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 recieve on the same channel using half duplex; therefore a system cannot simultaneously transmit and recieve. 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/recieve 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 sucessfully acheive full duplex MIMO communication, a few key requirements must be attained in order to ensure that the recieved signal is sufficiently unmodified to be reconstructed in the ADC. First, a high isolation between the transmit and recieve ports must be maintained at all times to avoid drowning out the recieved signal. Second, the isolation circuit must cancel signals coupled acoss 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 recieved signal. Since each transmit signal is split to opposing ports of the 4 port antenna, the isolation circuit is also responsible for divding this signal.

II. Implementation of a Musical Instrument

A. Frquency Generation

The source of maintaing high isolation lies in the circulator (noted (C) in Fig.1) which allows a signal to pass only to its neighbor in the clockwise direction. It is desired to replace this component due to the high cost and large volume of manufactured high isolation circulators. For cost effectiveness and ease

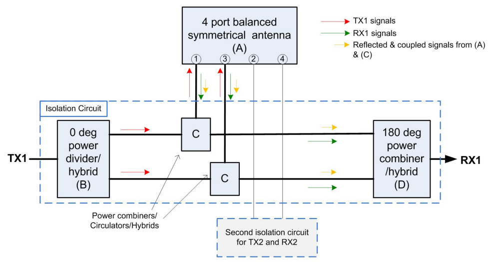

Fig. 1. Full Duplex 2x2 MIMO Antenna and Isolation Circuit Layout

of fabrication, it was desired to implement a microstrip circuit with few mounted components. The structure considered to provide the required isolation was the circular 180 hybrid as seen in Fig.2. Because the segments of the circuit are quarter wavelength multiples, some interesting properties arise depending on the port(s) the signals are applied to. As seen in Fig.2, signals applied at TX1 split evenly to ANT1 and ANT 2 and recombine destructively at RX1, ideally creating perfect isolation at the centre frequency. As well, identical signals applied at ANT1 and ANT2 recombine in phase at RX1 but recombine destructively at TX1, sucessfully splitting the transmit signals to the antennae and recombining the recieved signals at the RX1 port as required. Therefore, by applying the signals at the correct ports, this circuit structure can replace the function of all the isolation circuit components seen in Fig.1. However, due to the wavelength based properties of this structure, high isolation is only achieved at the centre frequency making it extremely narrow band. Work has been done previously on developing wideband 180 hybrid combiners as demonstrated in multiple papers as well as in the book titled Microwave Ring Circuits and Related Structures [1][2][3][4]. Of these designs, the one that seemed the most promising and most simple to fabricate was the structure presented in the paper by Quan Xue and Leung Chiu which regulated the narrow band issue by replacing the 3/4 wavelength section with a 180 parallel stripline phase shifter, allowing isolation across the band [3]. After simulating the structure proposed in [3], there was still significant error in the phase inverter structure, prompting an improvement in this part of the circuit structure.

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

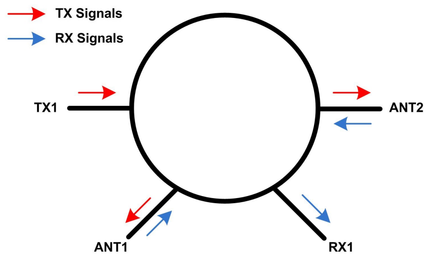

Fig. 2. 180 hybrid combiner properties for 2x2 full duplex MIMO use.

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.II-B 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, 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.

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.

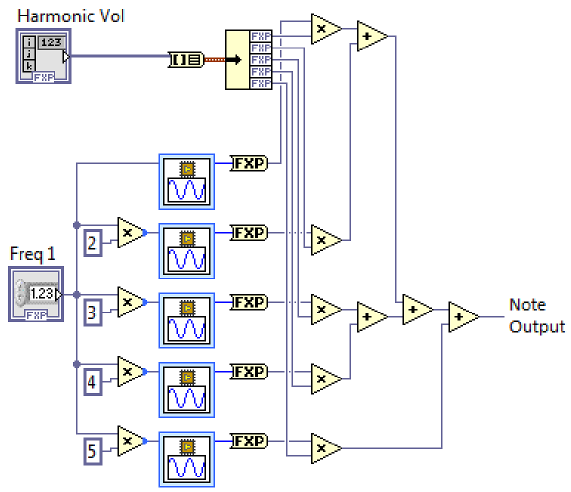

Fig. 3. LabVIEW code for generating the summation of a sine wave and four of its harmonics.

