RELIABILITY OF MOBILE PHONES

Dr U Daya Perera, Nokia Mobile Phones (UK) Ltd, Ashwood House, Pembroke Broadway, Camberley

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SUMMARY AND CONCLUSIONS

The paper addresses reliability aspects of mobile phones, also known as cellular phones. Mobile phones have been in use for about a decade. Early models were low in technology and usage was limited. However, the technology of phones has been improved significantly during the last few years. The market demand has been increasing in a similar manner over the last few years. It is anticipated to increase this trend in the foreseeable future.

In this highly competitive market, more and more products are released to satisfy the demand. In this situation, the product development cycle is getting shorter and the product costs need to be set at competitive levels. Also the product failure rate criteria is decreasing for successive products. Hence there is a continuous need to review reliability assurance and demonstration processes at product and component levels. Primary areas of concern are, reduction of test time, sample size and verification of corrective actions as soon as possible.

The current reliability assurance process for new products basically consist of testing a sample of about 50 phones at an elevated temperature with power cycling and radio transmitting at power on periods. This is a traditional reliability demonstration process where product reliability is demonstration with the assumption that the failure rate is constant.

One solution to achieve the above objectives was to introduce Test Analyze And Fix (TAAF) process (reliability growth testing). and to model test data to reliability growth models. Another solution being addressed is to assess the effectiveness of applying a Strife type of test. In Strife testing the aim is to search for potential failures by subjecting the product to multiple (cyclic) stresses and introduce corrective actions to eliminate recurrence through failure analysis, rather than attempting to quantify reliability estimates.

It is shown that application of reliability growth models is effective to demonstrate the product reliability. The effect of early life failures and corrective actions can be quantified, test time can be reduced and used more effectively. In order to achieve wider requirements, it is anticipated that Strife testing can be effectively used to reduces the test time further, by assessing the deviation of parametric measures with test time.

1. *INTRODUCTION*

This paper describes the reliability aspects of mobile phones. Aspects include those considered at different stages of the product development; design and development, reliability demonstration, environmental testing. Also considered is commercial issues that effect the product reliability.

There is a growing market for mobile phones. It is anticipated that it will grow over the next decade and the household acceptance would reach a similar or better level to the video recorder market. In this competitive market there is a continuing need to satisfy varying customer needs. It is apparent that the customer needs vary for different continents. In this area reliability related aspects play a significant factor. With the rapidly advancing technology and market requirements in mobile phones in a competitive market, new products are developed more frequently to keep customers updated with new technology. Consequently the product cycle time is getting shorter. In this situation there is an increasing demand to reduce the product development and test times.

The reliability demonstration of new products is carried out through the traditional testing of about 50 phones at an elevated temperatures for about six weeks. In these tests constant failure rate is assumed. In this situation, test data could be easily misinterpreted. TAAF together with reliability growth modelling would be a more effective solution. Observed failures are subjected to failure analysis and introduction of corrective actions to eliminate recurring failures.

Due to the decreasing failure rate criteria for new models, for traditional reliability demonstration tests, test time and test sample size increases for successive products. Hence, there is a continuous need to seek and experiment with new techniques that can reduce the test time. The Strife technique is considered, where test samples are subjected to power cycling and temperature cycling beyond the product specifications. The objective is to 'search' for potential failures and introduce corrective actions, rather than attempting to demonstrate the product failure rate. It is also attempted whether deviations in parametric measures with accelerated ageing can be used to assess the product reliability measures.

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Another proactive measure taken on new products is to introduce online stress screening processes. The objective is to protect customers from early manufacturing related problems, particularly during the production ramp up periods of new products.

2. PRODUCTS - MOBILE PHONES

The mobile phone is a relatively new concept of personnel communication, originated about twenty years ago. During the early period very high costs were involved in purchase, installation and running compared to the traditional hard wired phones. In this era the mobile phone was mainly limited to business use. However with advances in network and mobile phone technology there has been a significant acceptance of the mobile phone over the last five years, not only in business use but in the consumer market as well. In parallel, the cost factors involved in the use of mobile phones are decreasing significantly. Detailed aspects of mobile phones can be found in many journals relating to mobile communication, such as ref 1.

