

Volume 2-Number 1-2020-3

DEVELOPMENT OF A REMOTE-CONTROLLED BIT-ERROR-RATE TESTER SYSTEM FOR AVIAT NETWORKS

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Abstract

Aviat Networks is a global provider of microwave networking solutions in public and private operators of communications networks. Its main product line is repairing and servicing microwave equipment outdoor units (ODU). The company follows 9 standard procedures in repairing, and soaking process is the focus of this study. Soaking process measures the unit's reliability via Bit Error Rate (BER). The BER testing consumes 72 hours testing and requires physical monitoring by an in-charge engineer. Added to this, if power interruptions occur, the testing is discontinued and task will be repetitive causing a delay to its customers. This study aims to develop a remote-controlled Bit-Error-Tester System that is operational and accessible off-site, convenient, efficient, secured, monitors in real time, and configurable. The conduct of the study had made use of interviews, observations, surveys, experimentation and evaluation using ISO 9126. Software and hardware tools were used in configuring the network and interfacing hardware. Results show that the actual monitoring performance of BER testing on-site as compared with the proposed BER testing off-site shows no significant difference, or the proposed remote control monitoring displays 98% efficiency in its performance. Furthermore, the adoptability of the system improved the soaking process by 30% during

the period of testing and implementation. This implies an improvement in the soaking process and consequently provides lead time service to the company's customers. It may be considered for future studies, the use of mobile phones for implementing the system.

Introduction

Wireless technology has an impact in our daily lives that humans are incomplete without its advent. One of which is the Microwave Communication Technology. Microwave link connection is a wireless communications system that uses radio frequency streaming in microwave frequency in order to transmit information or signals between two fixed locations on Earth. The broadcaster uses a microwave link to send applications and programs from the studio to a transmitter that is miles away. Cell sites that have microwave links carry cell phone calls from the transmitter to the receiver. Wireless Internet service providers use microwave links to provide their customers with high-speed Internet access without cable connection (Engineering and Technology History Wiki, 2014). The advent of microwave communications would not be possible without the use of equivalent modern equipment from distinct suppliers, support services, and maintenance services.

Aviat Networks is a global provider of microwave networking solutions, providing private and public operators with communications networks to accommodate the exploding growth of Internet Protocol (IP), multi-gigabit data services. Based in Santa Clara, CA, Aviat Networks also has operations in Africa, Asia and the Pacific Ocean, Europe, Mexico, the Middle East, Russia and South America. In June 2010, the company has transferred his corporate functions to Santa Clara from Morrisville, North Carolina. On January 26, 2007, Aviat was established with the merger of Harris Corporation and Stratex Networks microwave communications and was registered under the name of Harris Stratex Networks. The company was renamed itself to become Aviat Networks on January 28, 2010 (Aviat, 2010).

Aviat Networks has two major repair centers, one that is located in the Hamilton, United Kingdom and the other is situated in Clark Field, Pampanga-Philippines. The repair center in the Philippines had been operating for more than 15 years and is manned by Electronics Engineers as technicians. These technicians have been thoroughly trained abroad, which provide services sent by the following countries:: Ghana, Nigeria, Australia, USA, Ivory Coast, Thailand, Afghanistan, Malaysia, Sri Lanka, Congo, Nepal, Kenya, Bangladesh, Korea, Singapore, Somalia, Mexico, Puerto Rico, United Kingdom, Maldives, Liberia, Saudi Arabia, Gambia, New Zealand, Canada, Sierra Leone, Iraq, Benin, Brazil, Tanzania, Dominican Republic, Togo, Costa Rica, Burkina, Kuwait, Chile, Hong Kong, Fiji, South Africa, Gabon, Denmark, Lesotho, Laos, Bolivia, Belgium, Argentina, Nicaragua, Cameroon, Netherlands, Antilles, Bulgaria, Swaziland, Mauritius,

Trinidad and Tobago, Bermuda, Indonesia, Jordan, Lebanon, Switzerland, Libya, Honduras, Angola, India, Egypt, Ecuador, Yemen, Guinea, South Sudan and the Philippines.

Among its client in the Philippines are the following telecommunications companies: Smart, Globe, White Tribe (former Liberty Telecoms), and other private companies.

With its array of services, Aviat Networks follows strict processes for repairs of microwave equipment. For Outdoor Units (ODU), nine (9) steps are carefully observed: (1) screening and diagnosing; (2) testing links; (3) debugging; (4) reworking; (5) final testing; (6) calibration on the automated test station(ATS); (7) soaking process; (8) final auditing, and (9) ready for shipping (Aviat Networks, 2010).

One significant process for this study is the soaking process, which is done last among the actual repair processes. At this point, the unit's reliability via Bit-Error-Rate (BER) is measured, this will provide information if the unit under test passed the standard reference or measurement.

Adeyemo and Raji (2010) stated that BER is a key parameter that is used in assessing systems that transmit digital data from one location to another. BER is applicable to radio data links, Ethernet, as well as fiber optic data systems. In this study, data that were transmitted, are prone to errors. This results in the need for system performance assessment. In data communication, assessment of errors per data or bit is done using Bit Error Rate (BER). BER assesses the full end to end performance of a system (transmitter, receiver, and channel).

