Performance Testing of 2x2 MIMO Radio with NuWaves NW-BA-12B04A-D27 BDA Module

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Note:

All measured data presented in this report represents the RF path loss and does not take into account external factors such as antenna gain, fade margin, slant angles, etc. The data represented here is intended to be used in calculating total system link budget without any other factors that may apply such as those mentioned above.

Test Setup Settings:

MIMO Radio Settings:

- Frequency: 2215 MHz
    - All data was taken at 2215 MHz
- Streaming Methods: Single Channel, Two Channel, Dual Streaming
- MCS Mode: MCS 0, 1, 2, 3, 4, 5, 8, 9, 10, 11, 255
- Bandwidth: 5 MHz, 10 MHz
- Radio Output Power: +27 dBm, +30 dBm, +33 dBm

NuWaves NW-BA-12B04A-D27 Settings:

- T/R Mode: Autosense – The BDA automatically senses the RF input power to switch between transmit and receive modes within 2us or less. NuWaves tested with both manual and autosense modes and did not notice any degradation when using autosense.

Setup Block Diagrams

NuWaves initially performed Radio to Radio testing to establish baseline performance of the link. The setup for collecting this data is depicted Figure 1. The performance was measured over various radio conditions in order to determine the optimal operating conditions to achieve maximum link distance. The streaming method, MCS settings, and bandwidth settings were all varied in this analysis. The measurements were performed using an automated test script to adjust the digital step attenuator in 1 dB steps, and then proceed to record an average TCP throughput for a 10s interval. The step attenuator increments by 1dB each iteration until the attenuation is increased to a point that the link cannot be established and the TCP throughput is 0 MBPS. All data was taken with the radio configured to a frequency of 2215 MHz.

