A 60GHz Line-of-Sight 2x2 MIMO Link Operating at 1.2Gbps

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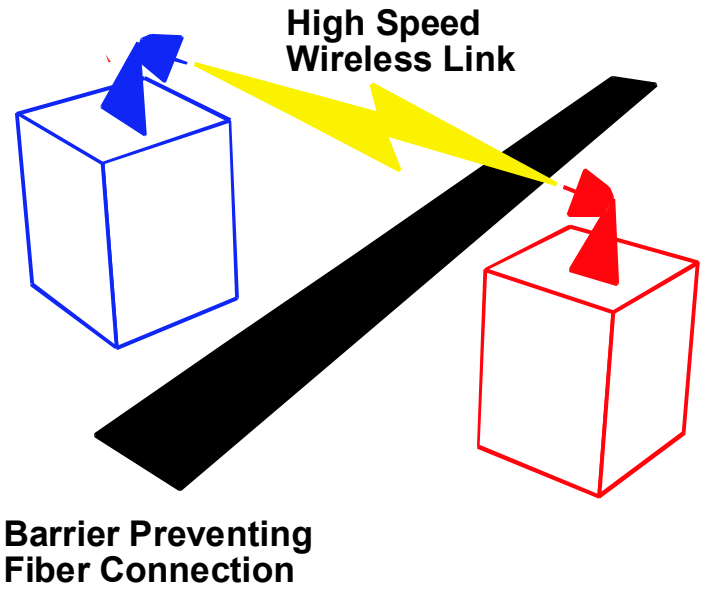
Outline

- Motivation: To build Line-of-Sight wireless links capable of data rates >320Gbps
- Proposed Solution: Exploit Line-of-Sight MIMO operation and wide bandwidth available at millimeter wave frequencies
- Hardware Prototype
- Results from Indoor Radio Link Experiments

Applications for High Speed Line-of-Sight Radio Links

- Wireless bridge for fiber links
- Backbone link for Wireless Local Area Networks
- Building to building high speed connections



Commercial Millimeter-Wave Line-of-Sight Links

GigaLink 6451e/6651e
MMW Transceiver

57-64GHz
1.25Gbps
>1km range

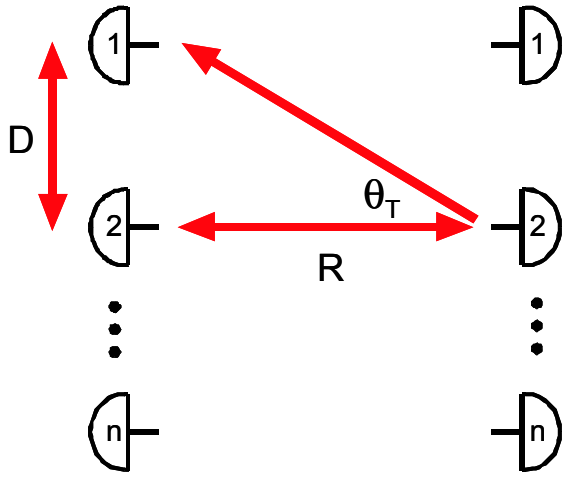
GigaLink 7451e MMW Transceiver

71-76GHz
1.25Gbps
>4km range

- Proxim Wireless GigaLink Series
- Marketed as a Fiber link replacement
- Can we build millimeter-wave line-of-sight links capable of significantly higher data rates?