A key measure of acceptance of a generic consumer products is the penetration level, the percentage of products per population at any given time. As would be expected, for mobile phones this value varies from one country to another. Scandinavian countries are leading (at about 8%), (Ref 2) while the penetration level in US is about 5%. In other European countries and continents this varies from around 0.4 to 4%. However the significant factor is that penetration levels are increasing rapidly. This implies that there is a significant potential world market for a number of years. A league table of mobile phone penetration levels in different countries is illustrated in figure 1. It is anticipated that during the next decade, penetration level would reach similar figures to that experienced for video systems, around 50% in western countries. This implies that there is a significant potential demand for mobile phones in the near future. The world subscriber mobile phone population during June 1993 was approximately 25 million.

Since introduction, the mobile phone technology has being increasing rapidly. Most recent technological improvement was the introduction of digital phones in 1993 (ref 3), superseding the analog technology. Main advantages of digital over analog phones are security, wider coverage, in particular international calls, and clearer voice. As digital technology is relatively new, these phones are more expensive than analog. It is forecast that by end of the decade the analog phone population would be replaced by digital technology. There are many different versions of the above technologies. These aspects are well outside the scope of this paper.

As would be expected, initial mobile phones were much bigger than current versions. As the technology improves the tendency is to make smaller and slimmer phones. It is also interesting to note that customer requirements based on market surveys vary markedly from one country to another. For example the main

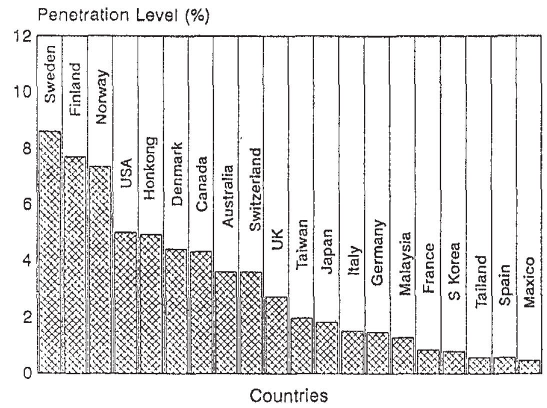

Figure 1 - Mobile Phone Penetration Levels (Ref 2)

requirement for one country can be size and weight while that for another country can be cost, warranty or reliability. Therefore manufacturers need to consider different market requirements in this competitive business. However, to be competitive, it is vital that mobile phones satisfy competitive reliability requirements as specified during the product development period.

2.1 *Reliability and Environmental Issues*

The reliability requirements of mobile phones are challenging when compared to many commercial products. This requirement is primarily due to the need to satisfy vastly varying environmental conditions. This is due to fact that a mobile phone can be used in; indoor, outdoor and in a motor vehicle. The indoor and outdoor environmental conditions can vary significant from one country or continent to another. Also the environmental conditions within a vehicle can significantly vary in different countries. These can be temperature and or humidity extremes and dusty conditions. Typical environmental conditions in which a mobile phone needs to operate are:

Temperature range -30 to +60 deg C

Other environmental factors that need to be addressed include:

Transportation and storage conditions:
- Temperature
- Rate change of temperature
- Vibration
- Shock

Fragility of plastic housing:
- Due to accidental dropping

Protection against ingress of:

Dust and Liquids
Mechanical wear/fatigue aspects of:
Key mat
Printing
Cables/connectors
Life characteristics of field replaceable units; eg. battery and antenna.

In addition, different accessories are required to be used with a mobile phone. The required accessories can vary based on where it is used; at home, office, car or a combination of these. Accessories include; car holder, car cradle, hands free, cigarette lighter charger, desk holder, mains charger, battery, etc; It is estimated that on average there are approximately four accessories used with a mobile phone. Even though all the accessories are not used at the same time, there is an increasing demand to improve and maintain the reliability of accessories at high levels. Phones and associated accessories are subjected to a series of reliability and environmental tests. The paper discusses only some reliability activities.

