**Attachment 1**

**LabVIEW Software Development Statement of Work**

1. **Period of Performance:** 
   1. Work must be completed in either one of two windows:
   2. Before 24 May 2015
   3. From 20 June to 26 July 2015
2. **Operating Procedure** 
   1. Configuration of test properties
      1. PNA is 100% configured at startup with previous setup from config panel.
      2. Configuration may be changed with config panel , Save and Restart button.
      3. Start automatic test does \*\*not\*\* configure before starting.
         1. Therefore the operator may manually set up the PNA, then start a test.
      4. Software does not read PNA settings back into the host PC.
   2. Manual.
3. **Background:**
4. The Earth Observing Laboratory (EOL) of the National Center for Atmospheric Research (NCAR) has developed a “brick” TR (transmit/receive) module printed circuit board (PCB). This board contains eight (8) TR modules, whose performance must be characterized automatically using a two port Agilent N5222A Vector Network Analyzer (PNA). The test setup for receive is illustrated in Figure 1; the test setup for transmit is similar, but involves a different physical connection for Port 1.
5. 
   * 1. *Figure 1: Test setup for Receive*
6. The “brick” TR module PCB communicates directly with the Array Controller (Zedboard) via an LVDS serial protocol. A laptop communicates with the Array Controller (AC) using a simple UDP protocol over a standard Ethernet connection. It also communicates with the PNA over a National Instruments (NI) USB to GPIB connection.
7. Each TR module on the “brick” is fed by a common RF input on transmit and produces a common RF output on receive; RF IN or RF OUT are connected to Port 1 of the PNA. Each TR module also operates in one of two polarizations, horizontal or vertical. The vertical or horizontal polarization is available at Port 2 of the PNA. Each TR module also has a 6 bit phase shifter and a six bit attenuator. The performance of each TR module must be characterized for each phase shift, each attenuation value, at both vertical and horizontal polarizations and for both transmit and receive modes. Table 1 is an example of a possible measurement sequence which could be used to characterize a single brick TR module PCB.

|  |  |  |  |
| --- | --- | --- | --- |
| 1. TR Mod # | 1. Mode | 1. Polarization | 1. # Measurements |
| 1. 1 | 1. Receive | 1. Horizontal | 1. 4096 |
| 1. 1 | 1. Receive | 1. Vertical | 1. 4096 |
| 1. 1 | 1. Transmit | 1. Vertical | 1. 4096 |
| 1. 1 | 1. Transmit | 1. Horizontal | 1. 4096 |
| 1. 2 | 1. Receive | 1. Horizontal | 1. 4096 |
| 1. 2 | 1. Receive | 1. Vertical | 1. 4096 |
| 1. 2 | 1. Transmit | 1. Vertical | 1. 4096 |
| 1. 2 | 1. Transmit | 1. Horizontal | 1. 4096 |
| 1. . |  |  |  |
| 1. . |  |  |  |
| 1. . |  |  |  |
| 1. 8 | 1. Receive | 1. Horizontal | 1. 4096 |
| 1. 8 | 1. Receive | 1. Vertical | 1. 4096 |
| 1. 8 | 1. Transmit | 1. Vertical | 1. 4096 |
| 1. 8 | 1. Transmit | 1. Horizontal | 1. 4096 |

1. *Table 1: Possible measurement sequence for 1 brick TR module PCB*
2. Human intervention is required between each series of 4096 measurements to change the PNA connections for the next series of measurements. A full system will consist of multiple PCBs each with a unique identifier. PNA S parameter measurements must be archived in such a way as to preserve the unique identity of the PCB, TR module and measurement performed.
3. **Scope of work:**
4. Develop a LabVIEW VI that executes an automatic test on a single “Board”, as described above. ***Existing LabVIEW software may be leveraged for this purpose. Its functional assessment is provided in Appendix A.*** The VI will provide a means for manually commanding the AC via a GUI. The LabVIEW VI will also execute a full board test that covers all V, H, phase shift, and attenuation settings for transmit and receive for each TR module. It will also execute partial testing for any subset of V, H, phase shift, and attenuation. This VI will run on one Windows PC in LabVIEW development mode and as an executable. The PC, instrumentation, sensors, cabling, and any other necessary hardware will be supplied by NCAR/EOL. Some programming and system integration will need to be performed onsite.
   1. Equipment List
      * 1. The VI will programmatically control the following devices. The combination
        2. of the devices, the PC, and interconnecting cabling can be considered the Test
        3. Station (see Figure 1).
      1. Array Controller (AC)
      2. Agilent N5222A PNA
   2. Breakdown of the LabVIEW VI functionality
      1. *Maintain configuration of the Test Station in a persistent file; this*

*includes but is not limited to:*

1. PNA address
2. AC address and port
3. PNA cal file name
4. may include location of data files
   * 1. *Dialog or screen for collecting “test properties.”*
5. Operator
6. Board number
7. TR Numbers
8. Test script name
9. Data file name
10. All applicable properties in the N5222A Stimulus menu. These properties will be maintained in a persistent file because there are many and they probably won’t all change often.
11. Date and Time stamp is automatically recorded.
    * 1. *Execution - Manual Mode*

Provide a LabVIEW window to send the following AC commands. No data will be saved in this mode.

