

# MWA Beamformer Measurements at ASU

Hamdi Mani, Judd Bowman

**Abstract**—The MWA beamformer was measured on the radio astronomy/cosmology lab at ASU. The crosstalk between the adjacent channels of the same polarization as well as the cross talk between inputs of different polarization were measured and were found to be lower than 30dB. The gain of one channel was measured and was found to vary from 36dB at 80MHz to 31dB at 300MHz. The delay of one channel was also measured with different delay settings. The goal of these measurements is to characterize the beamformer and get some familiarity with the hardware/software to allow its use for the experimental 4 X 4 MWA tile at ASU.

**Index Terms**— Analog beam forming, antenna, phase array antennas, square kilometer array...

## I. INTRODUCTION

The MWA beamformer is an analog beamformer based on selectable delay lines of different length. The delay lines are selected using a Labview program that talks to a microcontroller board (ARDUINO) which controls solid state switches mounted on a large FR4 board.

The beamformer combines the signals from 16 elements from each polarization. The 2 X 16 signal outputs of each 4 X 4 tile are combined using one beamformer box and the combined outputs X and Y are sent via coax to be digitized.

To reduce EMI emission, the RF signal, data and power are transported over coax making the system better RFI shielded and reducing the number of cables and wires.

Fig0 shows the setup used to do all measurements described on this report. Type F to SMA adapters are used to be able to connect to the SMA cables of the VNA.

Fig10 at the end of the report shows the “front-end” part of one of the beam former channels.

## II. S-PARAMETER MEASUREMENT OF 1 CHANNEL

The gains of Channel A polX and channel A polY were measured.

The channel A POL X input was connected to port 1 of the VNA and POLX combined output was connected to Port2

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of the VNA.

A DC block was used between the inputs and the VNA port to avoid having DC signals into the VNA.

The gain plots are shown on Fig1.

The 2 polarization channels have very similar gains. At 80MHz the gain is 35.9dB which rolls off to 31.2dB at 300 MHz.

The return loss (S11) of the input channel A pol X and output POLX was measured and is shown on Fig2.

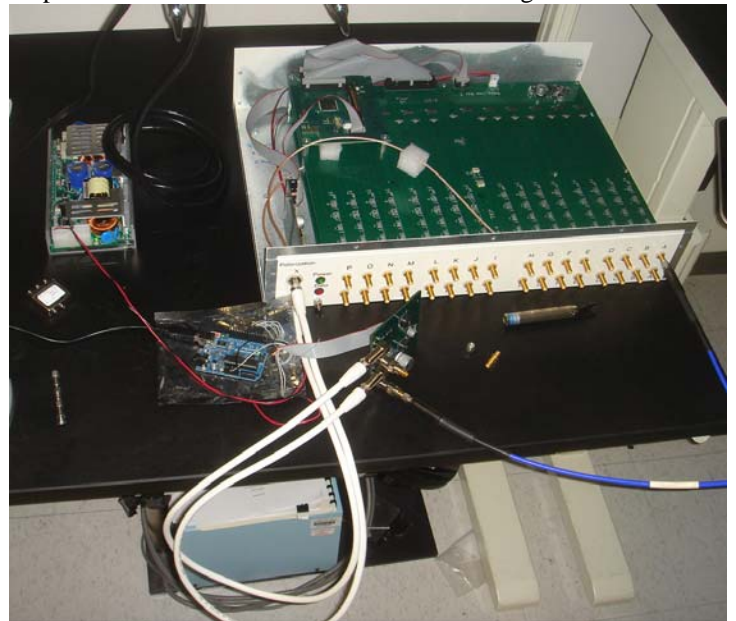


Fig0. Beamformer measurement setup: power supply providing the 48V, the arduino controller board and a 2 port VNA.