3. RELIABILITY DEMONSTRATION

The reliability demonstration process includes testing a sample (about 50) of phones at a constant high temperature with power cycling (power on and transmitting) at a prescribed frequency. Both, the sample size and test duration are a function of the product failure rate criteria. Typical test duration is about 6 weeks. The test acceleration is a function of both, temperature and power on/off and radio transmitting level and time. During the test process over thirty parametric measurements are taken at regular intervals. These measures have predefined criteria. In the event of a test measure outside the criteria being observed, the test unit is subjected to failure analysis and corrective action. Also in the event of a hard failure, the unit is subjected to failure analysis and corrective actions are introduced to eliminate recurrence. In analysis of failure data, constant failure rate is assumed. This assumption could be misleading; early life failure can be masked by more mature unit test hours. The effect of early life failure in the field and the effect of modifications could not be easily assessed.

Based on the observed failure rate trend it was found that in most applications data is most suitable for reliability growth models and in concurrent engineering, the reliability demonstration process can be replaced by a reliability growth process with a Test Analyze and Fix (TAAF) process. A Duane reliability growth plot (ref 4) applied to a mobile phone is illustrated in figure 2.

Apart from applying reliability growth testing, as the generic product failure rate decreases the test sample and or test time required to demonstrate the failure increases. Therefore there is a need to look for more effective methods which can reduce the test time and sample size with the decreasing product development cycle times. In this area it is necessary to exploit various aspects through experiments.

In general, temperature cyclic tests are favoured to induce potential failures more than constant temperature testing. Also it is necessary to research and evaluate reliability test methods being applied else where and how these could be best utilised.

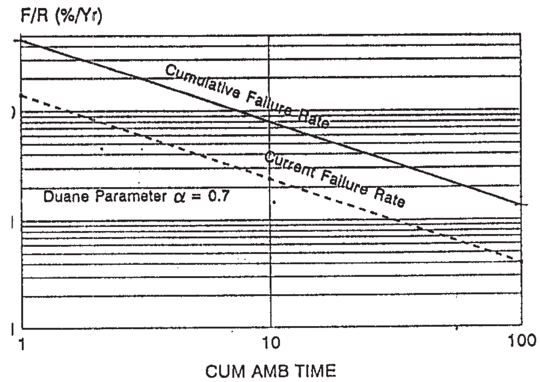

Figure 2 - Reliability Growth (Duane) plot of a Mobile Phone

Test methods developed over the last few years include; HALT (ref 5), HAST (ref 6), step stress tests (ref 7) and Strife (ref 8). The first two methods are very similar and limited to applications at component level. This is primarily due to the capability of applying very high stresses at component level and achieving correspondingly high accelerating factors. These tests are very effective in reducing the test time at component level. The step stress and Strife tests, again very similar and are applicable at system level. Strife (Stress + life) tests originated by Hewlett-Packard in early 1980s. Published studies to date are on computers systems and reported to be very successful.

The objective of Strife tests is to induce potential failures by the application of stresses, preferably multiple cyclic stresses. Often tests would commence at product specification extremes. Based on test results, stress levels can be extended beyond the specifications, provided no untypical failure modes are induced. The primary aim is to 'look' for potential failures and introduce corrective actions based on failure analysis, to make the product robust. It is understood that an improved failure precipitation can be achieved with cyclic stresses compared to constant level stresses. This is contrary to expectations in traditional reliability demonstration tests, where no failures are wanted. Another aspect in Strife tests is that no emphasis is placed on estimating reliability measures, but to make the product more reliable. Also based on published information, it has been demonstrated that both the sample size and test duration for Strife tests is significantly less than that required for traditional reliability demonstration tests at constant temperature,

4.0 STRIFE TESTING OF PHONES

In order to assess the effectiveness of Strife tests a sample of phones were subjected to temperature and power cycling, transmitting maximum level of radio frequency during the power on states. The test process was:

(1) Initially take (up to 30) parametric measures.
(2) Temperature cycling between -30 and +60 deg C, two hour cycle with one power on/off cycle per hour with transmitting. The dwell time at temperature was approximately half an hour.
(3) After five days, take parametric measures.
(4) Subject test sample to random vibration at 2g RMS, between the frequency range 20 to 500 Hz for one hour.
(5) Take parametric measures. Based on results, lift the upper temperature by 5 deg C.
(6) Repeat (2) to (5) above.

