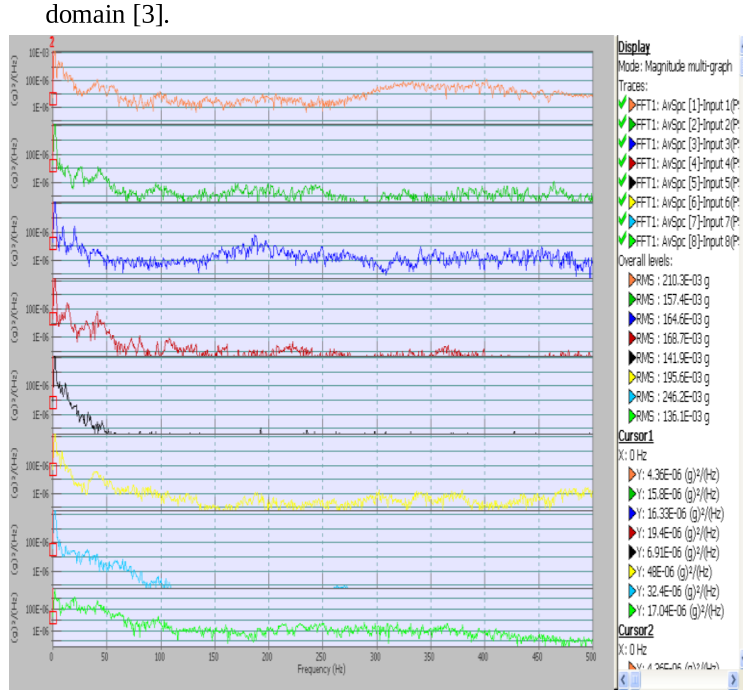
Graph 1.0 Shows data recorded in the frequency ranging from (0 – 500Hz) in time domain [2].



Graph 1.0 Data Measure in Time Domain

2.8 Post Analysis of Measure Data in Frequency Domain

Graph 2.0- Post Analysis of recorded data in frequency domain [3].



Graph 2.0 Post Analysis of Data in Frequency Domain

2.9 Measured Vibration level & Shock Level

Vibration & shock levels of the Weapon Locating Radar-SWATHI had been measured at different locations on different road conditions and speeds and tabulated in table below.

2.9.1 Measured Vibration level

Measured Vibration level of RSV running in different track shown on the table 1.0 for all the channels.

Table 1.0 Measure Vibration Level

		Asphalt Road	Cross Country Track
Sl. No.	Location	Speed 30-50km/hr (G_{rms})	Speed 10-30km/hr (G_{rms})
1	C1: On top of antenna frame -right front corner	0.0814	0.433
2	C2: On top of antenna frame – near Center	0.139	0.333
3	C3: Inside Antenna shelter, in ADCU compartment after the shock mount	0.104	0.214
4	C4: Inside Antenna shelter, in Chiller Unit compartment after the shock mount	0.148	0.307
5	C5: On top of the racks inside the Electronics shelter	0.061	0.133
6	C6: On bottom plate structure – right front corner	0.220	0.113
7	C7: On the sub frame in front of bottom plate structure	0.136	0.120
8	C8: On the sub frame (near Hydraulic Oil tank)	0.00146	0.00105

2.9.2 Measured Shock level

Measured Shock level of RSV running in different track shown on the table 2.0 for all the channels.

Table 2.0 Measure Shock Level

		Asphalt Road	Cross Country Track
Sl. No.	Location	Speed 30-50 km/hr	Speed 15-30km/hr
1	C1: On top of antenna frame – right front corner	2.06g, 2ms	5.54g, 1.8ms
2	C2: On top of antenna frame – near Center	2.21g,1.8ms	5.7g,1.3ms
3	C3: Inside Antenna shelter, in ADCU compartment after the shock mount	1.22g,1.5ms	4.46g,1.56ms
4	C4: Inside Antenna shelter, in Chiller Unit compartment after the shock mount	2.03g,1.6ms	1.82g,1.9ms
5	C5: On top of the racks inside the Electronics shelter	0.437g,0.8ms	0.746g,1.79ms
6	C6: On bottom plate structure – right front corner	0.17g,1.5ms	0.90g,2ms
7	C7: On the sub frame in front of bottom plate structure	0.183g,0.76ms	3.40g,1.06ms
8	C8: On the sub frame (near Hydraulic Oil tank)	0.002g,0.59ms	0.0016g,0.40ms

III Test Results & Interpretation

3.1 Results

Roadability test of the RSV is conducted to demonstrate that the equipment has a structural and functional life which is compatible with the system/sub system life requirements. Endurance environment is one which the equipment is required to meet the performance specification, no damage is allowed while it is operating and system must exhibit unimpaired performance when endurance test environment is removed.