http://www.proxim.com/products/gigalink/index.html

Line-of-Sight MIMO Theory



Angular separation of the Tx elements

$$q_T \cong \frac{D}{R}$$

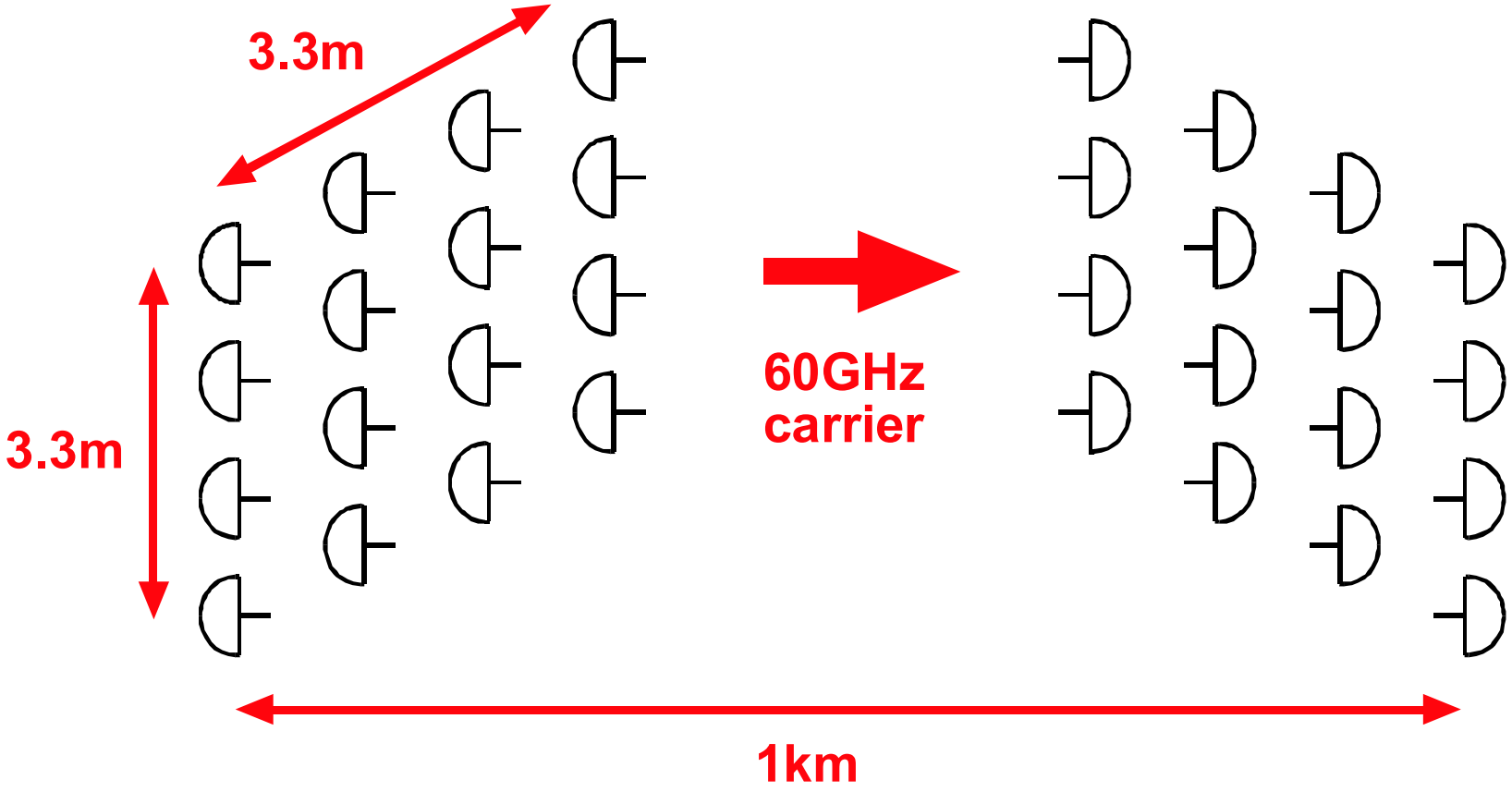
Angular resolution of the Rx array

$$q_{res} \cong \frac{l}{n \cdot D}$$

$$q_T \geq q_{res} \Rightarrow D = \sqrt{\frac{R \cdot l}{n}}$$

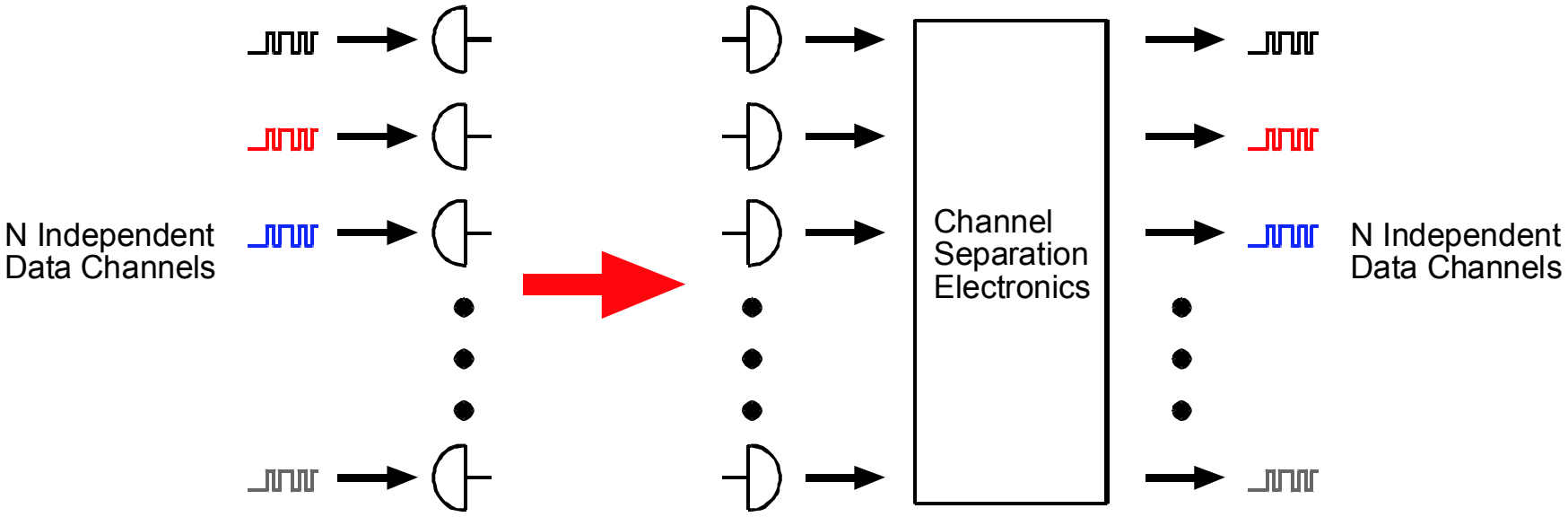
- System theory based on the principles of diffraction-limited optics (D. Gesbert, *IEEE Trans. Comm.*, 2002)
- Arrays built using the ideal antenna separation distance (D) are capable of data rates proportional to the number of TX/RX antenna pairs