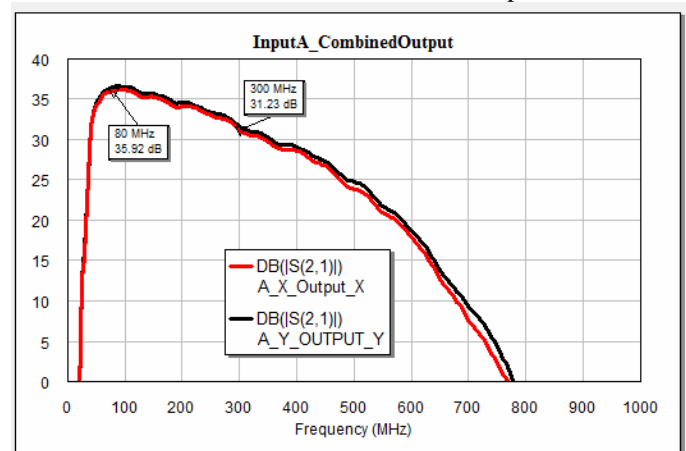


Fig1. Gain of Channels A Pol X and Y. (all other inputs are open circuited)

Each channel of the beamformer has gain up to 780MHz.

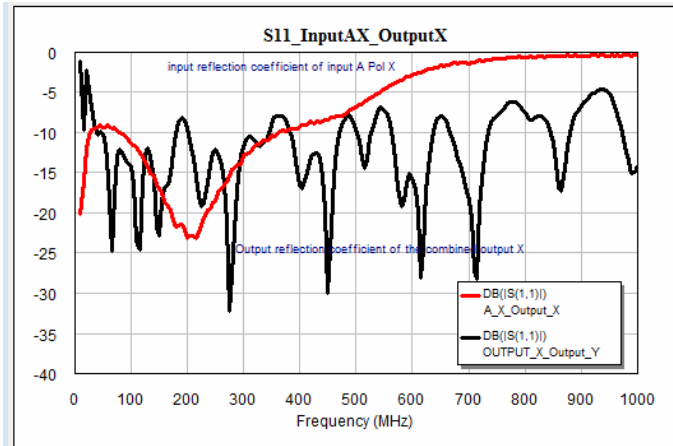


Fig2. Return loss of the input channel A Pol x and of the combined output X. The return losses are better than -10 dB over the MWA bandwidth.

### III. CROSSTALK MEASUREMENTS

The beamformer is made of 2 RF printed circuit boards which contain high gain amplifiers, delay lines and switches, each PCB has 16 channels closely packed together. To check any potential crosstalk, the transmission was measured between the channels of the same board and between channels on different boards.

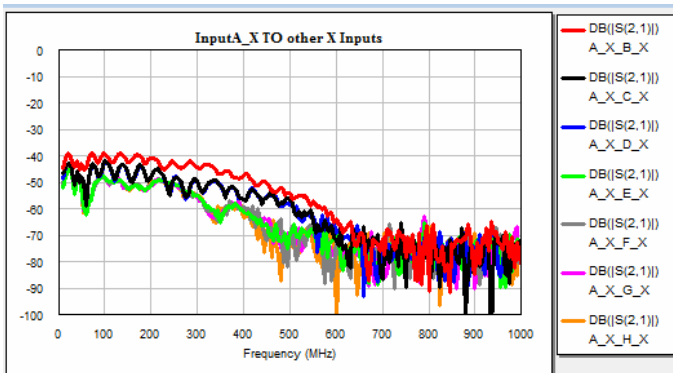


Fig3A. coupling between input A and other adjacent inputs on the POL X board. This was done with the delays turned OFF. All the channels are powered.

Fig3.A and 3B show very good isolation between the adjacent channels of the POLX board even when all the delay lines are switched on.