During the practicum period, the researcher observed and conducted a survey on BER testing, which is done during the soaking process. It was observed that BER testing consumes a large amount of time. For instance, there is a need for continuous monitoring of BER tester which usually lasted for 3 days/72 hours /259200 seconds. Repair & Return (R&R) Engineers usually performed it on-site, leaving it before weekends, the unit is then checked for any failures or occurrences of bit errors after weekends or usually the first business day, which is Monday. The observed amount of time consumed is practiced in order to give attention to other repairing tasks or processes. There are also observable instances that the technicians are required to physically check the unit even on weekends or holidays. This usually happens to assure the continuous testing of BER tester, and during which there is an expedite repair request from its client. Another situation that requires them to be physically present in the office while doing the soaking process is when the power interruption occurs, the BER tester would indicate a power failure, which will result in incorrect readings due to disconnection of BER tester to the unit under test. Failure on the BER test would require a re-run of the same procedure, this means it will consume another 3 days/72 hours /259200 seconds. If large BER is measured, the process will be prolonged. The microwave equipment unit under test will require undergoing debugging, which causes the delay in returning and delivery to its client. These are the

problems that the researcher needs to address in order to improve the BER testing of the soaking process of Aviat Networks.

As a result, the researcher developed a remote-controlled Bit-Error-Rate tester system for Aviat Networks to provide a system that is more productive, convenient, efficient, secured, off-site real-time monitoring, and configurable, which can be accessed by R & R Engineers even outside the company or off-site. The researcher believes that the developed system has met its objectives and will be able to help primarily the Engineers in contributing to the vision and mission of the company to be the recognized global innovation leader in wireless transmission solutions for next-generation IP networks.

Statement of the Problem

The general problem of this study is: How to develop a system that will remotely control and access BER tester equipment under soaking repair process in improving the overall repairing and servicing of microwave equipment at Aviat Networks?

Specifically, the study sought answers to the following questions:

1. Which among the working repair process of Repair and Return Engineers (R&R) needs innovation to improve the overall repairing of microwave equipment?
2. What is the current soaking repair process of the company in monitoring Bit-Error-Rate results of microwave links?
3. What innovation and solution must be considered to improve the Bit-Error-Rate testing under soaking process?
4. What are the hardware, software, and development tool requirements to develop the remote monitoring controlled Bit-Error-Rate tester system?
5. What are the features of the proposed system and the extent of controls that can be made for the Bit-Error-Rate tester off-site?
6. How acceptable is the system in terms of the ISO-9126 Software Quality Assurance Model in these quality characteristics
 - 6.1. functionality
 - 6.2. usability
 - 6.3. reliability
 - 6.4. performance and
 - 6.5 supportability?

Methodology

Systematic plan and organize data are vital so that the researcher can conceptualize the framework and effectively carry out the research. Thus, the researcher has adopted the action research in building the framework for the study and utilized the Modified Waterfall method in developing the system.

Action research refers to a wide variety of evaluative, investigative, and analytical research methods designed to diagnose the problem in an organization and develop a solution to address them quickly and efficiently.

The researcher had adopted the action research in this study to investigate the existing problems of Aviat Networks regarding their current processes and steps in repairing and servicing microwave equipment; and the current Bit-Error-Rate testing under soaking process. During the entire practicum period, the researcher observed and conducted a survey to the R&R Engineers about the current BER testing procedures that are being practiced. It was observed that BER testing is conducted manually, and moreover, is continued for three consecutive days. This leads to interruption of other important tasks of R&R Engineers, if the testing is severe, the possibility of repeating the whole BER testing must again be conducted. At this point, backlogged on other tasked is severely affected, and most importantly the delivery time for the company's client is compromised. These only show that there is a need to improve the overall repairing and servicing of microwave equipment of the company, in which the researcher would like to resolve.

The researcher utilized the use of the Modified Waterfall method in designing the system due to its simplicity, where all components needed can be determined prior to the development of the designed system (Munassar et al, 2010). The requirements must be stated before the design, unlike in pure waterfall, which has no overlap between stages, the modified waterfall enables the phases to overlap when needed.

Modified Waterfall Model emphasizes planning in the first stage, this is to consider possible issues before any process. This model also allows flexibility to return to the first stage (Munassar et al, 2010).

The stages of Modified Waterfall Model applied to the study:

Requirements Stage. At this stage, all the necessary information, datasheet of the electronic components, system compatibility, hardware specifications, and software availability were prepared, gathered and documented. The researcher conducted surveys and interviews with the R&R Engineers to further understand the details concerning the technical services being practiced in repairing and servicing of microwave equipment process. Inclusion to this, is the

pre-selection of related theories, literatures and studies from various references to serving as primary data or standard or references which were drawn from books, published journals, website articles, and other valid sources.

System and Software Design Phase. This includes necessary planning and problem-solving techniques to identify possible problem and requirements both for software and hardware. The researcher considered the details of the system's operation flow and specified the hardware, software and development tools needed to develop the system. The researcher also designed the block diagram and system flowchart that served as the basis for the structure and flow of the developed system.