System Example: High Speed Radio Link at 60GHz



16 *antenna pairs* x **10** *Gbps* x **2** *polarizations* = **320 Gbps**

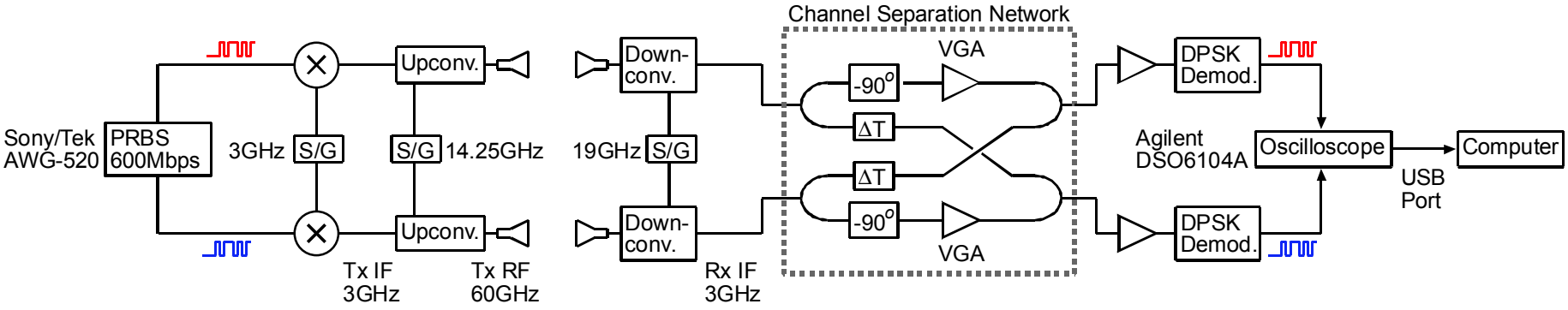
Line-of-Sight MIMO System Architecture



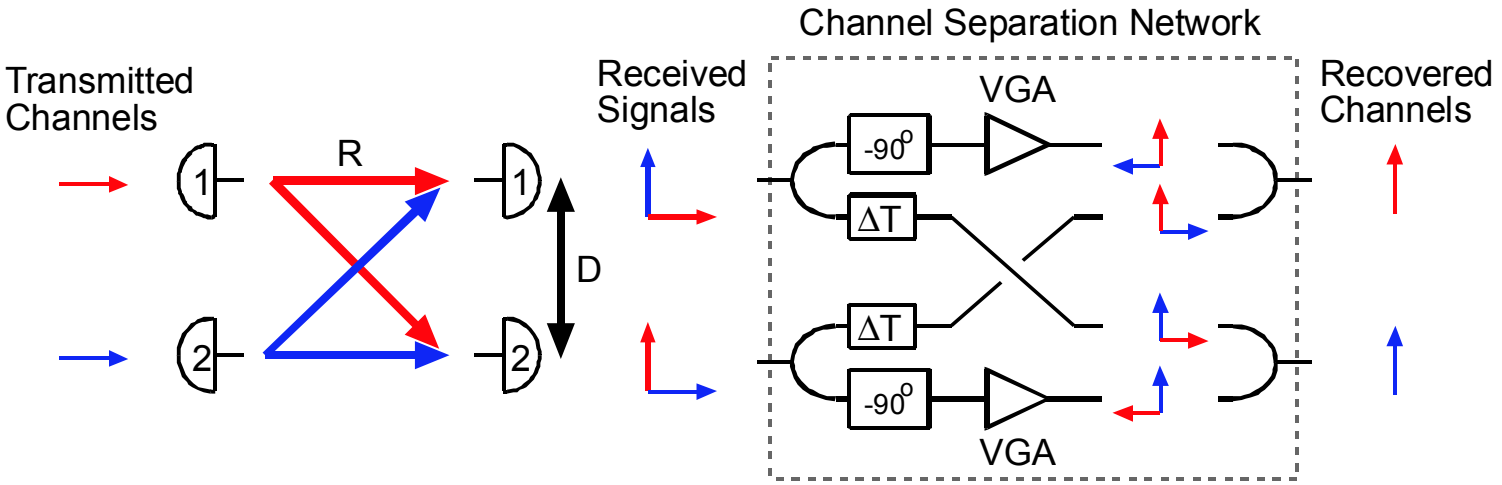
Challenge: Real time channel separation at the receiver

Hardware Prototype Block Diagram

- Two element transmitter
  - BPSK modulation; Two stage upconversion
- Two element receiver
  - IF channel separation network; DPSK demodulator

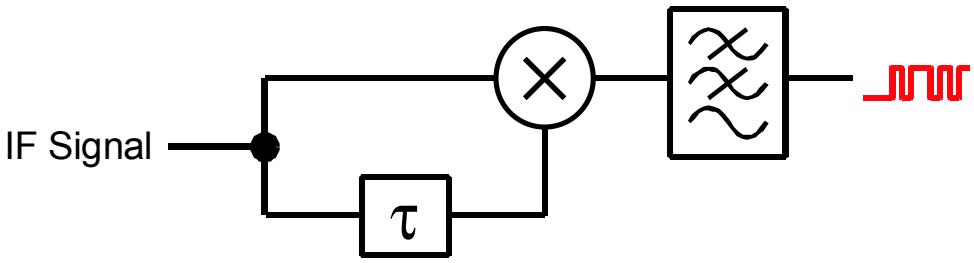


Receiver Channel Separation



- Channel Separation implemented at IF
- Manually tuned elements
- Future experiments will incorporate an automatically tuned channel separation network

Receiver Data Demodulation



- DPSK Data Demodulator
- Carrier recovery not necessary
- System architecture decouples channel separation from data demodulation