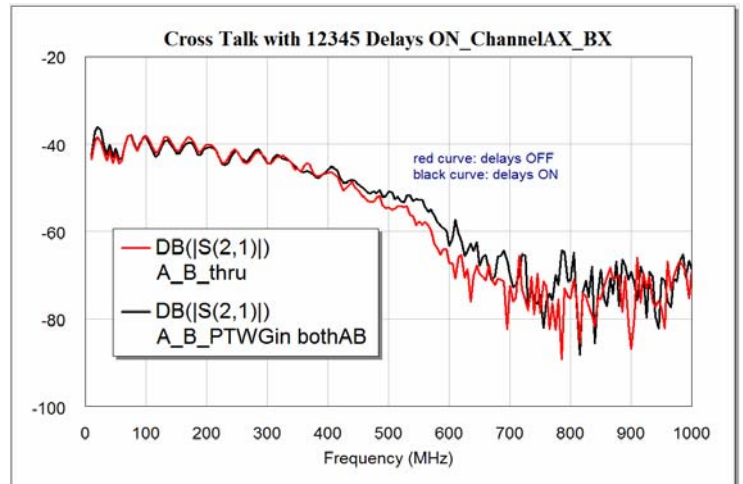


Fig3A. Coupling between input A and adjacent input B on the POL X board. This was done with all the delays turned ON for both channels A and B. All the channels are powered.

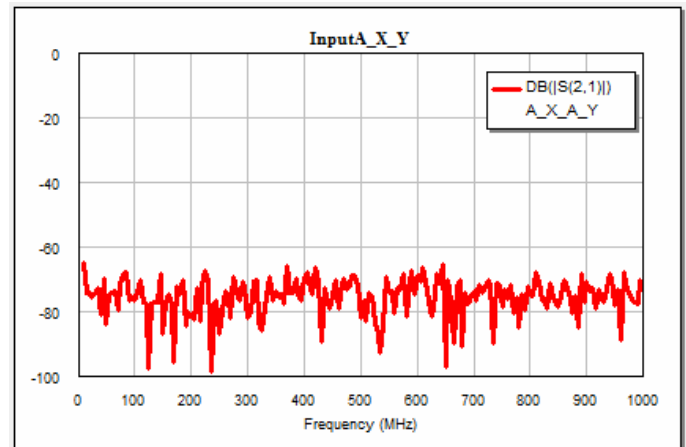


Fig4. coupling between POLX and POLY input A.

The crosstalk between the input A POLX and input A POLY is extremely low.

The coupling between the combined output X and Y was also checked by connecting Port1 of the VNA to the POLX output and Port2 to the POLY output on the DOC board.

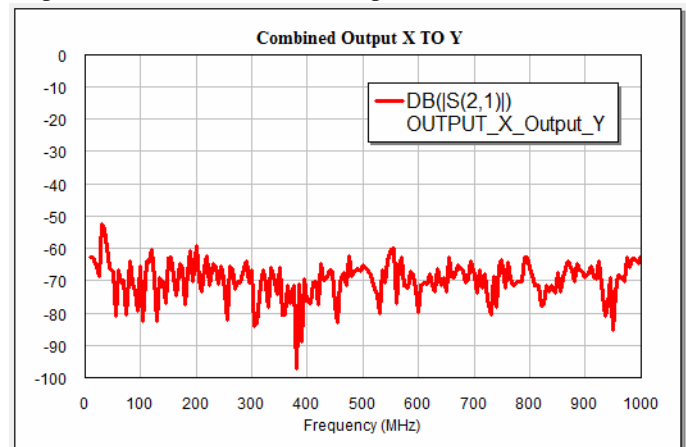


Fig5. coupling between the combined outputs X and Y.

It is clear from Fig5 that the 2 outputs X and Y are very well isolated on the DOC receiver board.

#### IV. DELAY MEASUREMENT

The time delay through input A POLX was measured with different delay settings. The measurement as done using the setup shown on Fig0. Fig6 at the end of this report shows the time delays with few selected settings. The delay varies from 17ns when the 1in delay line is selected to a maximum of 30ns when all delay lines are selected.

The ripple on the curve is believed to be caused by impedance mismatches on the SMA to Type F adapter. The SMA connector has a 50 ohm characteristic impedance while the type F connector has 75 ohm impedance.