Implementation and Unit Testing Stage. This stage examines the software components and produces a specification for how each component is implemented. The researcher examines the reference manuals of hardware and its specifications, after which the researcher studied the required software components. Upon consolidating the need information for hardware and software, the identified software for the system was installed in the test user's personal computer (pc). The developed system will imitate the function of an actual BER tester as used in the actual laboratory in the company. In this manner, the testing can be done anywhere outside the company.

Integration and System Testing Phase. It is the process of implementing the detailed design specification and determines whether the software meets the specified requirements and finds any errors present in the code. In this phase, the researcher had integrated the software program into hardware components. To ease the user of the development program, a graphical user interface was created and tested to check for any bugs, errors or possible adjustments. The researcher had run several testing to ensure thorough testing of the entire system for its functionality and operation. Errors had been encountered during the first phase of the trial, as a result, several adjustments and modifications have been conducted from the previous phase to correct the testing phase.

Operation and Maintenance Phase. Addresses problems and enhancement requests after the hardware and software releases. After meeting satisfies the desired objectives of the system, it was then introduced to R&R Engineers for the actual test. Several comments and suggestions had been accounted. To formalize the evaluation and assessment, the Engineers were requested to accomplish the evaluation forms. These forms are the research instrument to evaluate and to assess the acceptability and feasibility of the system. The comments, suggestions, and recommendations from the respondents were all welcomed by the researcher to further improve the performance and efficiency of the developed system.

Respondents of the Study

The respondents of the study were the immediate users or beneficiaries of this study, the Engineers of Aviat Networks. Since there are only six R&R engineers, all were able to participate and gave ample time for survey and interview. High interest can be observed from these engineers since they are the immediate users of the study. The same engineers who performed and handled outdoor unit of all microwave equipment, which is also the main services of the company. The following were the respondents, all of whom are ECE's and had international-extensive workshop and trainings: Engr. Jesus Eden Bulanadi, Engr. Ryan Concepcion, Engr. Darby Cordero, Engr. Allan Guido, Engr. Joseph Lenon and Engr. Bernardo Tumbaga. See Appendix F for the pictures of the researcher with the respondents.

Research Instruments

Survey forms and questionnaire to interview and evaluation were the research instruments used for this study.

These constructed forms consist of series descriptive statements and questions that will enable the researcher to statistically interpret the evaluation of the respondents. These forms were reviewed, checked, and approved by the research industry adviser after several modifications.

The forms consist of two parts: the respondent's profile and a table containing the set of criteria. The profile of the respondents includes only the relevant information needed for the study such as name, department, position and years of service. On the other hand, the evaluation table includes the quality factors based on the ISO-9126 Software Quality Assurance Model: the functionality, usability, reliability, performance, and supportability of the developed system. The researcher adopted the Likert scale. A table of the specification can be found in the forms to check whether the indicator variables are well presented in the scale.

Results and Discussion

Current Repairing and Servicing Process of the Company

The researcher presents the current existing system and its main concern is to identify the problem on which among the repair process of Repair and Return Engineers (R&R) needs innovation/s to improve the overall repairing of microwave equipment. In doing this, the researcher conducted the first survey which is divided into three portions. The first one, Survey Questionnaire A (See Appendix B), this is a survey for the Repair and Return Engineers, who handle current workflow repairing process of microwave equipment which consumes much time in repairing microwave equipment (ODU). Second, the Survey Questionnaire B (See Appendix B), this survey pertains to current workflow repairing process of microwave equipment which is too difficult to set-up in repairing microwave equipment (ODU). Lastly,

Survey Questionnaire C (See Appendix B), this survey is for current workflow repairing process of microwave equipment that needs the most improvement in repairing microwave equipment (ODU).

Figure 14 and 15 shows the eclipse repair area in R & R Department.

The Eclipse Repair Area is where the researcher was assigned and tasked to conduct the project study.

The block diagram of the steps and processes of repairing microwave equipment in Aviat Networks which was also observed and conducted by the group and the researcher.

Through the years, Aviat Networks (Philippines) has mastered its means in repair services. The overall repair process can be described in detail as follows:

Screening and Diagnosing entail inspection of the physical appearance of the unit and disassembly. In the screening, the unit's transmitter power output is tested using power meter & power sensor; and receiving signal output is tested using the signal generator. Transmitter power output and received signal level are compared with the equipment's data sheet. If there is no match in the results, it indicates that there is an error.

Testing links include putting the unit in a microwave link. Using the company's software, the configuration can be made on the equipment plug-ins of the computer. The equipment checks whether its functions such as alarms, link performance, and parameters are working based on the set of standards.

Debugging is done when a fault is found. When the transmitter power cannot meet the appropriate power levels, a spectrum analyzer is used to check the different gains of the Radio Frequency Integrated Circuit (RF IC) Amplifier in reference from its data sheet. Afterwards, the faulty ICs can be detected and be replaced later on. When the received signal level cannot meet the appropriate signal levels, a spectrum analyzer checks the output of the local oscillator (LO) and using a Multimeter, the bias voltage and voltage rails are checks in reference with its schematic diagram.