1. Direct out
2. TR Address
3. Select Command
4. Phase Shift (deg)
5. Attenuation (dB)
6. Temperature
7. Reset
   * 1. *S Parameter Sweep Test VI*

This LabVIEW VI will perform a single automatic test. This test will be

called repeatedly during automatic test. This test is defined as:

1. Prompt the operator to cable
2. Initialize and send the stimulus settings to the PNA as needed
3. Record temp with the AC temperature command
4. For multiple phase shift and attenuation combinations:
5. Send the AC direct out command to configure a single V or H

channel

1. Perform a single N5222A sweep
2. Retrieve and save the data
   * 1. *Execution - Full Auto Mode*

Execute test on entire board. This test performs multiple S Parameter sweep tests, as defined in paragraph 4.b.iv, for both Vertical and Horizontal ports, for both transmit and receive modes, for each of the 8 TR modules on the PCB (see Table 1).

* + 1. *Execution - Partial Mode*

A means will be provided that will enable a partial test, a subset of the full

auto mode test. An example of this would be to test all combinations of

phase shift and attenuation for a single V channel for receive. A partial

data file will be saved.

* + 1. *Execution - Prompts for the operator*

All modes except manual mode include text prompts to the operator for RF cabling.

* + 1. *Front Panel Execution Controls*

1. Enter test properties from ii
2. Start
3. Terminate
4. Pause
5. Resume
6. Exit the VI
   * 1. *Front Panel Indicators*
7. Progress indication - current TR #, R or T mode, V or H port, phase shift value, attenuation value, and %complete
8. Latest sweep result displayed
   * 1. *Data file*
9. One data file will be saved for each test execution.
10. Data may be inserted into an existing data file.
11. Data may overwrite data in an existing data file.
12. A new file may be created.
13. A data file for a full auto board test will be about 2.5 GB in size.
14. Data will be formatted as .csv, in the same way as the PNA data files.
15. Data file columns are defined:
16. **Freq(Hz),S11(DB),S11(DEG),S12DB),S12(DEG),S21(DB),S21(DEG),S22(DB),S22(DEG),TR Address, Select Command, Phase Shift (deg), Attenuation (dB), temperature, SectionTAG** 
    1. Note: SectionTag is another column to quickly ID the section for retest section replacement, or additional test insertion eg. RV3-95.625-21.5 (Rx/Tx, V/H, chan., PS, Atten).
    2. Instrument driver for the AC
       * 1. An instrument driver will be created for the AC according to National
         2. Instruments guidelines published at ni.com/idnet.
17. **Deliverables**
18. LabVIEW 2014 source code, main VI and sub-Vis as described in paragraphs 4.b and 4.c.
19. LabVIEW .lvproj file with .exe and installer build scripts
20. LabVIEW .exe for main VI
21. **Additional Information**
22. All equipment and any other necessary hardware will be supplied by NCAR/EOL. Some programming and system integration will need to be performed onsite.
23. NCAR/EOL will have an engineer that is familiar with the system hardware available to answer questions and explain the system on an ongoing basis.
24. **Appendix A**
25. ***State of Existing LabVIEW software.***
26. Following VIs were evaluated.
    1. configuration.vi for Array Controller
       * 1. This VI contains three UDP commands to the array controller, d, temperature, and reset. The UDP command appears to be constructed as a comma separated string: Address, T, R, H, V, Phase, Attenuation
         2. Status: Recommend creating a LabVIEW instrument driver library for the array
         3. controller per the guidelines at ni.com/idnet
    2. Agilent PNA Series.lvproj for Agilent N5222A PNA
       * 1. This is a LabVIEW instrument driver library that was downloaded from ni.com/idnet.
         2. Status: This is a good instrument driver library. No additional work is needed, but
         3. the vendor may possibly need to add a couple commands to it.
            1. Need to create an example VI that runs the sweep test onboard the PNA
         4. N52222A, and returns the .csv data file to LabVIEW at the end of the test.
    3. PNA\_TRACE\_DATA\_SCPI.vi for Agilent N5222A PNA
       * 1. This is a VI that uses raw scpi commands to control the N5222A.
         2. Status: Do not use this VI. Do not use this style. Agilent PNA Series.lvproj
         3. instrument driver (b.) should be used for all control of the N5222A PNA.
    4. LabVIEW Codes Handbook
       * 1. Contains some useful context for the existing system
         2. and software.