The S11, S22 and S21 of the channel was recorded at the different delay lines settings.

The output match S22 does not change as shown on Fig7.

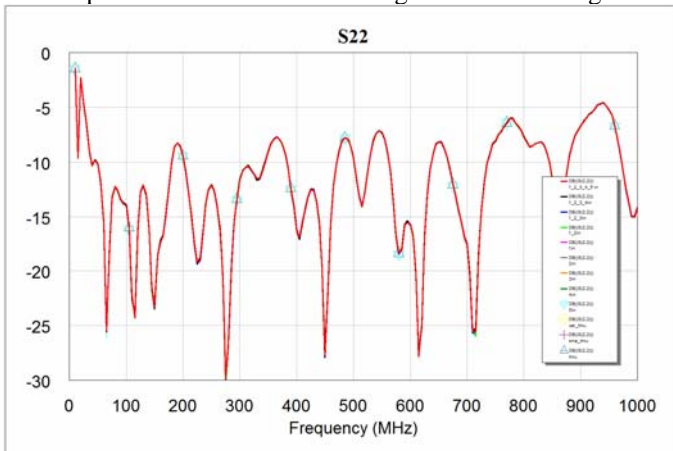


Fig7. S22 of the channel (return loss at the output X) with different delay lines settings.

The S11 and the gain of the channel changes slightly as the delay lines are switched on and off as shown on Fig8 and 9.

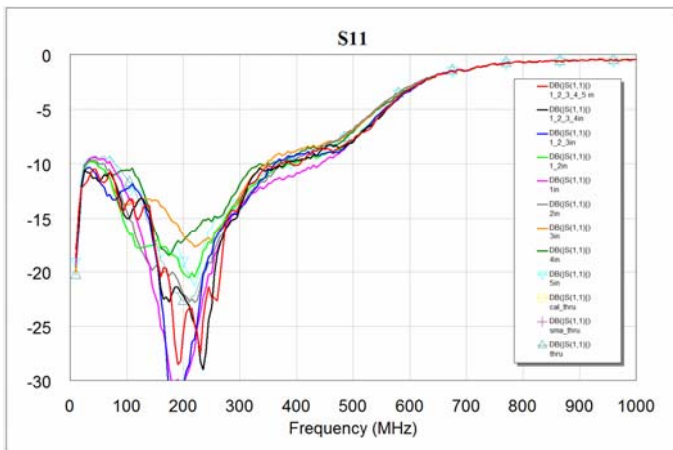


Fig8. input return loss of channel A with different delay line settings.

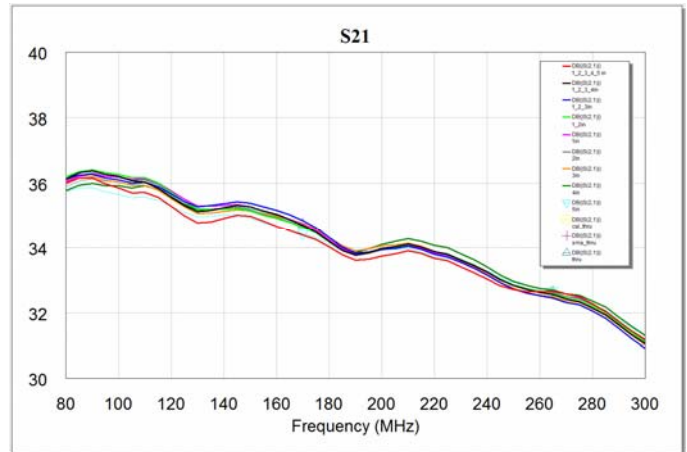


Fig9. gain of channel A with different delay settings. The change in S21 is caused by increased loss of the longer lines or when they are cascaded.