Re-working is the replacement of the faulty component or IC. This is done using soldering (pen-type soldering station) Metcal or ball grid array (BGA) rework machine.

Final Testing comprises the reassembly of the unit and re-testing of links.

Calibrating is placing the unit in the Automated Test Station (ATS), it is a machine station where all the test equipment are connected via general purpose interface bus (GPIB), for at most two hours for calibration. In here, unit's parameters are check if it meets the required standards through the machine's calibration file. Calibrating of ODU's, are made by using another ODU as

a receiver, then it is paired via a microwave link that simulates the actual performance of the ODU.

Soaking process is placing the unit in a microwave link continuously for a minimum of 72 hours or 3 days via a tester (FIREBERD6000A) to monitor its bit error rate (BER). If the BER tester shows an unacceptable level of error, which should not be greater than 1×10^{-6} , the unit must be returned to debugging. If no error is found, the unit proceeds inside an environmental test chamber for 72 hours, or that could be done 8 hours a day for three cycles of hot and cold temperature ranging from -30°C to $+55^{\circ}\text{C}$ to see the unit performance in simulated/actual working conditions. Then, the unit can proceed to its final audit.

For final auditing, the unit is reassembled and labelled properly. Documentation is made through its course of repairs and testing. Finally, the unit is now ready to be returned to the company's client through shipping.

During the practicum period, the researcher was able to work along with R&R Engineers, who were trained here and abroad to have hands-on repair and test of microwave communication equipment. See Appendix G for the researcher performing the process of repairing microwave equipment.

Final Audit Documentation of Course Repair of ODU's was written on Aviat Networks Traveler Form. See Appendix H for other traveler forms that the proponent repair while having practicum in Aviat Networks.

The following were the findings in the evaluated surveys. The tables shown hereafter are the overall ratings of the R&R engineers on the repair process.

Table 1 presents the evaluated survey A: Survey to the Repair and Return Engineers in AVIAT Networks on which current workflow repairing process of microwave equipment's which consume much time in repairing microwave equipment (ODU).

Table 1

Survey Result on Time Consumption of Repairing Microwave Equipment

Time Consumption of Repairing Microwave Equipment (ODU)	5	4	3	2	1	Mean	Remarks
Screening and Diagnosing	2	4	0	0	0	4.33	Slightly Time Consuming
Testing Links	0	2	4	0	0	3.33	Time Consuming
Debugging	0	0	1	1	4	1.50	Mostly Time Consuming
Reworking	0	1	2	3	0	2.67	Time Consuming
Final Testing	1	1	4	0	0	3.50	Time Consuming
Automated Test Station (ATS) or calibration station	0	0	2	3	1	2.17	More Time Consuming
Soaking Process (BER Testing)	0	0	0	1	5	1.17	Mostly Time Consuming
Final Auditing	0	5	1	0	0	3.83	Slightly Time Consuming
Ready for Shipping	1	5	0	0	0	4.17	Slightly Time Consuming
Total Mean		2.96					Time Consuming

Table 1 shows that debugging and the soaking process are the most time-consuming yielding means of 1.50 and 1.17 respectively. The total mean is 2.96 remarked as time-consuming.

Table 2 presents the evaluated survey B: survey on which current workflow repairing process of microwave equipment which is too difficult to set-up in repairing microwave equipment (ODU).

Table 2

Survey Result on Setting up of Repairing Microwave Equipment (ODU)

Setting up of Repairing Microwave Equipment (ODU)	5	4	3	2	1	Mean	Remarks
Screening and Diagnosing	2	1	0	2	1	3.17	Average to Setup
Testing Links	0	1	5	0	0	3.17	Average to Setup
Debugging	1	1	4	0	0	3.50	Average to Setup
Reworking	1	3	2	0	0	3.83	Easy to Setup
Final Testing	0	3	3	0	0	3.50	Average to Setup
Automated Test Station (ATS) or calibration station	0	2	4	0	0	3.33	Average to Setup
Soaking Process (BER Testing)	0	0	1	5	0	2.17	Hard to Setup
Final Auditing	0	3	1	2	0	3.17	Average to Setup
Ready for Shipping	2	1	0	3	0	3.33	Average to Setup
Total Mean	3.24				Average to Setup		

Table 2 shows that the soaking process is difficult or hard to set up with a mean score of 2.17.

The total mean score is 3.24 which means that the entire process, in general, is moderately difficult or average to set up.

Table 3 presents the evaluated survey C: survey on which current workflow repairing process of microwave equipment which needs to improve the most in repairing microwave equipment (ODU).