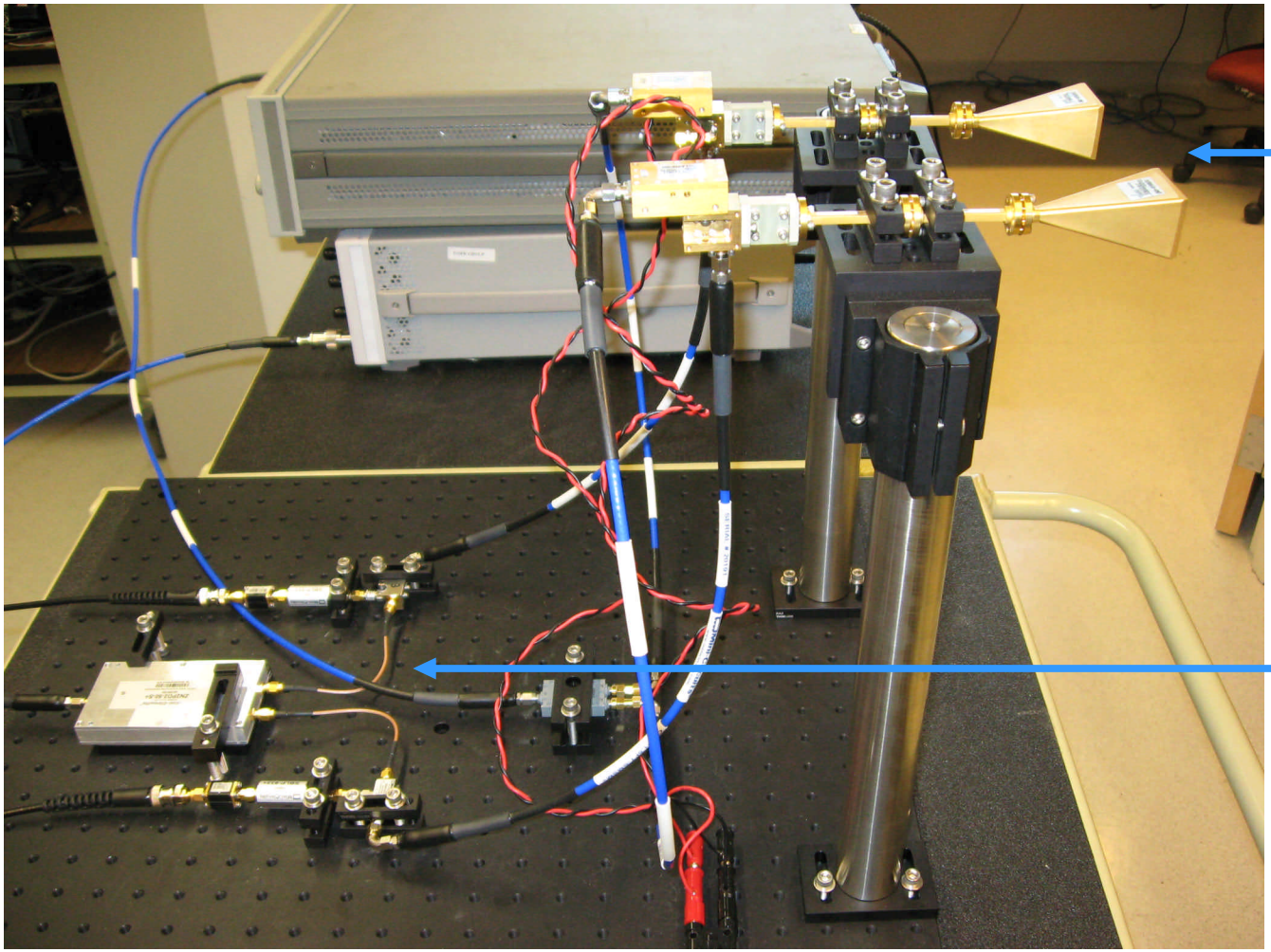
Radio Link Budget

$$\frac{P_{rx}}{P_{tx}} = D_{tx} \cdot D_{rx} \cdot \frac{l^2 \cdot e^{-a \cdot R}}{(4p \cdot R)^2}$$

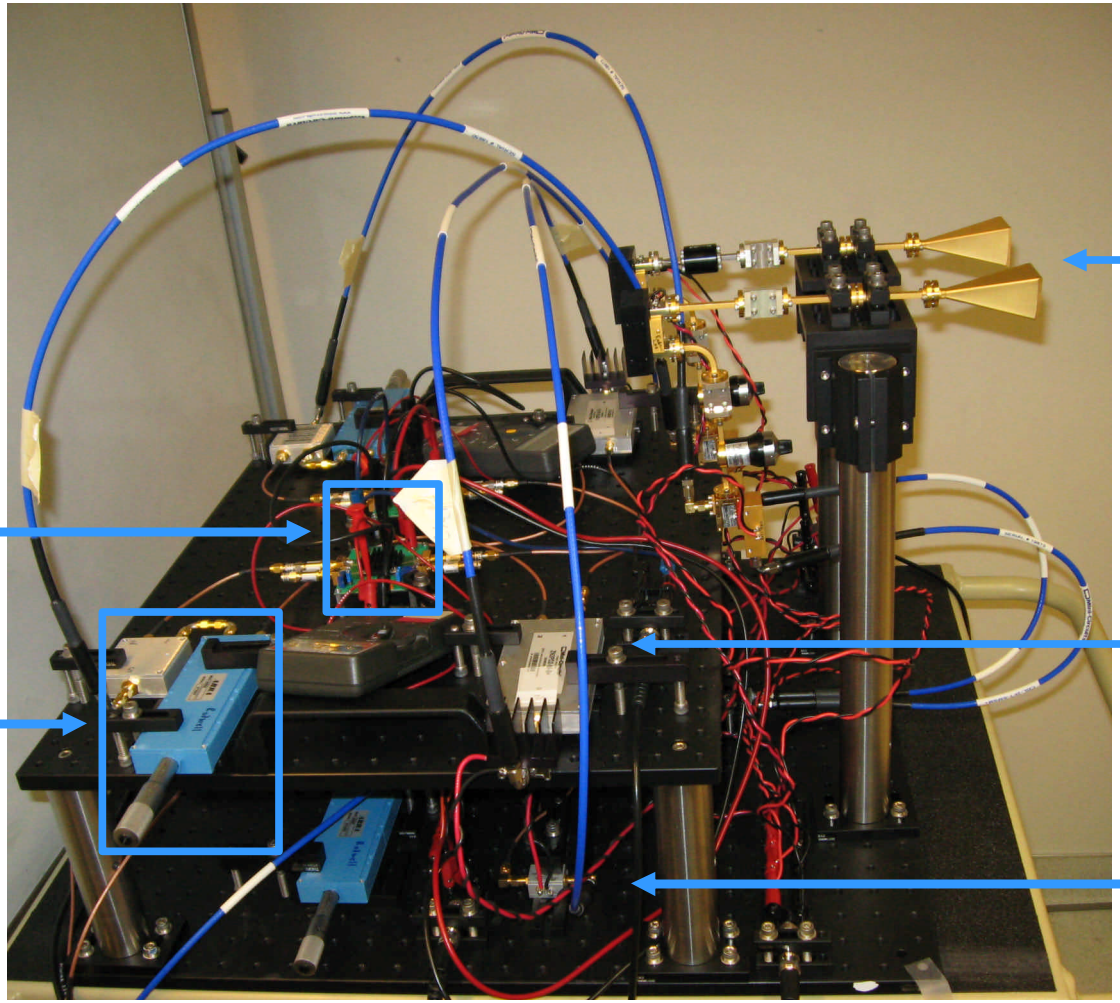
P_{tx}	D_{tx}	D_{rx}	Data Rate (per channel)	Range (BER=10^{-6})
-16dBm	24dBi	24dBi	600Mbps	6m (current prototype)
-16dBm	24dBi	40dBi	600Mbps	41m (outdoor experiment)
+9dBm	40dBi	40dBi	10Gbps	400m