#### V. CONCLUSION & DISCUSSION

#### VI. ACCOMPANYING FILES

#### AKNOLWEDGEMENT

#### REFERENCES

- [1]
- [2]
- [3]

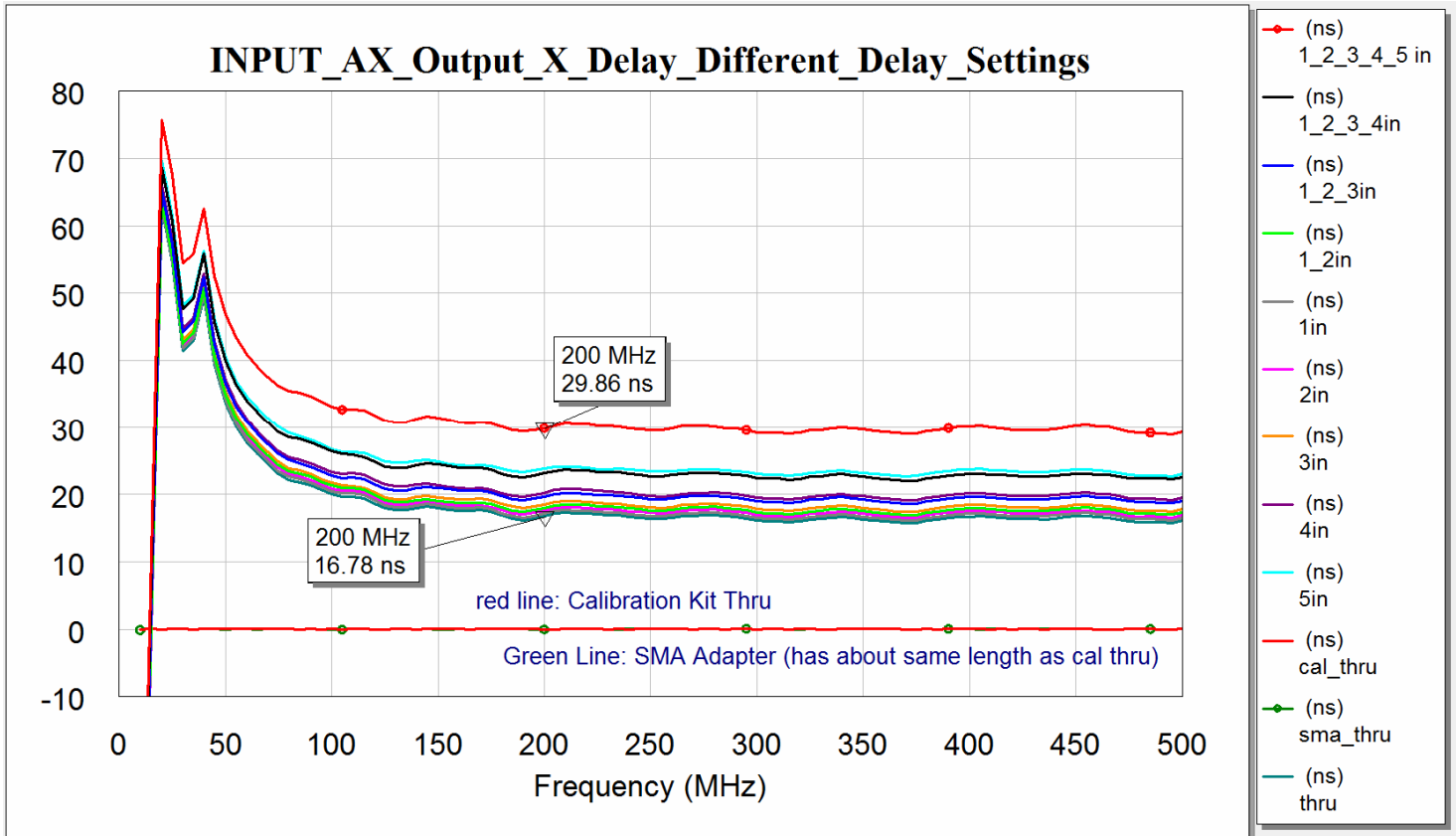


Fig6.A Time delay through channel