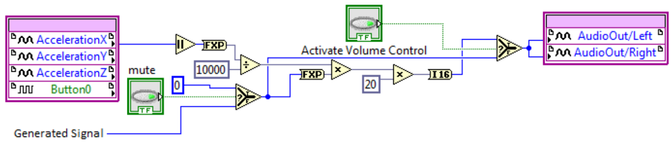

Fig. 4. LabVIEW code for changing the gain on the output signal using accelerometer data and controls.

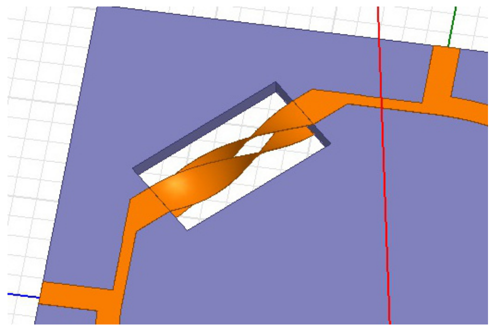

Fig. 5. Twisted line phase inverter structure.

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].

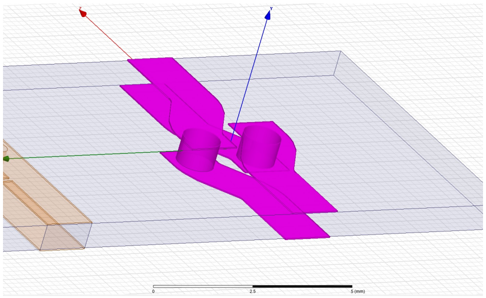

Fig. 6. Meandered line phase inverter structure.

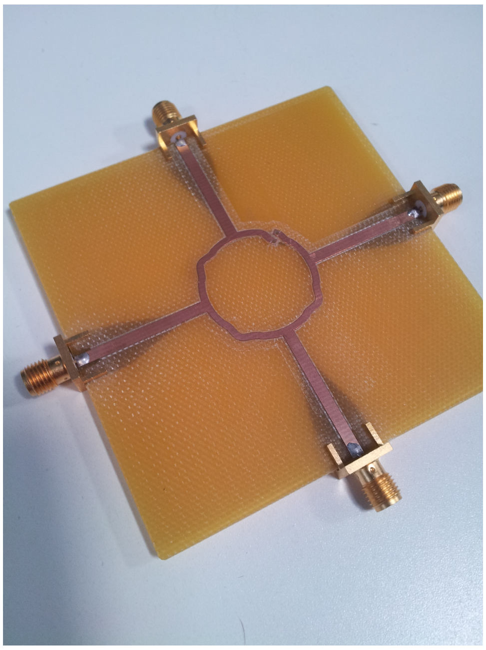

Fig. 7. Final fabricated circuit structure with included phase inverter, balun taper and path length correction.

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 meanedered 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 recieve 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 improvent over the structure presented in [3].

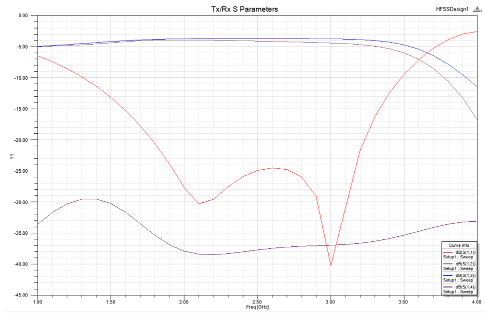

Fig. 8. Simulation results from final optimized structure

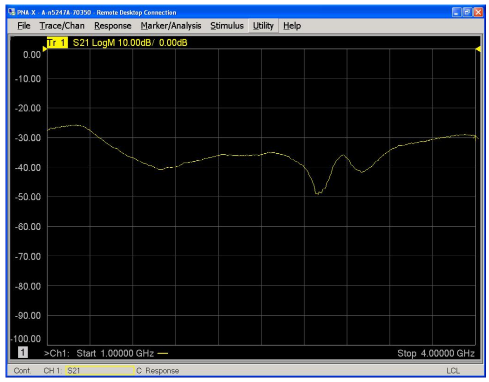

Fig. 9. Test results with VNA and terminated antenna ports

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 is effective and extremely inexpensive to manufacture, with a TX/RX isolation of only -38dB it still needs improvement before it can be sucessfully 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.

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