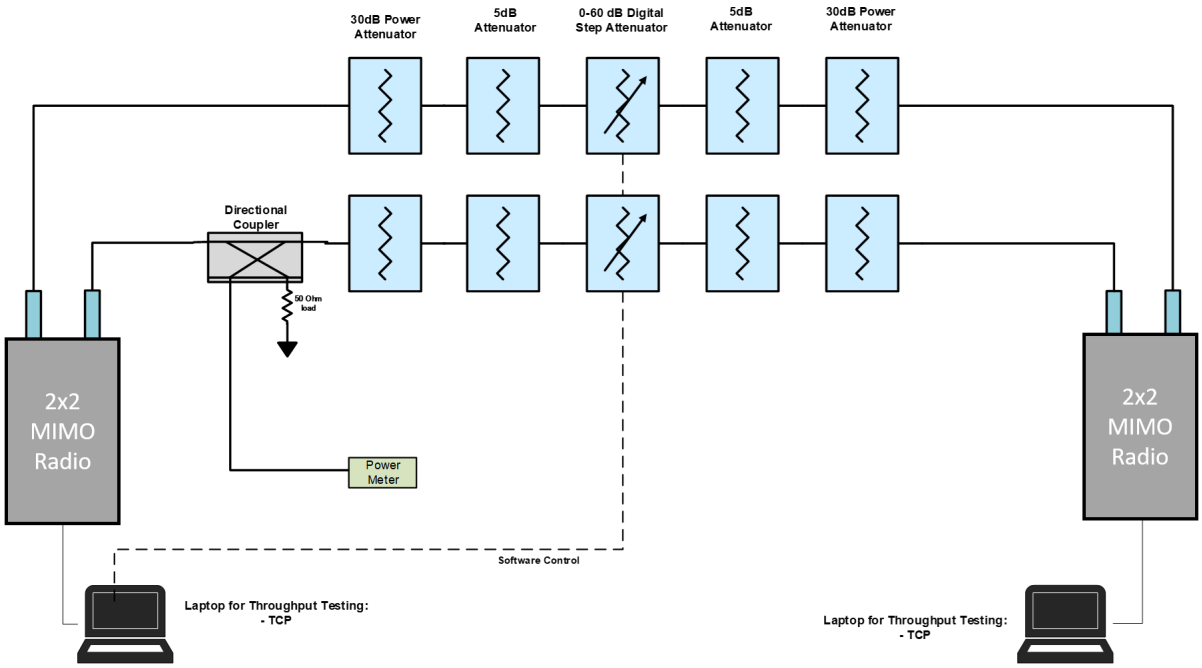


Figure 1: Radio Baseline Setup

Next, NuWaves incorporated the BDAs (NuWaves PN: NW-BA-12B04A-D27) into the system setup to achieve improved link distance as depicted in Figure 2. This test setup utilized qty 4 BDAs to establish a fully symmetric link. Similar to the radio to radio testing, the radio settings were varied to optimize the streaming method, MCS settings, and bandwidth settings for optimal link distance. The MCS mode was manually adjusted to optimize the radio's waveform modulation characteristics versus the BDA compression. The MCS mode determines the radio modulation characteristics giving the user the ability to manually select the modulation for their application. Alternatively, the radio can automatically determine the optimal modulation to operate at any given time when MCS255 mode is selected. The MCS mode ultimately determines the amount of data throughput that can be passed. For purposes of this report, the manually adjusted and automatically adjusted (MSC255) modes are shown.

