

Custom Instrument and Audio Effects Processor Using NI MyRio

Eric Gubiani, Jeffrey Kirman, Jose Mastrangelo, and Justin Mendonca

Abstract—This paper presents a custom instrument and an audio effects processor consisting of master volume, 3 band equalization, echo, and left-right balance. These applications were implemented on two separate National Instruments MyRio boards using labView.

Index Terms—3 band eq, echo, MyRio, labView, audio processing.

I. INTRODUCTION

CURRENT Wi-Fi and LTE systems transmit and receive on the same channel using half duplex; therefore a system cannot simultaneously transmit and receive. A full duplex system would allow a cellular base station or Wi-Fi access point to achieve this simultaneous communication, ideally doubling the throughput and enabling the service of twice as many users in the same amount of time and using the same power as a half duplex system. This project considers circuit structures to passively maintain high transmit/receive isolation in a full duplex 2x2 MIMO setup with a symmetrical 4 port antenna. Unlike other methods of achieving full duplex, this setup relies on the symmetry of the antenna and circuit setup to provide all the isolation.

A. Full Duplex 2x2 MIMO Requirements

In order to successfully achieve full duplex MIMO communication, a few key requirements must be attained in order to ensure that the received signal is sufficiently unmodified to be reconstructed in the ADC. First, a high isolation between the transmit and receive ports must be maintained at all times to avoid drowning out the received signal. Second, the isolation circuit must cancel signals coupled across the balanced 4 port antenna. As well, transmitted signals internally reflected by the antenna must be cancelled in the isolation circuit to avoid mixing with the received signal. Since each transmit signal is split to opposing ports of the 4 port antenna, the isolation circuit is also responsible for dividing this signal.

II. IMPLEMENTATION OF A MUSICAL INSTRUMENT

A. Frequency Generation

B. Signal Generation and Processing

The instrument creates a tone quality for each note by generating the fundamental frequency signal and combining it with the four subsequent harmonics. Since the operations

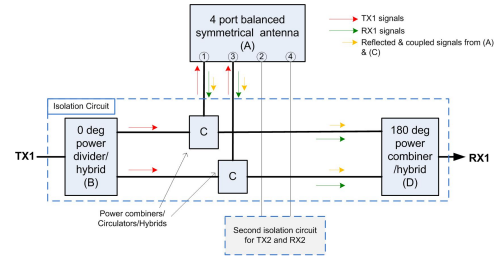


Fig. 1. Full Duplex 2x2 MIMO Antenna and Isolation Circuit Layout

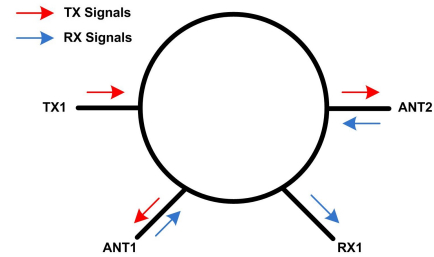


Fig. 2. 180° hybrid combiner properties for 2x2 full duplex MIMO use.

required for signal generation and processing require fast performance, the signal generation and processing logic is designed on the onboard FPGA of the NI MyRio. Fig.3 shows the implementation of signal generation in LabVIEW. Sine wave generator blocks are used to produce a sine wave at a calculated frequency. To produce four subsequent harmonics, the calculated frequency is multiplied by integer factors, two through five, and the resultant frequencies are used as input to separate sine wave generator blocks. An array of fixed point numbers contain the gain level of each harmonic are converted into a cluster, de-bundled, and then multiplied to the output of their respective sine waves before they are summed together. This allows for variable tone quality by changing the volume of each harmonic. Multiplication is carried out using fixed point arithmetic for increased precision.

Three instances of the signal generation code are used to generate three separate notes. Similar to the harmonic volume each note is multiplied by a fixed point number gain to control the volume of each note. Chords are enabled by a summation of the three separate notes.