3.2 Functionality of the radar electronics

3.2.1 Vibration

Radar subsystems independently qualified for 1.5grms. The maximum level obtained during field data analysis was 0.433grms has been measured at C1: On top of antenna frame – right front corner .The vibration level measured is within the functional qualification level hence it can be concluded that radar system will meet functional requirements. The radar was functionally checked after the roadability test and found satisfactory.

3.2.2 Shock

To meet the transportability requirement functional shock test of 20g, 18ms, half sine has been carried out in all radar subsystems during qualification. While conducting roadability test maximum shock observed was 5.54g, 1.8ms is measured at C1: On top of antenna frame – right front corner. The Shock level measured is less than the level tested during qualification and hence it can be concluded that the radar system vehicle is safe and meet all its functional test requirements [4].

3.3 Fatigue Life of the Radar System Vehicle

The following relationship is used to demonstrate the required test times at functional levels to satisfy endurance requirements [5].

(W0/W1)= (T1/T0)1/M -- -- -- (1)

Where: W = Vibration levels (Acceleration spectral density)
T= Time (hrs),
M= Material constant (Random S/N curve)

The relationship is simplified expression of linear fatigue damage accumulation for typical materials used in electronics equipment. The recommended value of M=4.0 for random vibration.

Case-I : Maximum 'Grms' measured is considered to estimate fatigue life

In this case maximum measured vibration is in cross country track i.e., Grms value is 0.433 at C1: On top of antenna frame- right front corner.

W0 = 1.50grms
W1= 0.433 grms
T1= to be calculated
T0=1hrs/axis
M=4.0 (empirical value for random vibration)
By using equation (1), T1 is calculated as

T1= 144hrs

In terms of kilometers run this is equivalent 2880kms (144hrs x 20km/hrs). This is the worst scenario and hardly vehicle will travel continuously in this kind of track always.

Case-II: Maximum Grms measured on Asphalt Road to estimate fatigue life

In the case of Asphalt road maximum measured Grms value is 0.22 at C6: On bottom plate structure – right front corner.

W0 = 1.50grms
W2= 0.22grms
T2= to be calculated
T0=1hrs/axis
M=4.0 (empirical value for random vibration)
By using equation (1), T2 is calculated as

T2= 2161 hrs

In terms of kilometers this is equivalent 86444 kms (2161 hrs x 40 km/hrs). This is the scenario of vehicle running on Asphalt road.

Case-III: Miner's Cumulative Fatigue Damage ratio to estimate the fatigue life

To estimate the cumulative fatigue life Miner's cumulative fatigue damage is used. In this case 50% operation in Asphalt road and 50% in worst case scenario is considered to arrive cumulative damage potential.

By using equation (1) (W0/W1)M = (T1/T0)
$T1^1$ = T0 (W0/W1)M , T0= 0.5hrs(Cross Country track)
$T2^1$ = T0 (W0/W1)M , T0= 0.5hrs(Asphalt road)
By using above equation $T1^1$ = 1440Kms and
$T2^1$ = 43222 Total km of run.

Total km of run = ($T1^1$ + $T2^1$)
= 1440 + 43,200
= 44,640 kms

IV Conclusion

Roadability test and field data analysis is carried out for RSV to demonstrate that the Antenna electronics (Phased array antenna populated with PCMs, Transmitter, Receiver Signal processor etc.,) has a structural and functional life which is compatible with the system/sub system life requirements.

Fatigue life analysis of Radar Sensor Vehicle is carried out using Miner's cumulative fatigue damage ratio and conclude that the vehicle is capable of operating to specified performance criteria throughout the range of its functional environment and provided reasonable assurance that life requirement of RSV been met

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