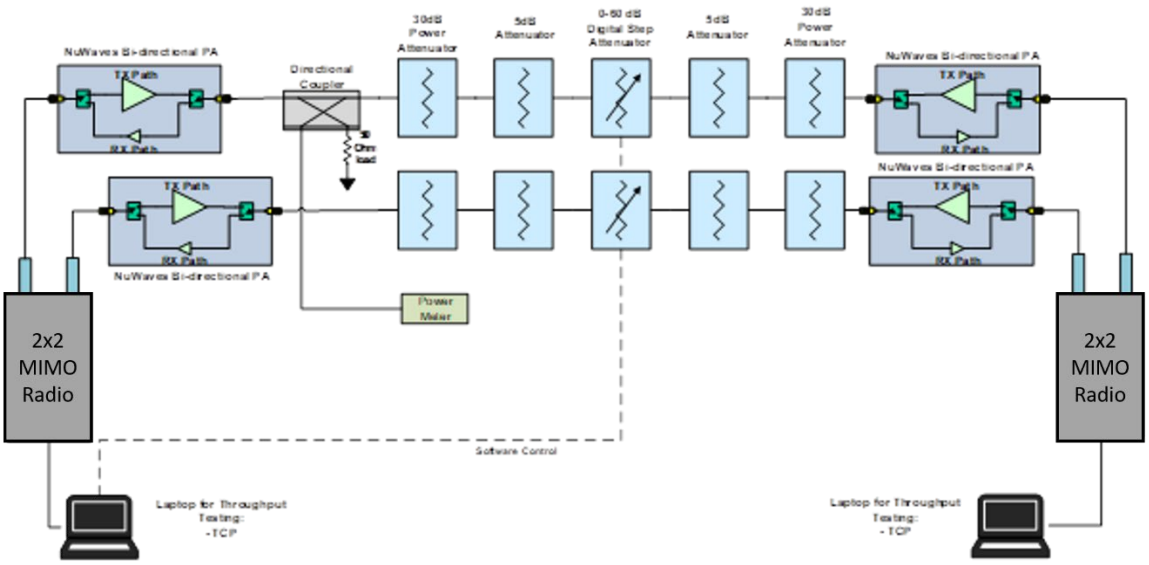


Figure 2: Radio/BDA Setup

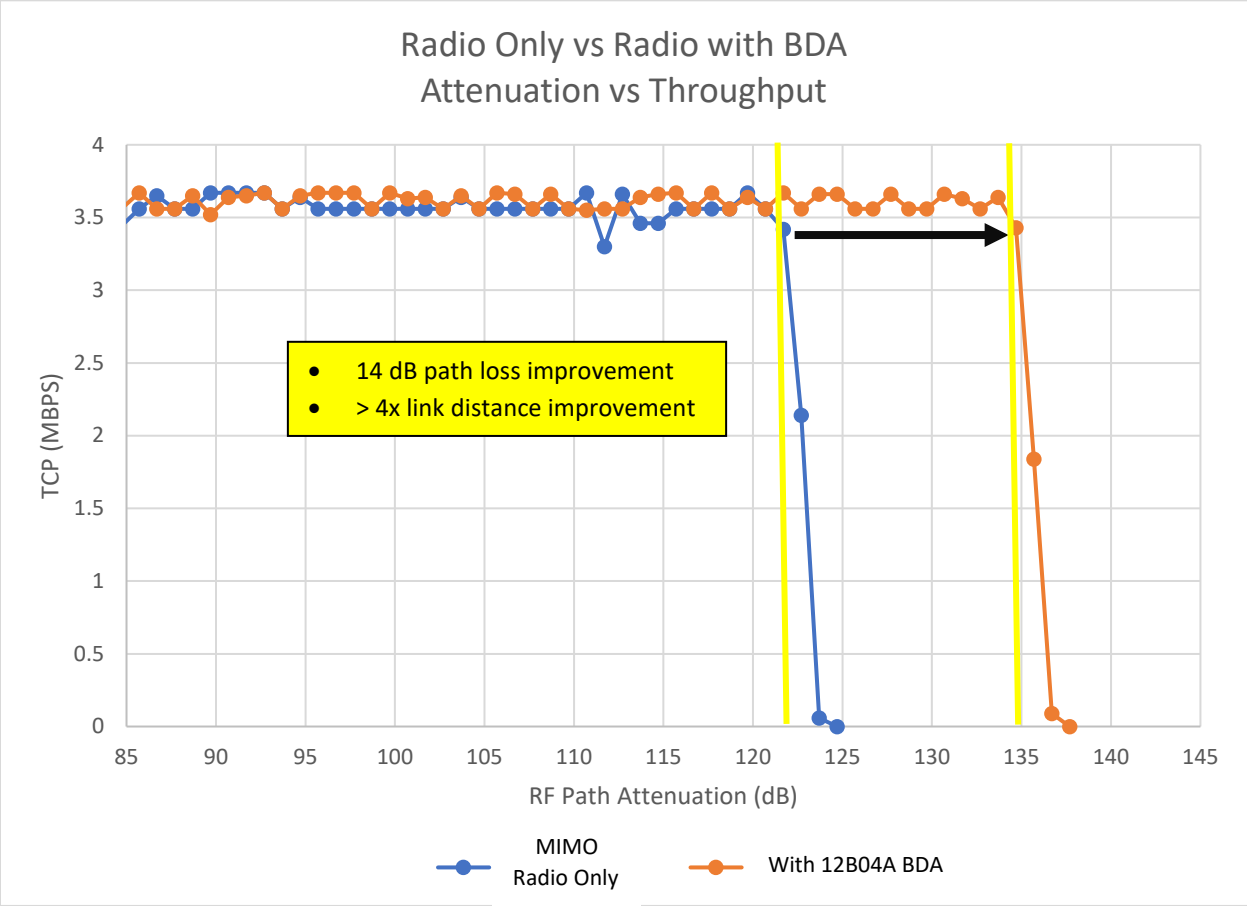
BDA comparison graphs

Performance measurements are provided in the following graphs to summarize the link margin improvements using the NuWaves NW-BA-12B04A-D27 BDAs. The RF path attenuator value as indicated on the horizontal axis of the graphs represents path loss and can be used to determine link distance. NuWaves chose to represent the link distance in terms of path loss since the overall link distance will vary on other system parameters such as antenna gain, fade margin, etc and these parameters will vary from system to system.