8dB NF
13dB Link Margin

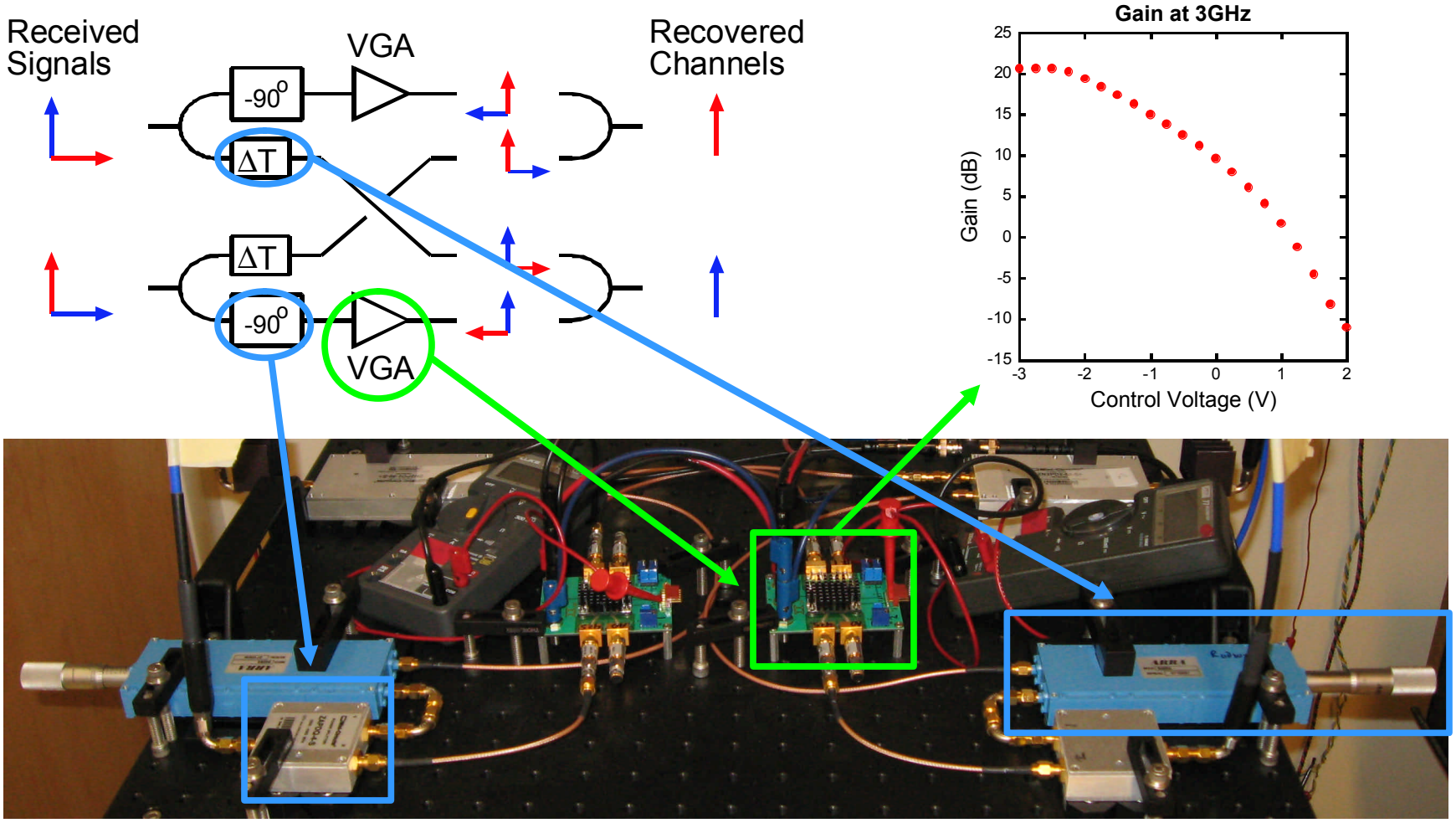
60GHz Transmitter Prototype



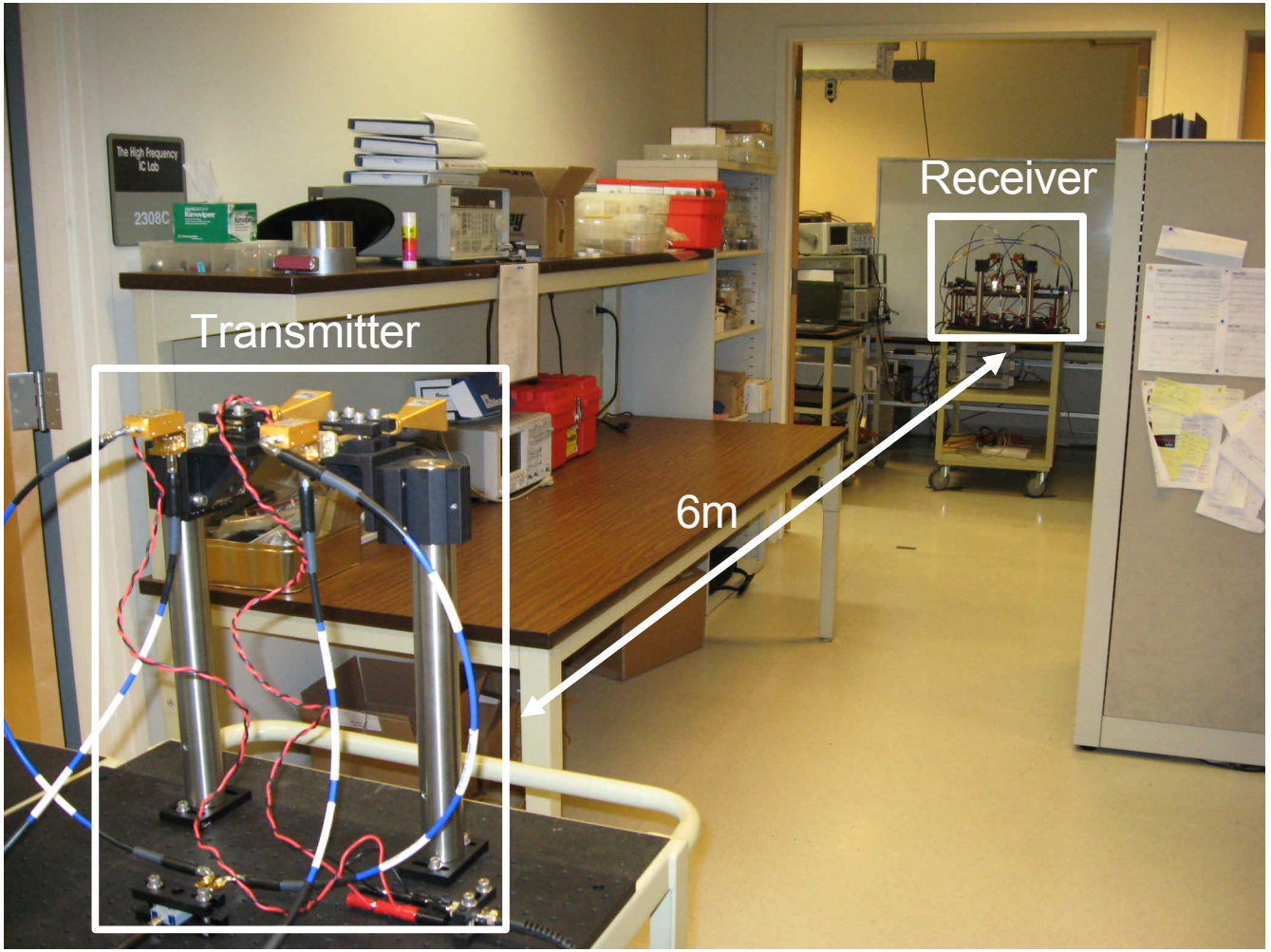
Two Element Receiver Hardware