The test is being carried out on 12 phones which were previously used in the reliability demonstration tests. No hard failures were observed, the upper temperature was increased by 5 deg C each time, from the second entry in to thermal cycling. A limited number of parametric measurements are illustrated. Box-Whisker plots of four parametric measures are illustrates below. Figures 3 to 6 illustrates; Transmission frequency error, transmission mute error, receiver signal strength indicator and transmission signal to noise ratio, respectively. With the limited number of points (six) no trend can be observed with any parametric measure. This indicates that the applied stresses had no effect on these parameters during the considered test period. This can be due to reasons such as:

(a) Robust Parameters, specially as these were subjected to reliability tests previously.
(b) Low severity of Applied stress levels.
(c) Insufficient test duration.

In order to ascertain which of above reasons is applicable, it is planned to continue the test programme.

Thermal cycling and power cycling with transmitting primarily would address electronic components and joints. As mechanical parts are not activated, Strife tests would

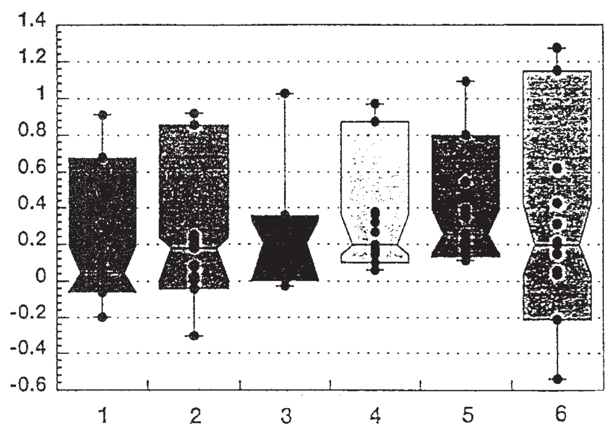

Fig 3 - Transmission Frequency Error vs Test Level

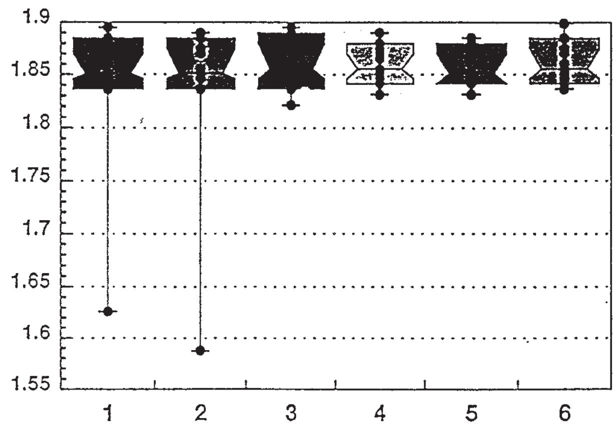

Fig 5-Receiver Signal Strength Indicator vs Test Level

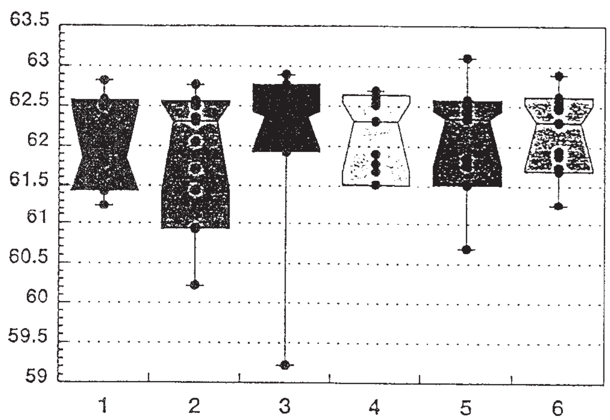

Fig 4 - Transmission Mute Level vs Test Level

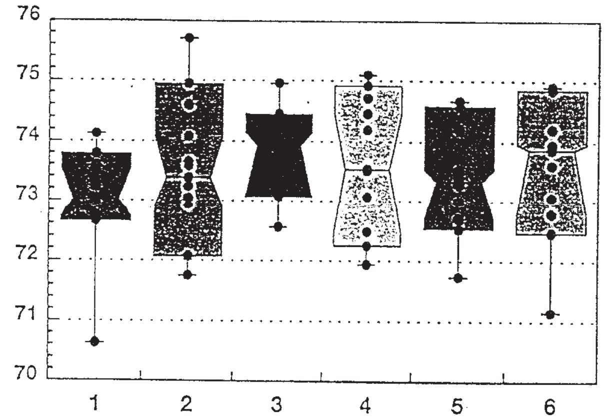

Fig 6 - Transmission Signal/Noise Ratio vs Test Level not address mechanical problems. These include; antenna, base connector, keymat, key contact actuators, cable, etc. It is necessary to carryout separate tests to assess their reliability.