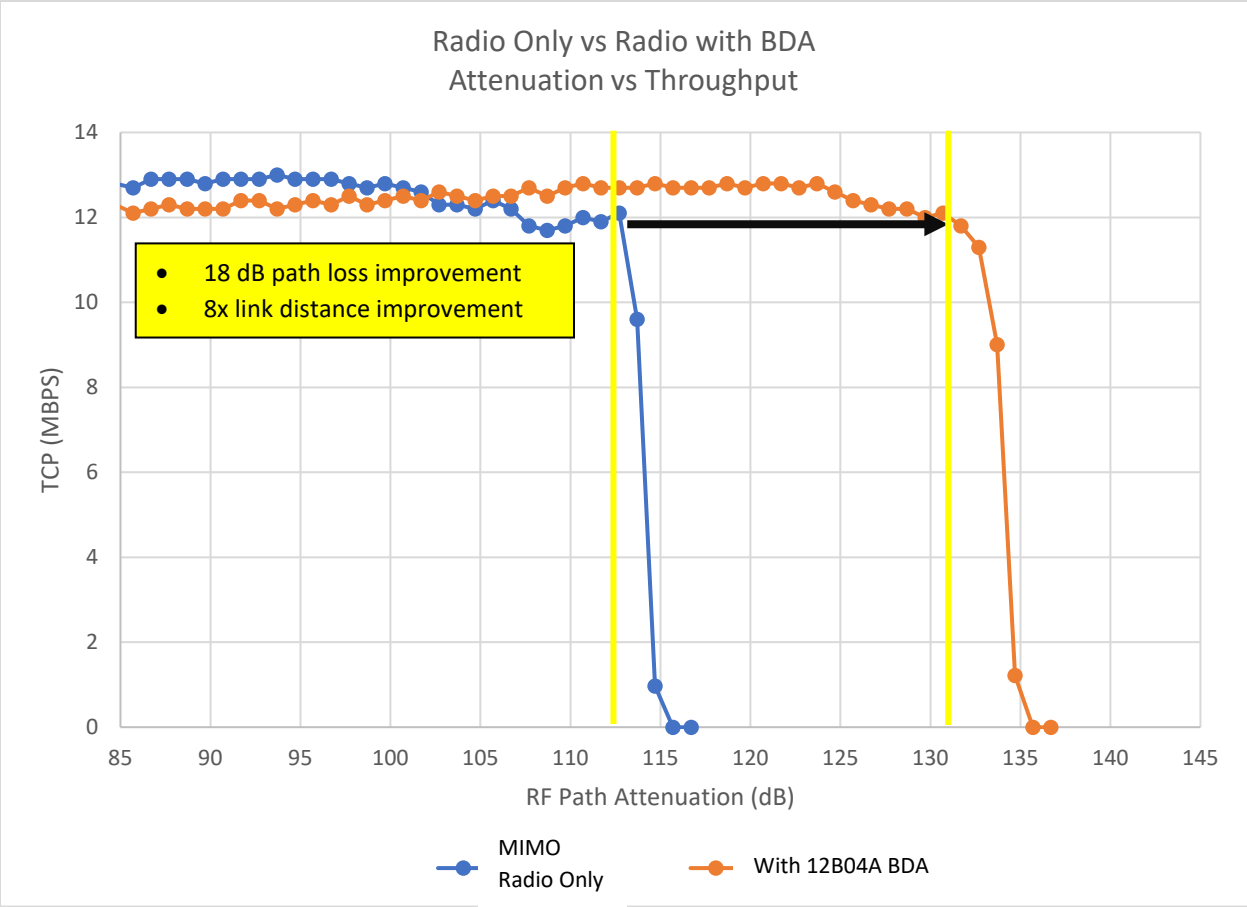
Graph Notes:

- Vertical Axis is TCP throughput in MBPS
- Horizontal Axis is Attenuation value in 1dB steps

Radio Settings: 5 MHz BW, MCS9 mode, (15dB PA gain, +27dBm max PA power in GUI), Single Channel