A POLX with different settings

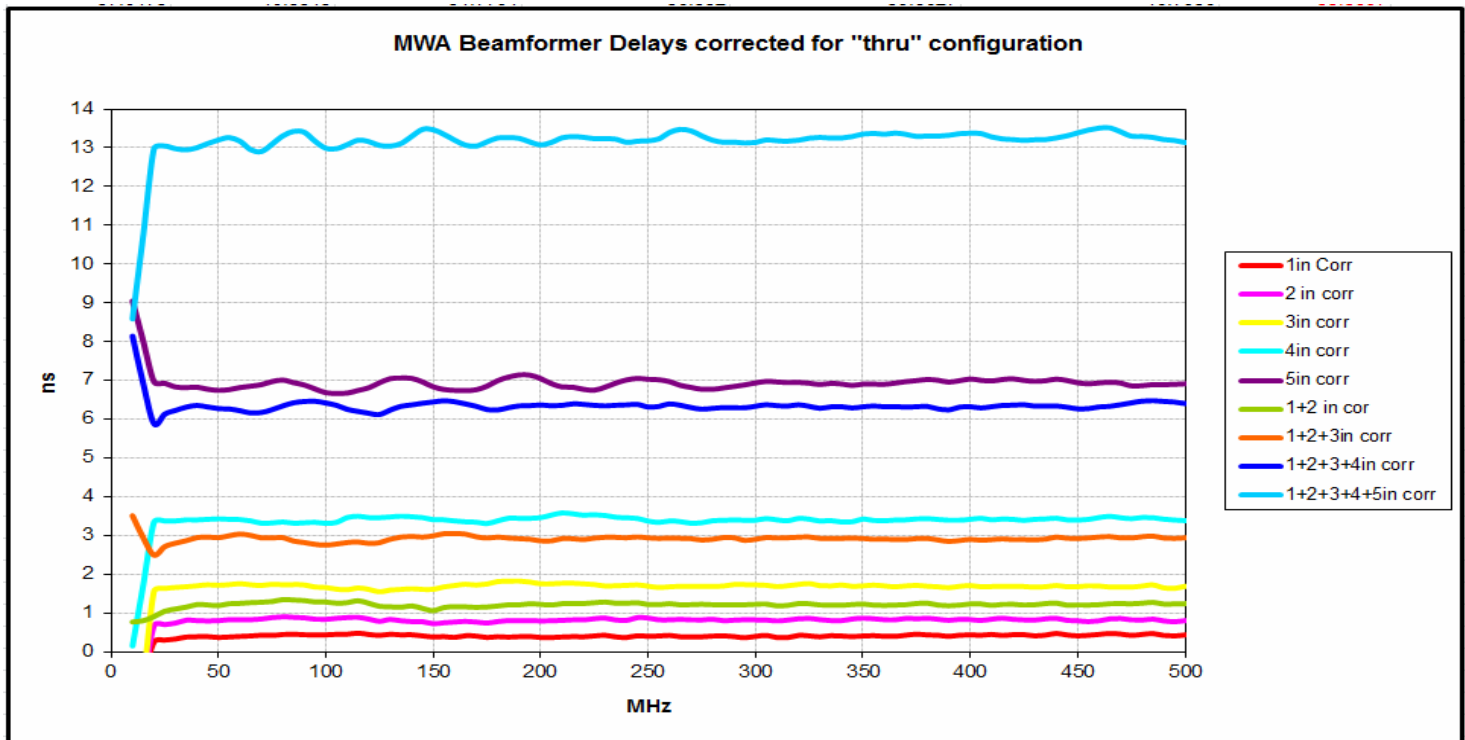


Fig6.B Time delay through channel A POLX with different settings, the delay of the "thru configuration" was subtracted