Acceleration controlled volume level of the output signal is achieved through scaling the raw acceleration data from the native accelerometer to the NI MyRio, and multiplying the result with the output signal. Similar to signal generation,

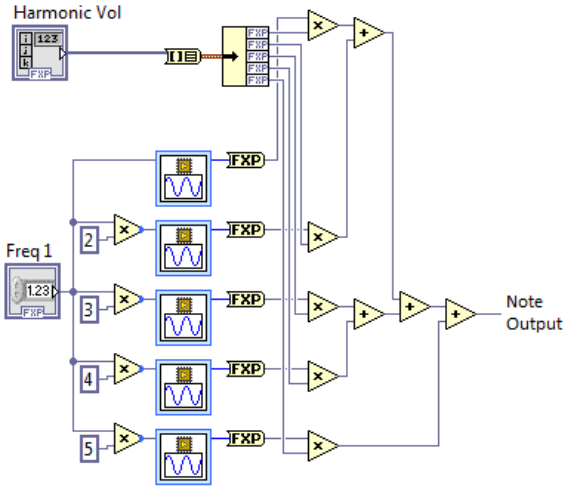


Fig. 3. LabVIEW code for generating the summation of a sine wave and four of its harmonics.

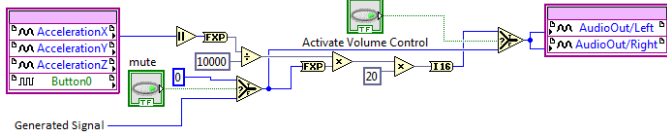


Fig. 4. LabVIEW code for changing the gain on the output signal using accelerometer data and controls.

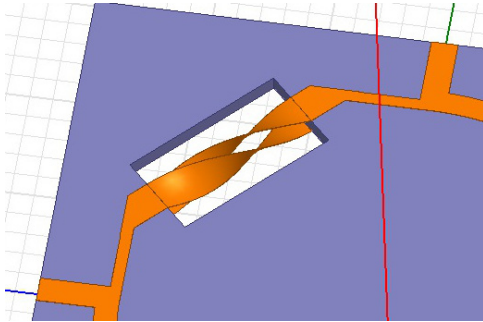


Fig. 5. Twisted line phase inverter structure.

multiplication is carried out using fixed point numbers for precision. Fig.4 shows the implementation of signal volume control in LabVIEW. A select block controlled by a control is used to switch between the signal at acceleration controlled volume and at maximum volume. Mute functionality is implemented similarly with a select block switching between the generated signal and no signal.

1) *Twisted Line Structure:* One of the simulated inverter structures consisted of cutting a slot in the PCB and fabricating two copper strips which would be individually twisted to connect the opposing top and bottom lines as seen in Fig.5. Simulations for this structure showed improvement in both S11 and phase inversion from the original structure. However due to the difficulty in replication of fabrication, this structure was abandoned.

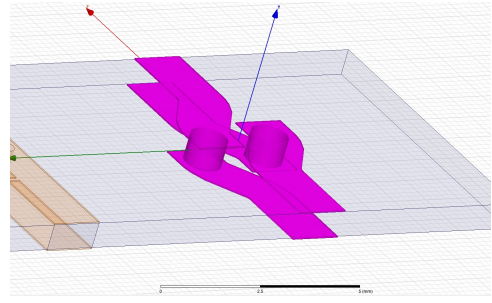


Fig. 6. Meandered line phase inverter structure.

2) *Meandered Line Structure:* Due to the improvements in the previous structure where the line was not cut, it was desired to find a similar method of swapping the top and bottom signals without cutting into the line. Using a variation of the original structure, a straight cut was made all the way through the line and both sections were extended and meandered to end side by side as seen in Fig.6. An identical modification was made to the bottom but with the lines meandering in the opposite direction allowing the top and bottom lines to line up. Via holes were added to connect the top and bottom lines. This modification to the structure allowed for the lines to maintain their width as well as allowing for the inclusion of larger via holes. Simulation results revealed this structure to behave similarly to the twisted line structure, but allowed for much more consistency in fabrication.

C. Balun Taper

In order for the balanced parallel stripline structure to make connection with an unbalanced SMA connector, a balanced to unbalanced (balun) taper was needed. Using an approximation of the Klopfenstein taper, this structure was simulated in HFSS until adequate impedance matching results were achieved [5].

D. Final Assembly and Modifications

Including both the modified phase inverter structure and the balun taper, the circuit was simulated until optimum results were achieved. Due to the extra path length introduced by the meandered phase inverter structure and the via hole, the circuit was not exactly symmetric. In order to compensate for this added pathlength, small arcs were added to the other three quarter circle sections. Adjusting the length of these arc sections during simulation yielded the final results seen in Fig.8. The final circuit structure used can be seen in Fig.7.