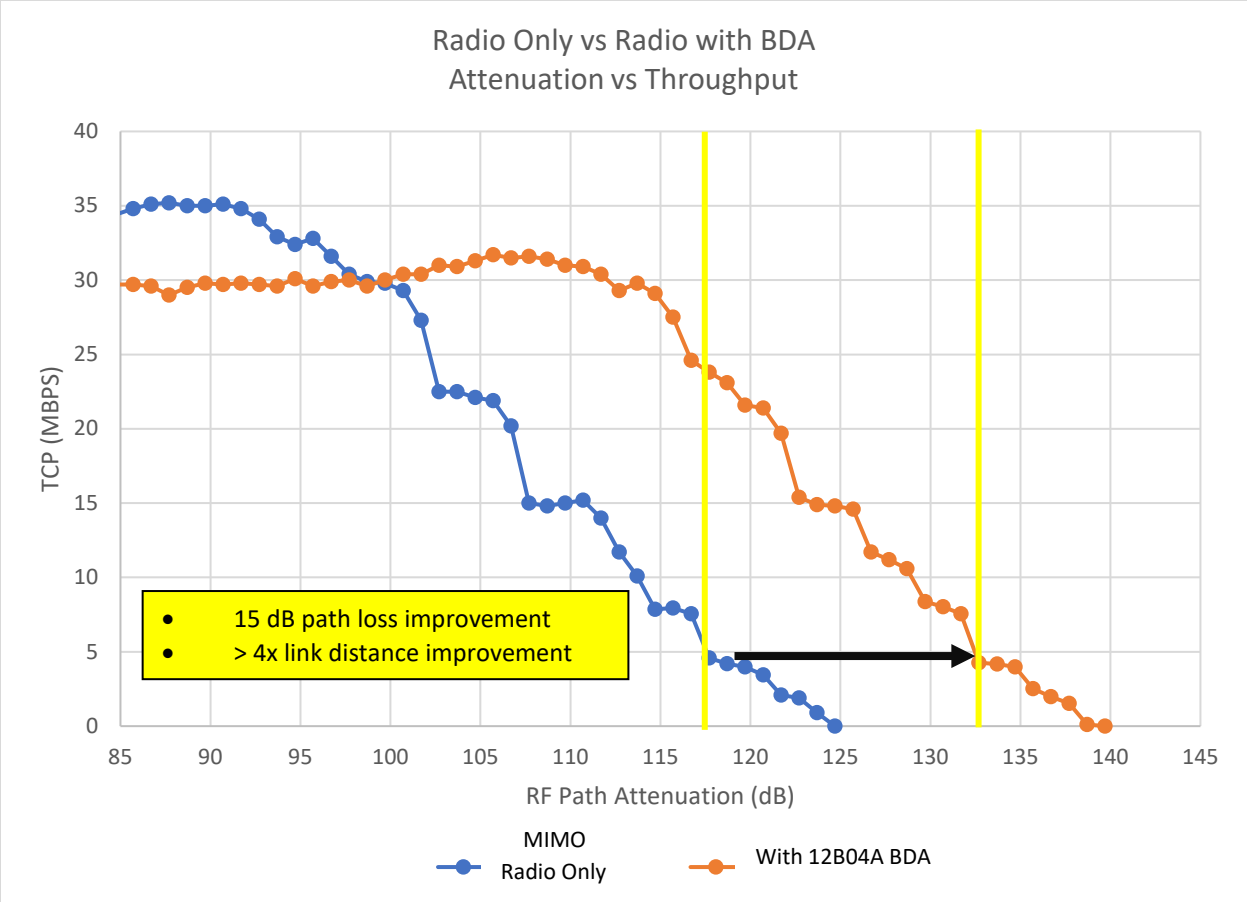
Radio Settings: 10 MHz BW, MCS10 mode, (15dB PA gain, +33dBm max PA power in GUI)



In the graph below, the Radio only (Blue curve) and w/ BDA (Orange curve) begin to deviate at low attenuation settings. This is due to the compression introduced from the BDA, and though it may limit throughput at low attenuations, the benefit of range extension is still achieved at higher attenuation values. This deviation at low attenuation settings occurs when the radio is operating at higher order modulations, such as the MCS 255, and the larger peak to average ratio (PAPR) of the waveform causes distortion within the BDA. In this example, the maximum throughput is a tradeoff with maximum distance.