Channel Separation Network

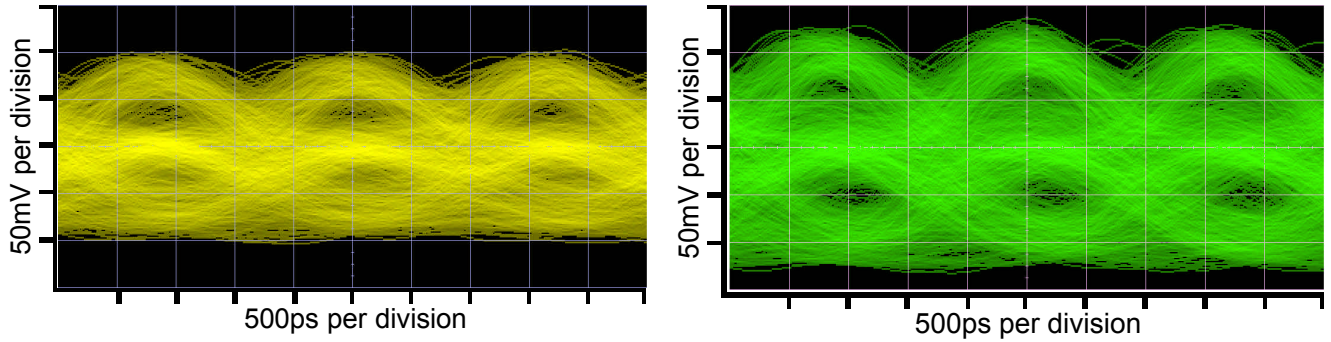


Indoor Radio Link Experiment

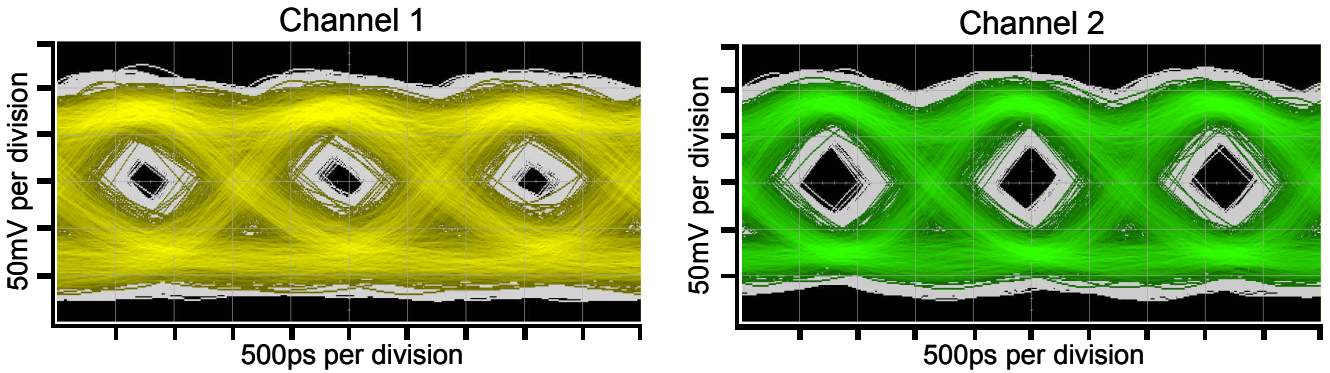


600Mbps Time Domain Results