Table 3

Survey Result on Improvement of Repairing Microwave Equipment

Improvement of Repairing Microwave Equipment (ODU)	5	4	3	2	1	Mean	Remarks
Screening and Diagnosing	3	2	0	1	0	4.17	May Need Improvement
Testing Links	0	4	1	1	0	3.50	Slightly Needs Improvement
Debugging	0	1	3	1	1	2.67	Slightly Needs Improvement
Reworking	0	3	2	1	0	3.33	Slightly Needs Improvement
Final Testing	0	0	4	2	0	2.67	Slightly Needs Improvement
Automated Test Station (ATS) or calibration station	1	0	4	1	0	3.17	Slightly Needs Improvement
Soaking Process (BER Testing)	0	1	1	1	3	2.00	Needs Improvement
Final Auditing	5	0	1	0	0	4.67	Doesn't Need Improvement
Ready for Shipping	5	0	0	1	0	4.50	May Need Improvement
Total Mean	3.41				Slightly Needs Improvement		

Table 3 shows that the soaking process needs improvement with a mean score of 2.00. The total mean score is 3.41 which means, in over-all slight improvement is necessary.

The Current Soaking Repair Process of the Company in Monitoring Bit-Error-Rate Results of Microwave Links

After the conduct of the first survey, it was found out that among the workflow process in repairing and servicing microwave equipment it is the soaking process that needs innovation and improvement. The researcher conducted another survey to the respondent's experiences on Bit-Error Testing under the current soaking process.

Table 4 presents the survey result based on the experiences of the respondents on Bit-Error-Rate testing.

Table 4

Survey Result on Experience in Bit-Error-Rate Testing Under Soaking Process

Experienced in BER Testing Under Soaking Process	5	4	3	2	1	Mean	Remarks
Accuracy of Bit Error Test	3	3	0	0	0	4.50	Very Satisfactory
Consistency on Continuous Monitoring	0	0	3	3	0	2.50	Needs Improvement
Completed within the expected 3 days	3	3	0	0	0	4.50	Very Satisfactory
Dependent on the reliability of the ODU	2	3	1	0	0	4.17	Very Satisfactory
Remotely accessible	0	0	1	1	4	1.50	Poor
Convenient to test during weekends and holidays	0	0	0	4	2	1.67	Needs Improvement
Ability to verify repair ODU during weekends required to be shift on Monday	0	2	2	1	1	2.83	Satisfactory
Bit Errors Found(determine if passed or failed)	1	4	1	0	0	4.00	Very Satisfactory
Total Mean						3.21	Satisfactory

Table 4 shows that the accuracy of the bit error test, the completion within the expected 3 days, the dependent on the reliability of the ODU, and the Bit Errors Found(determine if passed or failed) attained a total mean of 3.21 with a descriptive rating of satisfactory. Whereas, the remote accessibility is poor with a mean score of 1.50. Though the overall rating is satisfactory with a mean score of 3.21, the design solutions for outstanding results is still achievable.

The researcher prepared set of questions to conduct an interview to the same set of respondents, refer to Appendix B for the interview questions. Most of the R&R Engineers have similar answers with regards to most questions. The following are the responses based on the interview conducted: 1) the typical schedule is from Monday to Friday, 8:30 am to 5:30 pm. When needed, working during holidays and in some special cases are considered as overtime, 2) There are instances when there are emergencies or urgent repairs that need to attend to on the weekends or holidays, 3) Though there is a wide range of microwave equipment being service, the common equipment that the R&R engineers repair are Eclipse IDU's and ODU's, 4)The general workflow in microwave equipment involves the following process: *Screening and Diagnosing* means checking the unit physically for defects or any type of damages, *Testing* means testing the unit, finding what kind of fault encountered in the unit. When a unit is found faulty it will undergo in the process of debugging, *Debugging* is the process in-depth checking of the unit using circuit analysis, schematic diagrams, and data sheets. After debugging, when a faulty component is found it will be pulled-out, isolate, and proceed in the process called Rework. *Reworking* means replacing the faulty component with working component. Final Test

is conducted when the unit will be tested on a working link. For ODU's, the test includes an

Automatic Test Station ATS/ *Calibrating*, the unit needs to pass the parameters required that will last for about two hours. *Soaking Process* is placing the test unit in a microwave link continuously for a minimum of 72 hours or 3 days via BER tester (FIREBERD6000A) to monitor its bit error rate (BER). If the BER tester shows an unacceptable level error of not greater than $1 \times 10E-6$, the unit must be returned to debugging. If none, the unit proceeds inside an environmental test chamber for 72 hours that could be done 8 hours a day for three cycles of temperature ranging from -30°C to $+ 55^{\circ}\text{C}$ to see the unit performance in simulated/actual working conditions. Then, the unit can proceed to its final audit. *Final Auditing* refers to reassembling and labeling of the tested unit. A documentation (traveller form) is secure from R & R department to certify that it had been repaired and tested and now ready to be released for shipping. 5) Screening and diagnosis is the easiest part of the repair process, whereas debugging varies given certain parameters. The soaking process needs special attention, 6) Different problems among units give a wide range of time of repair, but are always completed on the standard service time of 20 to 30 days. Among the processes, the soaking process takes 3 days of continuous monitoring via BER tester, 7) It is evident that the R & R engineers agree that the soaking process has a lot to improve, and one way to innovate it is by having remote access, 8) The FIREBERD (6000A) BER tester and the environmental chamber are the equipment used for the soaking process. The former equipment measures BER whereas the latter is for simulating the outdoor scenarios, 9) BER testing is essential because it measures how much the microwave equipment transmit data correctly or in an acceptable tolerance level of error. Very low BER means the equipment can move on to the next process of repair, 10) There is no remote access with the BER tester, 11) It is possible to set and leave the equipment for the weekends or holidays. However, any intervention or monitoring would require physical presence of the R & R engineers in the repair center, 12) BER test results can only be observed when inside the company, and at present, outside observation is not possible 13) Sometimes, clients ask for a fast service of their equipment, which R&R engineers are obliged to do the work even on weekends or holidays or even render an overtime on Friday, 14) During power interruption, the BER tester would indicate power failure. It would have incorrect readings because of the discontinuity of the connection among the BER tester and the tested equipment, 15) Failure on the BER test would require a rerun of the same process. Another 72 hours will be consumed and if a large BER is found, it will proceed again to debugging. On the other hand, if the equipment passed the test, it will proceed for the final audit.