5.0 ASSOCIATED RELIABILITY ASSURANCE ACTIVITIES

During various development stages products are subjected to different test and evaluation activities. These include thermal evaluation using infra red imaging, and evaluation of components such as; key mat printing, keymat switch activators, base connector, antenna; etc; at development stages. Also stress screening is applied to precipitate early life failures, primarily during the initial product ramp-up periods. A number of these aspects are considered below: in particular at the early

5.1 *Thermal Imaging*

Infra red thermal imaging is carried out to evaluate thermal distribution of circuit boards. The primarily objective is to ascertain whether there are hot spots during the phone usage. Thermal imaging is carried out at all operational modes. Although no hot spots should be present if component derating factors have been kept at low levels as specified, often hot spots are observed during the early product development stages. This can be due to unforseen factors such as; timing errors, electrical over stress, etc. When the temperature of a component exceeds expected acceptable levels, the circuit is analyzed and corrective actions are introduced to alleviated the temperature.

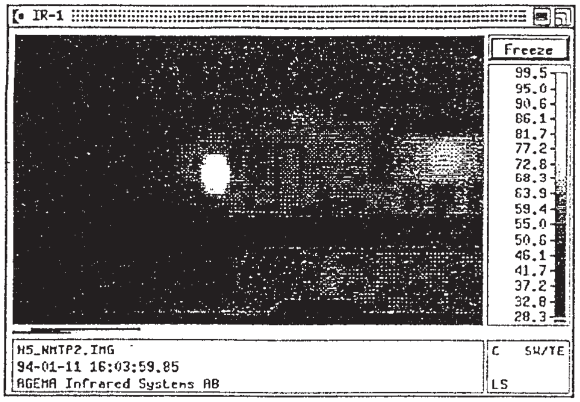

Figure 7 - An Infrared Thermal Image of a PCB

Figure 7 illustrates a thermal image of a phone circuit board. It can be observed that the case temperature of the diode is high, the temperature was in the order of 100 deg C, in a 25 deg C ambient temperature. The junction temperature can be in the order of 115 deg C. At higher operating temperatures, say 70 deg C, the junction temperature would rise to about 150 deg C. Cleanly this is not acceptable. Failure analysis revealed that the high temperature was caused by a timing error, a software modification alleviated the hot spot.

5.2 *Component Evaluation*

In component evaluation, components are subjected to various tests to evaluate reliability and durability and in certain instances to evaluate process related problems. Primarily the components tested are mechanical parts which are not tested or exercised in reliability tests at the phone level.

5.3 *Stress Screening*

Certain phones are subjected to stress screening to production and ramp up periods. The primary objective is to screen as many phones as possible at the early production stages and to introduce corrective actions through failure analysis before the full production ramp-up. When satisfied with the early life performance, an Ongoing Reliability Test (ORT) is introduced to monitor the manufacturing process stability. A typical stress screen profile would include temperature cycling between -30 and +85 deg C, power cycling with transmission during power on periods.

5.4 *Commercial Issues*

There are a number of commercial challenges mobile phones are facing in the current competitive market. These include; extended warranty, smaller and lighter phones, high availability (Improved field service), etc. It is anticipated that technological improvements in progress over the last few years will continue to address current and future challenges.

6.0 CONCLUSIONS

(1) The Mobile phone is subjected to very harsh environmental conditions compared to many commercial products.

(2) The traditional reliability demonstration process can be inefficient and misleading and needs to be replaced by a reliability growth tests with TAAF activities.

(3) Strife tests have not degraded test samples. This may be due to a reasons such as; applied stress levels not severe enough, test duration is inadequate or phones are robust. Particularly so as the test sample was subjected to reliability tests previously.

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