Before Channel Separation



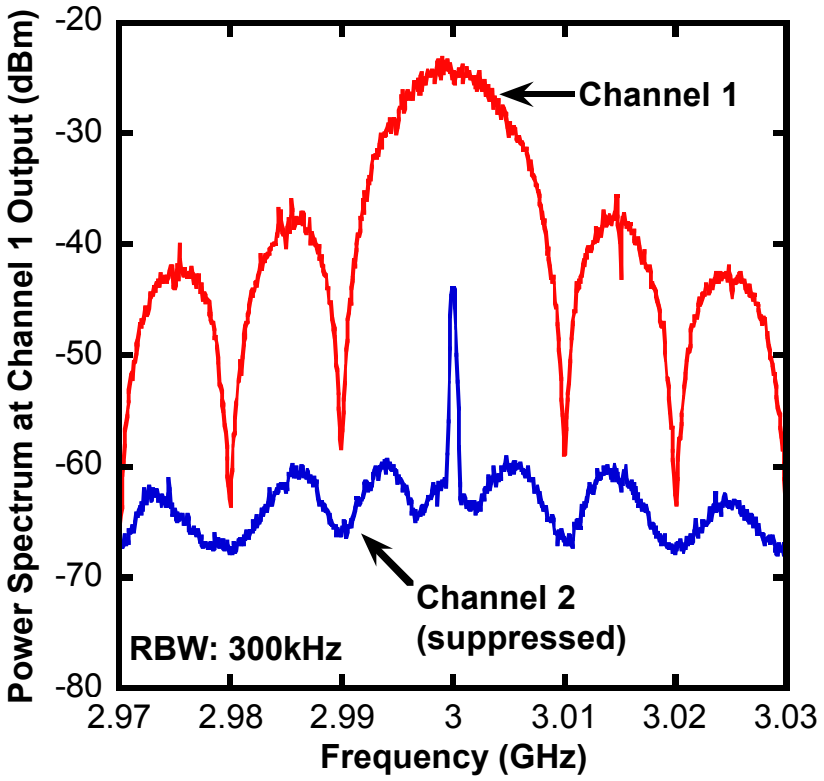
After Channel Separation



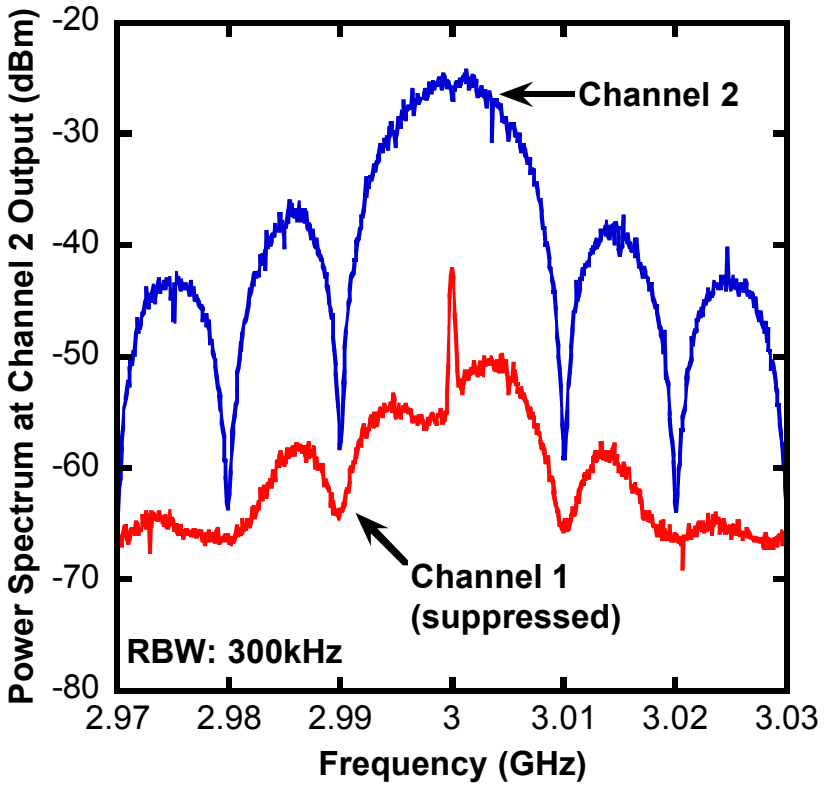
BER measurements limited by receiver hardware