In the processes of repairing and servicing microwave equipment, from screening to calibrating, the R&R Engineers and the researcher always follow their standard references which are found in the data sheets and manual which contains the block diagram of the microwave equipment. The researcher has given privilege tasked to repair some of the ODU. In order to do so, the first

action that was taken is to study the block diagram of a typical ODU radio. The Aviat Network's ODU radio has the typical block diagram as shown in Figure 18.

ODU 300ep for 5 to 15 GHz and 18 to 38 GHz, differ in respect of the synthesizers used to derive the signal sources for the transmitter (Tx) and receiver (Rx) mixer stages. For the 5 to 15 GHz ODU, separate synthesizers are used. For 18 to 38 GHz, a common synthesizer is used. The quadrature modulated 311 MHz IF signal from the RAC is extracted at the N-Plexer and passed via a cable AGC circuit to an IQ demodulator/modulator. Here the 311 MHz IF is demodulated to derive the separate information (I) and quadrature (Q) signals using the 10 MHz synchronizing reference signal from the RAC. These I and Q signals modulate a Tx intermediate frequency (IF), which has been set to a specific frequency between 1700 and 2300 MHz, such that when mixed with the Tx local oscillator signal (TXLO) in the subsequent mixer stage, provides the selected transmit frequency. Both the IF and Tx local oscillators are synthesizer types. Between the IQ modulator and the mixer, a variable attenuator provides software adjustment of Tx power. After the mixer, the transmit signal is amplified in the PA (Power Amplifier) and passed via the diplexer to the antenna feed port. A microprocessor in the ODU supports configuration of the synthesizers, transmit power, and alarm and performance monitoring. The ODU microprocessor is managed under the NCC microprocessor, with which it communicates via the telemetry channel. A DC-DC converter provides the required low-voltage DC rails from the -48 Vdc supply.

In the receiver side, the signal from the diplexer is passed via the LNA (Low Noise Amplifier) to the Rx mixer, where it is mixed with the receive local oscillator (RXLO) input to provide an IF between 1700 and 2300 MHz. It is then amplified in a gain-controlled stage to compensate for fluctuations in receive level, and in the IF mixer, is converted to a 126 MHz IF for transport via the ODU cable to the RAC. The offset of the transmit frequencies at each end of the link is determined by the required Tx/Rx split. The split options provided are based on ETSI and FCC plans for each frequency band. The actual frequency range per band and the allowable Tx/Rx splits are range-limited within Eclipse to prevent incorrect user selection. A power monitor circuit is included in the common port of the diplexer assembly to provide the measurement of transmitted power.

It is used to confirm transmit output power for performance monitoring purposes, and to provide a closed-loop for power level management over the specified ODU temperature and frequency range. (Source: Eclipse User Manual Aviat Networks, 2008)

After the repaired ODU undergoes the processes of screening to calibrating, it will now proceed to BER testing under soaking process.

The current soaking process of repairing microwave equipment starts with the setting-up and configuring microwave test links. For ODU's, another ODU as a receiver is paired and connected

via a microwave link that simulates the actual performance of the ODU, putting a unit in a microwave link continuously for a minimum of 72 hours or 3 days using a tributary cable to the Bit-Error-Rate tester(FIREBERD6000A) to monitor manually its bit error rate.

Innovation to Improve the BER Testing Under Soaking Process

The researcher developed a system that remotely controls, real-time monitor and access BER tester equipment under soaking repair process which is more productive, convenient and efficient to improve the overall repairing and servicing of microwave equipment that will be used by the R&R Engineers of Aviat Networks.

The main concept of this project was to establish a remote-controlled BER tester for Aviat Networks. It starts with testing the links of the microwave equipment's which are both connected to a BER test instrument. It is then connected to a computer with graphical instrument program using Vee Pro. There is also access to the company private network and servers, via username and password of authorized personnel, which is then connected to the internet via VPN. For outside used or access, the developed system can be monitored and controlled remotely with a computer that also has Vee Pro. Access is allowed to users with authorized username and password. In this manner, the attached computer to the BER tester is mirrored to the offsite computer or the process perform on-site is can now be performed off-site.

The Hardware, Software and Development Tool Requirements

Table 5 presents the hardware requirements of the system.