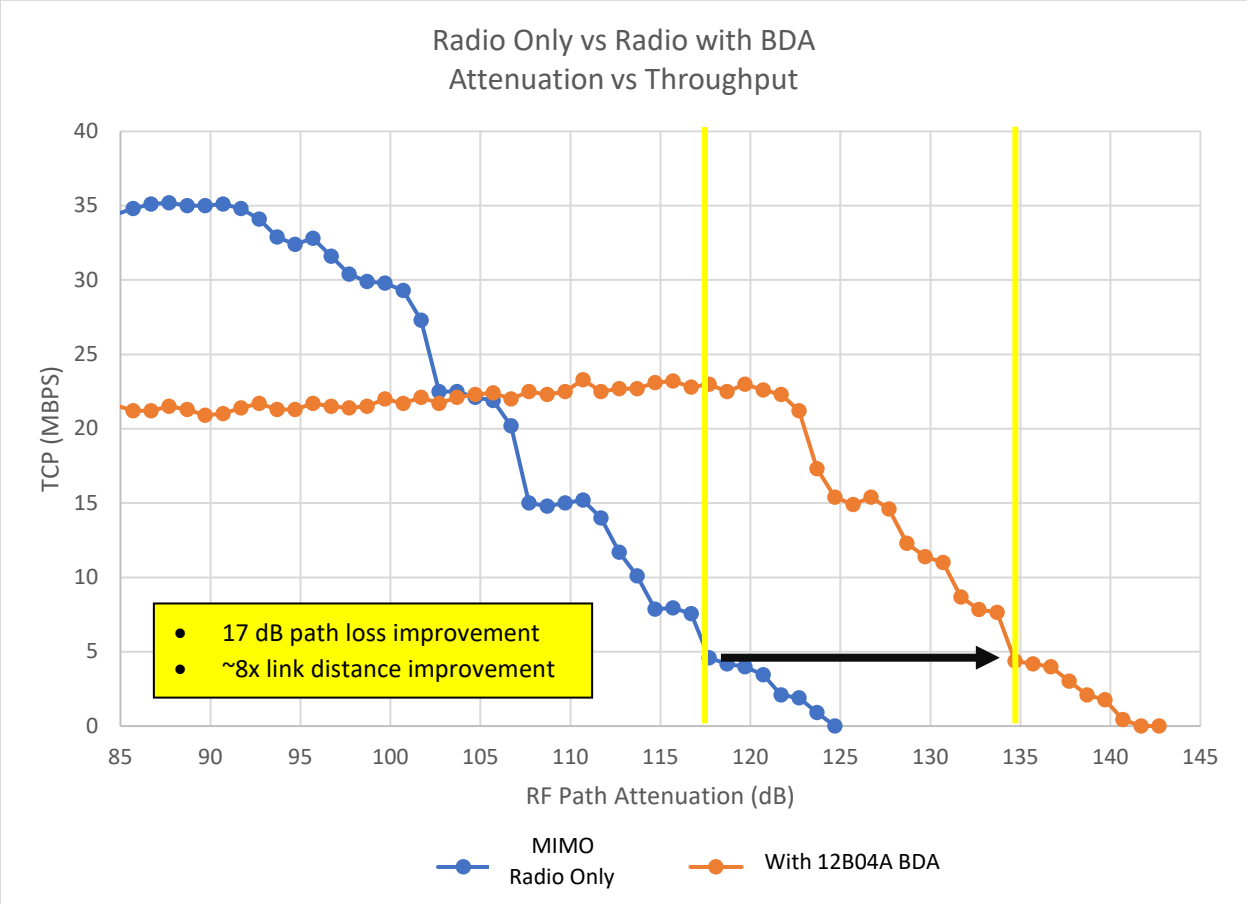
If desiring to maintain very high throughput at lower attenuation values while optimizing maximum link distance, the radio could be set to automatically adjust the MCS modes and radio output power to optimize throughput vs link distance when operating with the BDA. This would allow the BDA to be backed off to operate in a more linear region so the BDA compression does not limit the throughput and only for purposes of maximizing throughput at lower link distances. Similarly, when desiring to achieve further distances the BDA could be driven at a higher input power or the radio could operate at lower order modulations from the radio to achieve maximum link distance. These options can be a great way to maximize link distance and throughput across the entire link budget.

Radio Settings: 10 MHz BW, MCS255 mode, Dual Streams, (15dB PA gain, +27dBm max PA power in GUI)