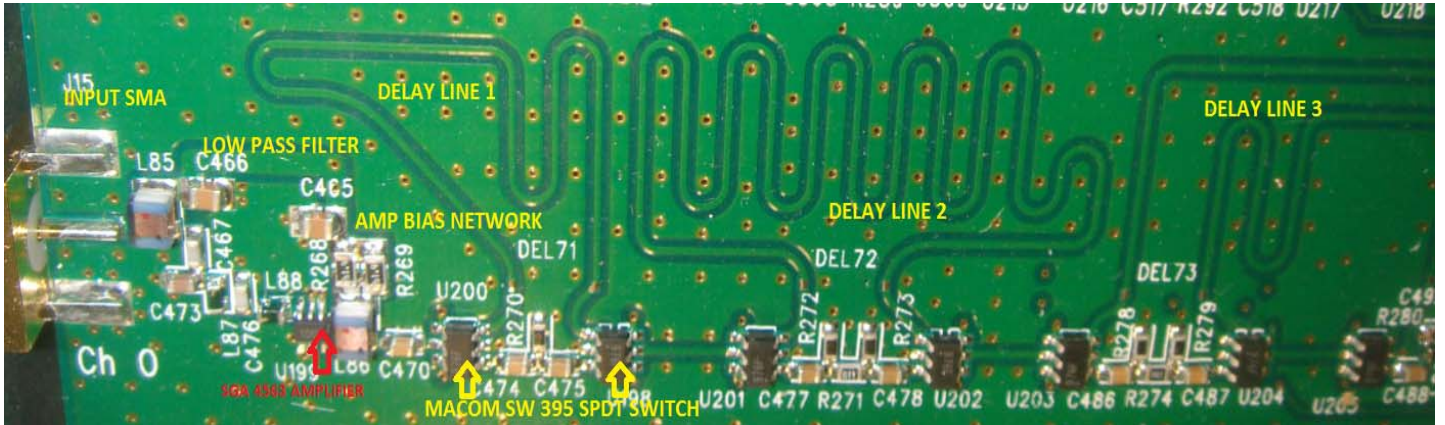


Fig10. Front-End part of the one of the beam former channels.