Table 5

Hardware Requirements of the System

Category	Recommended
ON-SITE	
Aviat Network Microwave Equipment Link	ODU 300 (See Appendix C for datasheet)
BER Tester	Tektronix FIREBERD6000A (See Appendix E for manual)
Desktop Computer	Company's Desktop Computer (Test PC)
Cable connector from BER tester to IDU	Tributary Cable Connector
Cable connector from BER tester to Desktop Computer	Test Instrument Communication Protocol Adapter (GPIB card) National Instrument GPIB-USB
OFF-SITE	
Remote Computer	Company's Laptop Computer

The researcher recommends hardware requirements for on-site and off-site. For on-site requirements, the researcher used the ODU 300 paired in (in-door unit) IDU for the Aviat Network Microwave Equipment Link and this is subject to BER testing. For BER Tester the

researcher recommends the FIREBERD6000A. For the on-site desktop computer, the researcher

recommends the company desktop computer as Test PC which has the registered username and password of R&R Engineer and is connected to the company's network internet. For the cable connector from BER tester to IDU, Tributary Cable Connector is recommended. For cable connector from BER tester to Desktop Computer/Test PC, the Test Instrument Communication Protocol Adapter (GPIB card) the National Instrument GPIB-USB is recommended. For the off-site hardware requirements, the researcher highly recommends the company's laptop computer given to each R&R Engineer, which has the registered username and password of the user for security purposes.

Table 6 presents the software and development tools requirements of the system.

Table 6

Software and Development Tools Requirements of the System

Category	Recommended
ON-SITE	
Operating System (Test PC)	Windows XP and above
Aviat Microwave Equipment Software	Aviat Microwave Equipment Portal
Graphical Dataflow Programming Software	Agilent VEE Pro (See Appendix E)
Internet Connection	Company's Internet and Server
OFF-SITE	
Operating System (Company Laptop PC)	Windows XP and above
Remote Desktop Connection and VPN software	Pulse Secure VPN (with password)
Internet Connection	1 Mbps or faster data rate

The researcher recommends software and development tools requirements for on-site and off-site. For on-site requirements, the researcher recommends a Test PC with an operating system of Windows XP and above. The researcher used the Aviat Microwave Software which is the Aviat Microwave Equipment Portal to configure the ODU in creating microwave links with the supervision of R&R Engr. For the Graphical Dataflow Programming Software, the researcher recommends the Agilent VEE Pro For off-site or remotely access, the company's laptop is recommended which has an operating system of Windows XP and above and registered username and password. For Remote Desktop Connection and VPN software, the researcher recommends Pulse Secure VPN with username and password, which is connected to the head office VPN for a secure connection and security purposes. In addition, a reliable and fast internet connection is highly recommended for the operation and remote access to the Test PC containing VEE Pro program.

Figure 27 to 29 shows the actual software and development tools requirements used in the system.

Figure 27. Aviat Network portal

The Aviat Networks portal is a software tool used by Repair and Return Engineers to configure and create microwave links for the microwave equipment.

The Test PC or the desktop computer in the Aviat Networks is installed with Graphical Dataflow Programming software Agilent VEE Pro to clone same functions of the Bit-Error-Rate Tester.

The Virtual Private Network (VPN) software is used with the Pulse Secure tool which is installed on the remote computer/laptop. It has log-in with username and password of the authorized personnel and Engineers of Aviat Networks.

Features of the Developed System

The developed system starts at powering-up the BER tester (FIREBERD6000A) and the microwave radio link, configure and confirm that there are no alarms, then BER Tester cables is to be connected to microwave link set up, activate BER Tester, and confirm 0 error displayed, if 'yes' then proceed to GPIB connection to BER, if 'no' check the BER tester if it is power up. After the connection of GPIB with BER, start and run the VEE program, if the BER tester detected by VEE? If yes, access the Test PC (containing VEE) via remote PC through internet/VPN (Pulse Secure) with username and password, if no, check the GPIB connection to BER Tester. Then check if the results viewable on the remote PC and can the BER tester be controlled? If yes, BER Test Results, if no check GPIB connection to BER Tester.

The program flowchart was made from Graphical Dataflow Programming Software the VEE Pro because Agilent VEE Pro can control any standard instrument and many vendor's PC plug-in cards with an instrument driver, a vendor-supplied DLL, or via Agilent VEE Pro's easy and powerful Direct IO capability. Instrument addresses and other parameters can be verified at runtime and changed on the fly, without reconfiguring programs. Agilent VEE Pro automatically handles different data types, providing automatic conversion and giving you powerful data handling capabilities with a minimum of complex programming. Agilent VEE Pro programs also can be monitored and diagnosed remotely via the web or network.

The researcher made use of this software to create the program needed with the graphical user interface to have the same functions that of the actual BER Tester. Programmable visual language and commands from the FIREBERD6000A were used to build the program and interface. The functions included in the panel view are title text display, bit error counter, timer, and basic controls to manipulate the program.