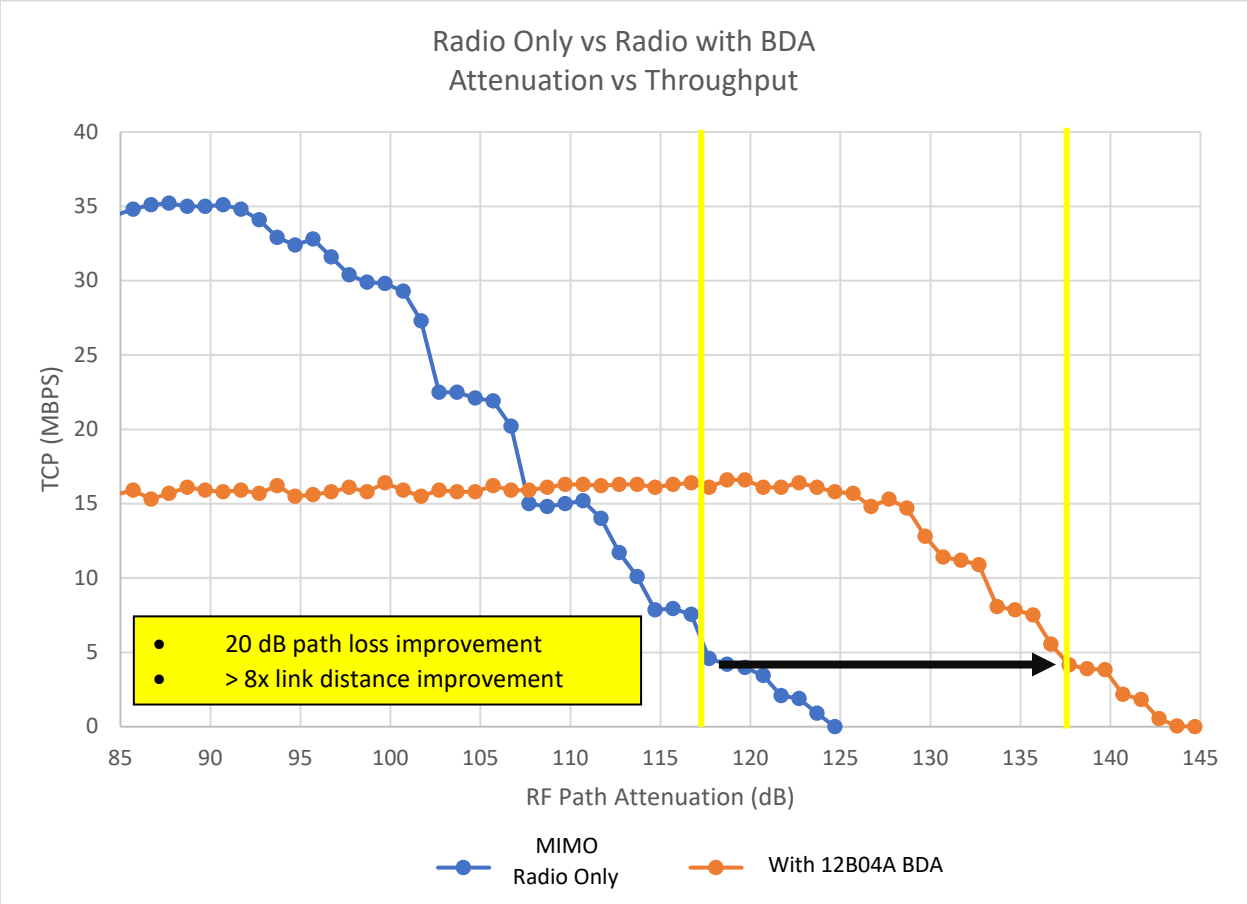
In the graph below the deviation begins to increase between the Radio only (Blue curve) and w/ BDA (Orange curve). This is due to the radio now operating with a +30 dBm max PA power from the radio compared to +27 dBm max PA power in the previous graph. This increase in RF input drive to the BDA causes the BDA to operate further into compression, and hence, limiting the maximum throughput that can be achieved at lower attenuation settings.

Radio Settings: 10 MHz BW, MCS255 mode, Dual Streams, (15dB PA gain, +30dBm max PA power in GUI)