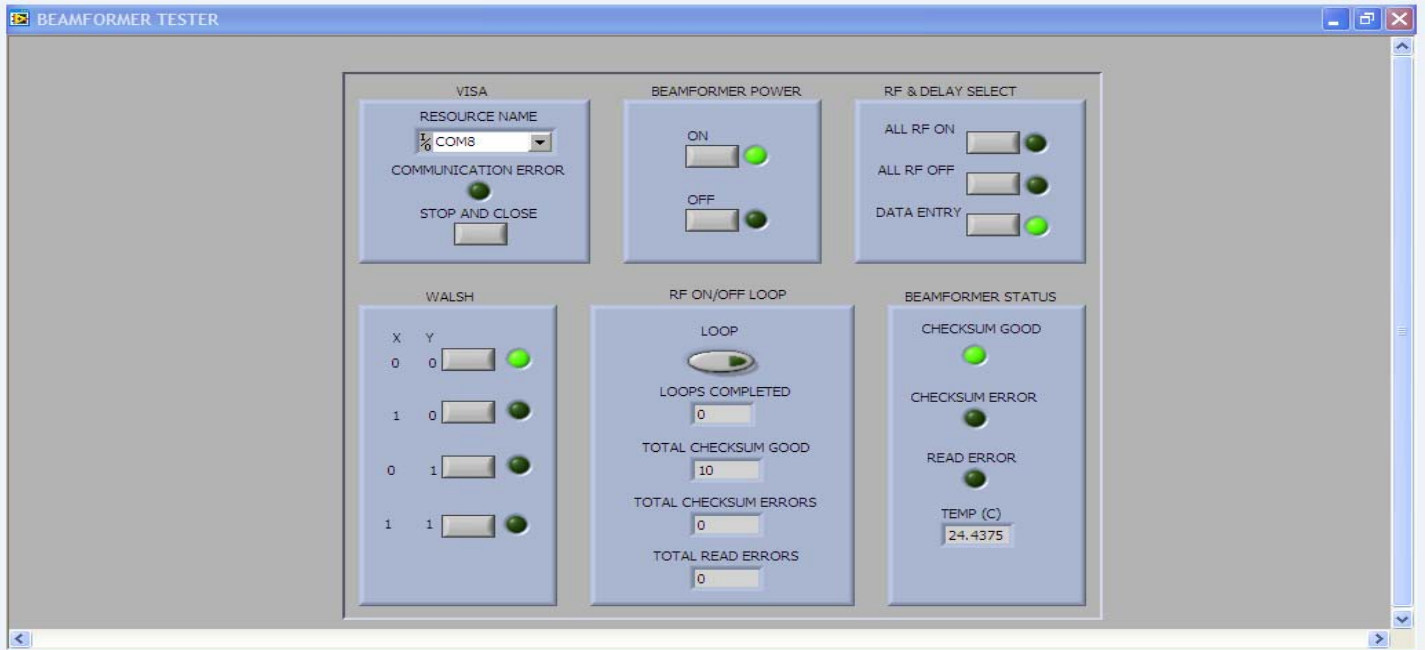


Fig11. Screen shot of the Labview program used to control the beamformer during testing.

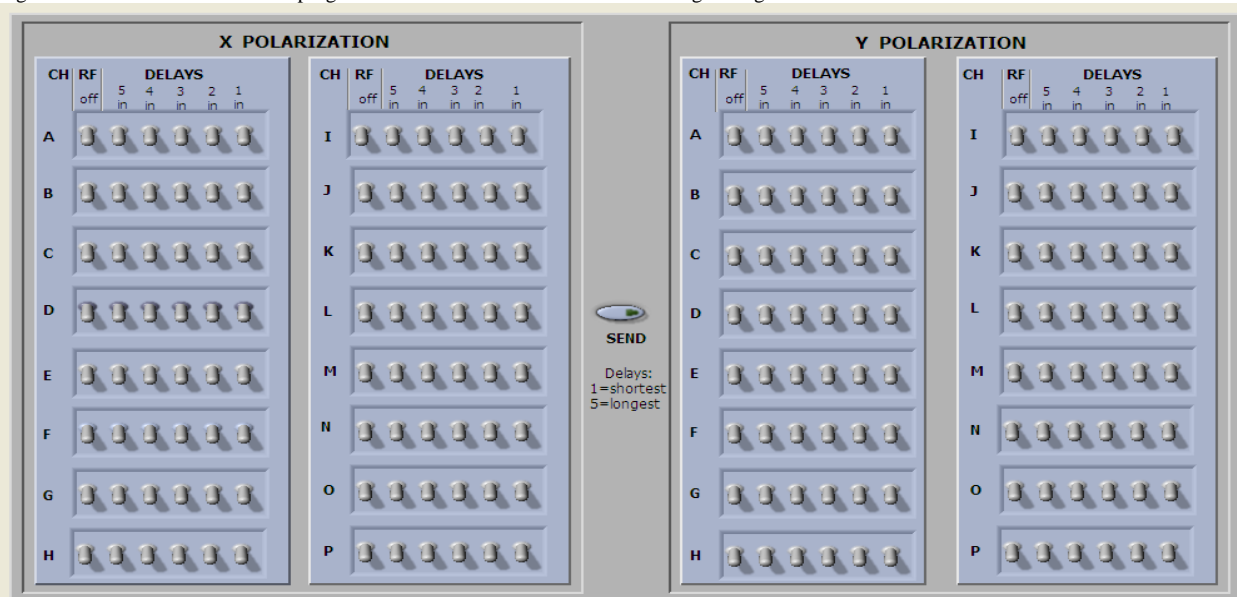


Fig12. Screen shot of the labview program used to switch ON/OFF delay lines.