The panel view shows the actual real-time reading from the BER Test Equipment (FIREBERD 6000A)

The main feature of the developed system was that the BER can be accessed remotely by the R&R Engineers. It monitors in real-time and it has the basic extent of controls to make some

configuration and intervention if necessary even outside the company such as the BER count, reset, and quit. When accessing the Test PC (containing VEE) via remote PC through internet/VPN, the test pc will be locked requiring the username and password of the head supervisor Engineer, Sir Joseph Lenon. For the Pulse Secure VPN software, credentials of Engineers are needed for security purposes. For the remote PC, the company's laptop given o Engineers is the allowable pc to use with their username and password as well.

Testing and Evaluation of the Developed System

Actual testing is one of the challenging and important phases to check if each component of the system developed is working properly as it was planned and designed. The researcher conducted several test trials on the developed system with six different ODUs.

Table 7 presents the trial testing of Bit-Error-Rate.

Table 7

Trial Testing of BER

Microwave Equipment	Elapsed time (sec)	BER Count FIREBERD6000A	BER Count Test PC (On-Site)	BER Count Laptop (Off-Site)
ODU 1	634	0	0	0
ODU 2	1931	3	3	3
ODU 3	12	0	0	0
ODU 4	3700	308	308	308
ODU 5	259200	198139	198139	198139
ODU 6	84002	67543	67543	67543

The summary of testing of the ODU microwave equipment is shown in table 7, containing the following: elapsed time in seconds, comparison of the BER count results on-site are the FIREBER6000A, Test PC containing the developed graphical program using VEE Pro, and the off-site BER Count using the company laptop. Based on the test results the BER count of the on-site has no difference with the off-site.

The accuracy of the results of BER count of the FIREBERD6000A Tester with the BER count on Test PC compared to BER Count of the remote computer/laptop can be quantified by calculating the percent error. The percent error is defined as the ratio between the difference of the true value and experimental value to the true value multiplied by 100.

For the trial testing of BER, the true value is the BER count on FIREBERD6000A with the Test PC and the experimental value is the BER count on the remote computer/laptop.

The percent error for all the trial testing of the Bit-Error-Rate count of the Microwave Equipment Outdoor Units (ODU) was 0% which means that the results were accurate.

The researcher compares the elapsed time and BER count of the FIREBERD6000A and in the Test

PC containing program using VEE Pro.

Evaluation of the System's Level of Acceptability

The researcher conducted an evaluation by means of a survey to determine the level of its acceptability and feasibility of the system. The respondents were the R&R Engineers, who rated the functionality, usability, reliability, performance, and supportability of the system using the provided evaluation forms structured in Likert format.

After the evaluation, the researcher analyzed the collected data by computing for their weighted means and interpreted them using the Likert scale to determine whether the results are highly acceptable, acceptable, neutral, unacceptable or highly unacceptable.

Table 8 presents the descriptive measure of the system's level of acceptability in terms of functionality.

Table 8

Over-all Mean and Verbal Interpretation of the System's Acceptability

Evaluation Criteria	Average Mean	Verbal Interpretation
Functionality	4.61	Highly Acceptable
Usability	4.17	Acceptable
Reliability	4.56	Highly Acceptable
Performance	4.50	Acceptable
Supportability	4.67	Highly Acceptable
Overall Mean	4.50	Acceptable

The results of the system's evaluation were interpreted as "highly acceptable" in terms of its functionality, reliability, and supportability criteria and "acceptable" for the usability and performance. Overall, the evaluation results were interpreted as "acceptable" with an average mean of 4.50.

The respondents have seen the system's performance with consistency on giving correct BER count on the BER tester of microwave link of microwave equipment both on-site and off-site monitoring.

Findings show that improvement in the soaking process could be much improved when monitored remotely the BER testing of microwave links; it is much convenient, saves time, observes productivity, and most importantly the ability to make interventions if necessary using the extend controls of the program such as the reset control.

Conclusions

Based on the results and findings of the study, the following can be concluded:

1. Among the repair process, the soaking process is the most time consuming, hard to set-up and needs improvement. The current BER testing under soaking process can be done only inside

the company, requiring the R&R Engineers to render overtime or obliged to do the work even

on weekends or holidays in order to check the BER results and make necessary interventions if the power interruption occurs. Failure on the BER test would require a re-run of the same process. Another 3 days/72 hours/259200 seconds of time will be consumed. A test unit will proceed to debug if worse BER had been observed causing a delay of service to its client.

2. The developed system provides innovation and improvement on BER testing under soaking process through remote access. This improves the user's productivity, provides convenience, improves user's efficiency, and prevent delayed repairs to clients.

3. The system is tested and evaluated by the respondents and it was proven to be helpful in monitoring and controlling the BER tester undergoing the soaking process remotely at the respondent's convenience.

4. The respondents strongly believe that the developed remote-controlled BER tester system for Aviat Network can significantly improve the soaking process and the over-all repairing services of microwave equipment, therefore recommended for its implementation.

Recommendations

The following are recommended based on the comprehensive summary and conclusions for future studies:

1. The R&R Engineers may also consider the developed system in BER testing of other Aviat microwave equipment.

2. A sound notification may be added whenever there is a bit error count to inform R&R Engineer and make necessary actions.

3. Future researchers can conduct feasibility studies regarding remote-controlled BER tester that can be accessed using a mobile phone with Android application.

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