III. RESULTS AND DISCUSSION

After optimizing the structure in simulation, a prototype was fabricated as seen in Fig.7. The circuit was tested using a VNA and both antenna ports on the circuit connected to 50 ohm terminals. The isolation value S21 was measured from the transmit to the receive port on the circuit. The results in Fig.9 show almost identical behaviour to the final simulation seen in Fig.8. It should be noted that these results show approximately 10dB isolation improvement over the structure presented in [3].

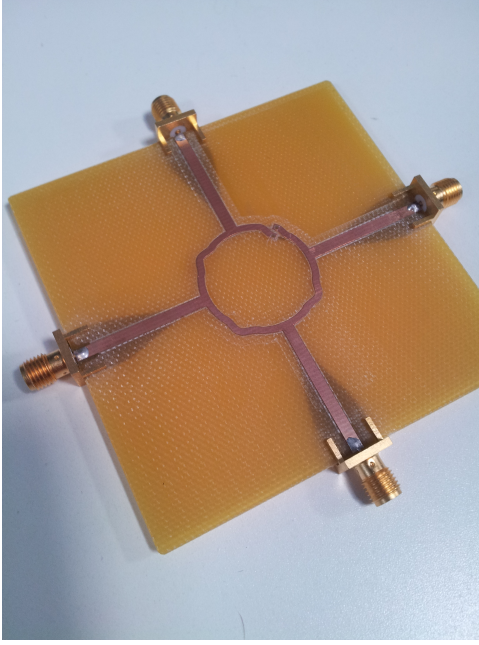


Fig. 7. Final fabricated circuit structure with included phase inverter, balun taper and path length correction.

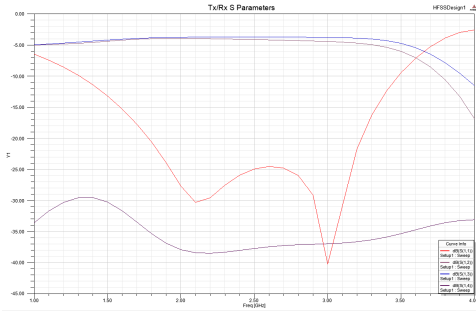


Fig. 8. Simulation results from final optimized structure



Fig. 9. Test results with VNA and terminated antenna ports

is effective and extremely inexpensive to manufacture, with a TX/RX isolation of only -38dB it still needs improvement before it can be successfully applied to long range communications. With more time to develop and simulate this circuit structure, this isolation level could be improved and tested with the 4 port antenna.

ACKNOWLEDGMENT

Thank you to my supervisors Thanh Ngon Tran and Robert Morawski as well as fellow undergraduate student Harry Lee and Prof. Tho Le-Ngoc for all the guidance and support.

REFERENCES

- [1] W. Chang, C. Liang, and C. Chang, "Wideband high-isolation and perfect-balance microstrip rat-race coupler," *Electronics Letters*, vol. 48, no. 7, pp. 382–384, Mar. 2012.
- [2] S. Taravati, "Miniaturized wide-band rat-race coupler," *International Journal of RF and Microwave Computer-Aided Engineering*, vol. 23, no. 6, pp. 675–681, Oct. 2013. [Online]. Available: <http://onlinelibrary.wiley.com/doi/10.1002/mmce.20703/abstract>
- [3] L. Chiu and Q. Xue, "Compact and wideband parallel-strip 180 hybrid coupler with arbitrary power division ratios," *International Journal of Microwave Science and Technology*, vol. 2013, p. 10, 2013.
- [4] K. Chang and L.-H. Hsieh, *Microwave Ring Circuits and Related Structures*, 2nd ed. Wiley-Interscience, 2004.
- [5] S. Rizvi and R. Khan, "Klopfenstein tapered 2 #x2013;18 GHz microstrip balun," in *2012 9th International Bhurban Conference on Applied Sciences and Technology (IBCAST)*, Jan. 2012, pp. 359–362.

IV. CONCLUSION AND FUTURE IMPROVEMENTS

A modified 180° hybrid combiner for use in broadband 2x2 MIMO applications was presented and developed as an isolation circuit to be used with a symmetrical 4 port antenna. The structure proposed in (reference) was improved upon and applied to full duplex applications. While this circuit structure