	Channel Number	1	2
BER	Single Active Transmitter	$<10^{-6}$	$<10^{-6}$
	Two Active Transmitters	$<10^{-6}$	$<10^{-6}$

10Mbps Frequency Domain Results

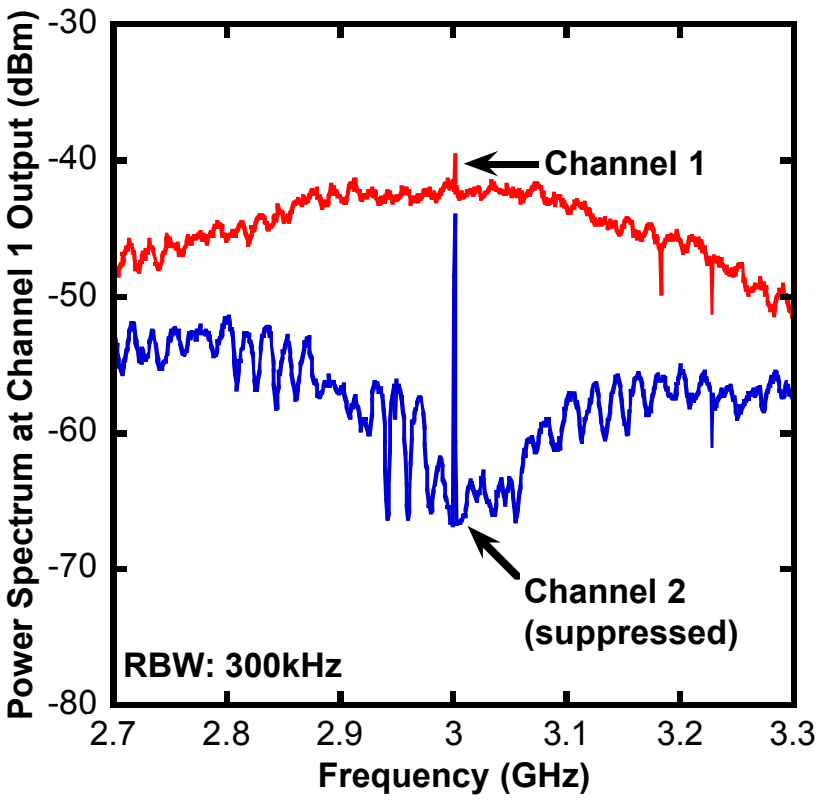


Main Lobe Channel Suppression Ratio: 30dB

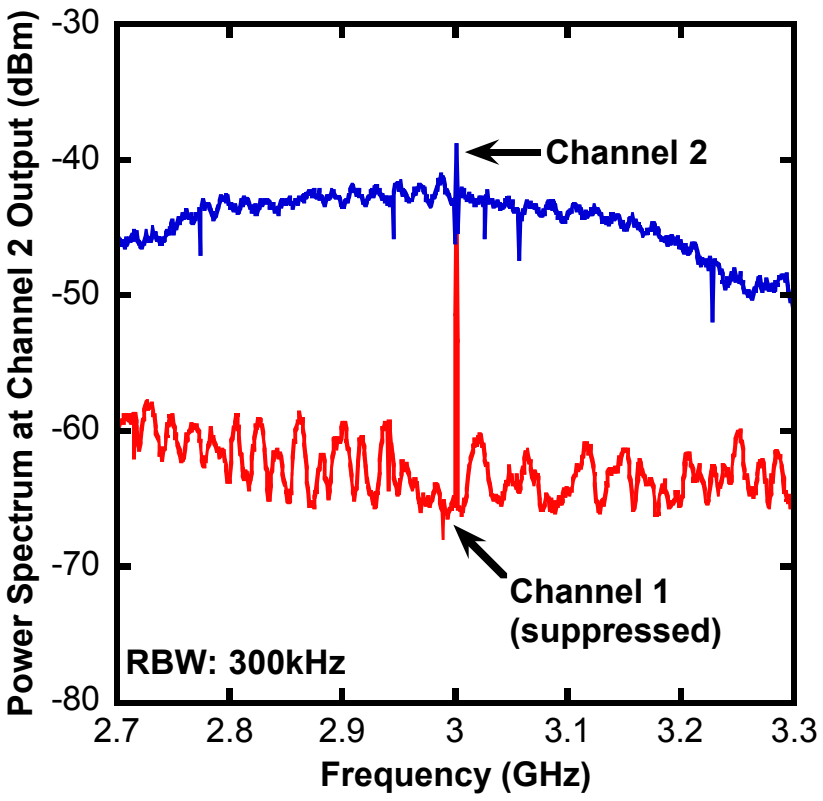


Main Lobe Channel Suppression Ratio: 24dB

600Mbps Frequency Domain Results



Channel Suppression Ratio:
12dB



Channel Suppression Ratio:
18dB

Summary

- Demonstrated a scalable architecture for a Line-of-Sight MIMO link capable of large data capacities
- Indoor radio link experiment
  - 6m range
  - 1.2Gbps with BER $<10^{-6}$
- Future work
  - Long range outdoor experiments
  - Baseband receiver signal processing with automated control loop

Questions?