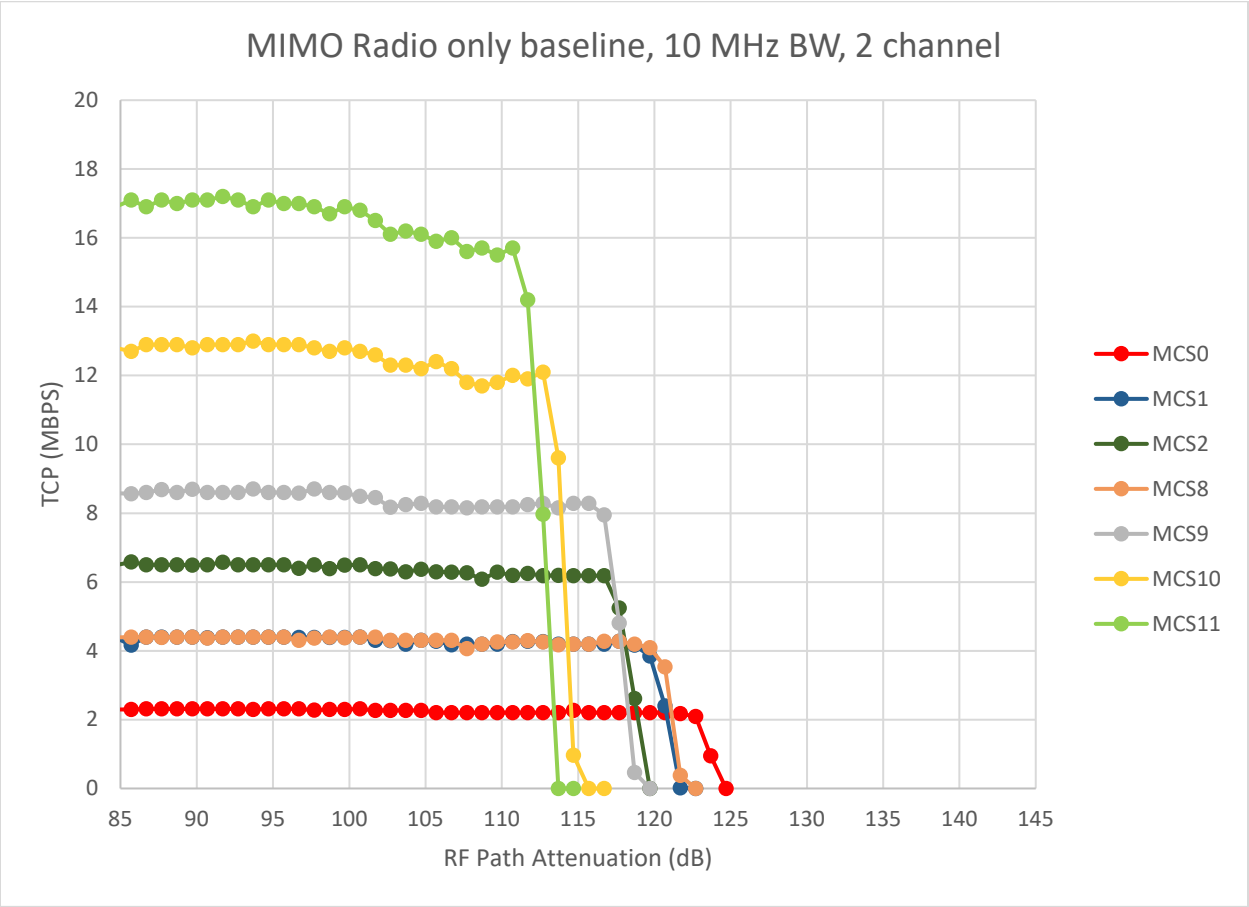
In the graph below the deviation continues to further increase between the Radio only (Blue curve) and w/ BDA (Orange curve). Similarly, this is due to the radio now operating with a +33 dBm max PA power from the radio compared to +27 dBm and +30 dBm max PA power in the previous graphs. This increase in RF input drive to the BDA causes the BDA to operate further into compression, and hence, limiting the maximum throughput that can be achieved at lower attenuation settings. Regardless of this effect, the BDA still provides significant link distance improvements over operating the radio alone.

Radio Settings: 10 MHz BW, MCS255 mode, Dual Streams, (15dB PA gain, +33dBm max PA power in GUI)



The graph below details the different MCS modes and their performance when operating only a radio to radio link without the BDAs.

Radio Settings: 10 MHz BW, Radio only baseline. MCS mode comparison



This graph summarizes the different MCS modes and their performance when operating the radios with the BDAs. The results show that 4 MBPS is achievable up to a total path loss of 140 dB when including the BDAs in the link.

Radio Settings: 10 MHz BW, Radio with BDA, MCS mode comparison, (15dB PA gain, +33dBm max PA power in GUI)