



Persistent Systems MPU 5

Link Margin Enhancement Using S-Band 25W BDAs

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Revision History

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1. Overview

This document details a series of tests performed with the **Persistent Systems MPU 5** radios used in combination with **Triad RF Systems 25W S-Band BDAs**.

The MPU5 radio is used in a variety of military and commercial applications. Some of the applications in which these radios are used may present difficult RF or physical environment conditions.

The objective of this effort was to demonstrate, with some basic RF testing, that measureable link distance increases can be achieved by pairing the radios with BDAs. Data throughput and RF link attenuation limit testing were performed on both stand-alone radios and on radio/BDA combinations:

The first test determined the maximum link distance achievable using regardless of modulation or data rate

The second test determined the maximum link distance whilst maintaining an OFDM modulation and data rate.

Free space path loss was simulated by increasing the RF attenuation level between the radios and radio/BDA combinations using the **Triad RF Systems T002**, a custom made MIMO-capable electronically controlled attenuator rack. The data obtained was then visualized and compared in order to display the performance gains achieved when integrating bi-directional amplifiers into the data link. The T002 rack is configured to provide between 80 and 145dB of path loss for up to four MIMO streams, and can be internally re-configured to create higher maximum attenuation values if required.

2. DUT Specifications

A brief outline of electrical and RF specifications of the devices under test have been listed in the sub-sections below.

2.1 Persistent MPU 5 Specifications

Parameter	Min	Typ.	Max	Unit	Notes
Operating Frequency	2200		2500	MHz	
Power Output (per channel)	16.5		33	dBm	Adjustable in 0.5 dB steps.
Channel Bandwidth	5		20	MHz	5, 10, and 20 MHz channel bandwidth
Modulation	BPSK		64QAM	--	
Tx/Rx Operating modes	SISO		3x3 MIMO	--	
Data Rate			100	Mbps	~33 Mbps per channel
Input Voltage	8		28	VDC	

2.2 Triad RF Systems 25W S-Band BDA Specifications

Parameter	Min	Typ.	Max	Unit	Notes
Operating Frequency	2300		2500	MHz	
PSat Power Output		44		dBm	
Linear Power Output		37		dBm	64QAM @ -27dB EVM
Linear Gain	20	22		dB	
Gain Flatness (peak to peak)		1.0		dB	
Input Return Loss	-12	-16		dB	
Maximum Input Power			33	dBm	100% Duty Cycle, CW
Operating Voltage	24	28	30	VDC	
Current Draw		1.0	2.4	A	Max current draw conditions are reached @ 44 dBm Output 100% Duty Cycle, CW Signal

2.3 Triad RF Systems T002 Attenuation Rack

Parameter	Min	Typ.	Max	Unit	Notes
Operating Frequency	0		6000	MHz	
Attenuation	80		145	dB	Adjustable in 0.5 dB steps
Max Power Input			50	W	Average, 500W peak

3. Test Setup Configuration

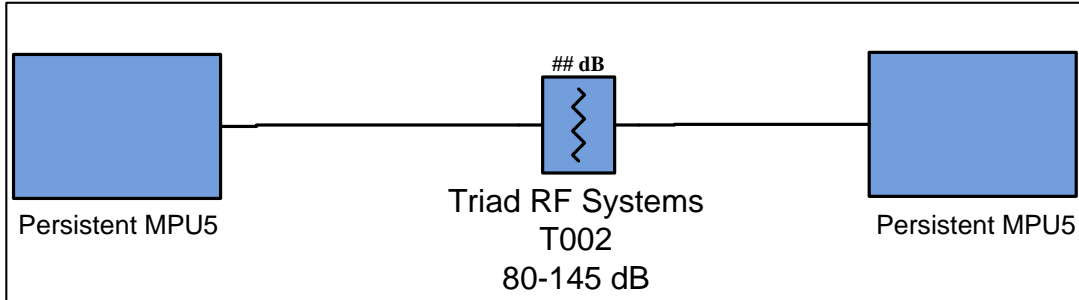
Below are block diagrams outlining how the devices under test were connected for the tests performed.

3.1 Equipment

- Two Persistent Systems MPU5 Radios
- Two Triad RF Systems TTRM1004 25W S Band BDAs
- One Triad RF Systems T002 MIMO Test Rack
- JPerf network throughput utility (both external to the radios and the built-in utility)
- VLC for UDP streaming from one radio to another, for observing streaming HD video quality

3.2 Persistent MPU5 Stand-Alone Radio Test Set-up

3.2.1 Block Diagram

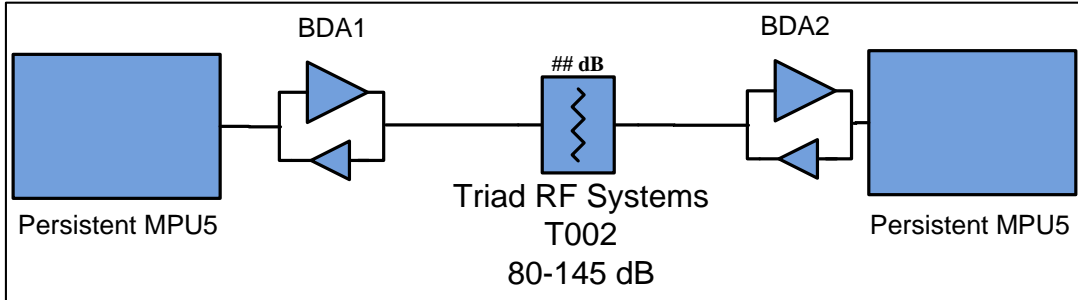


3.2.2 Setup Photo

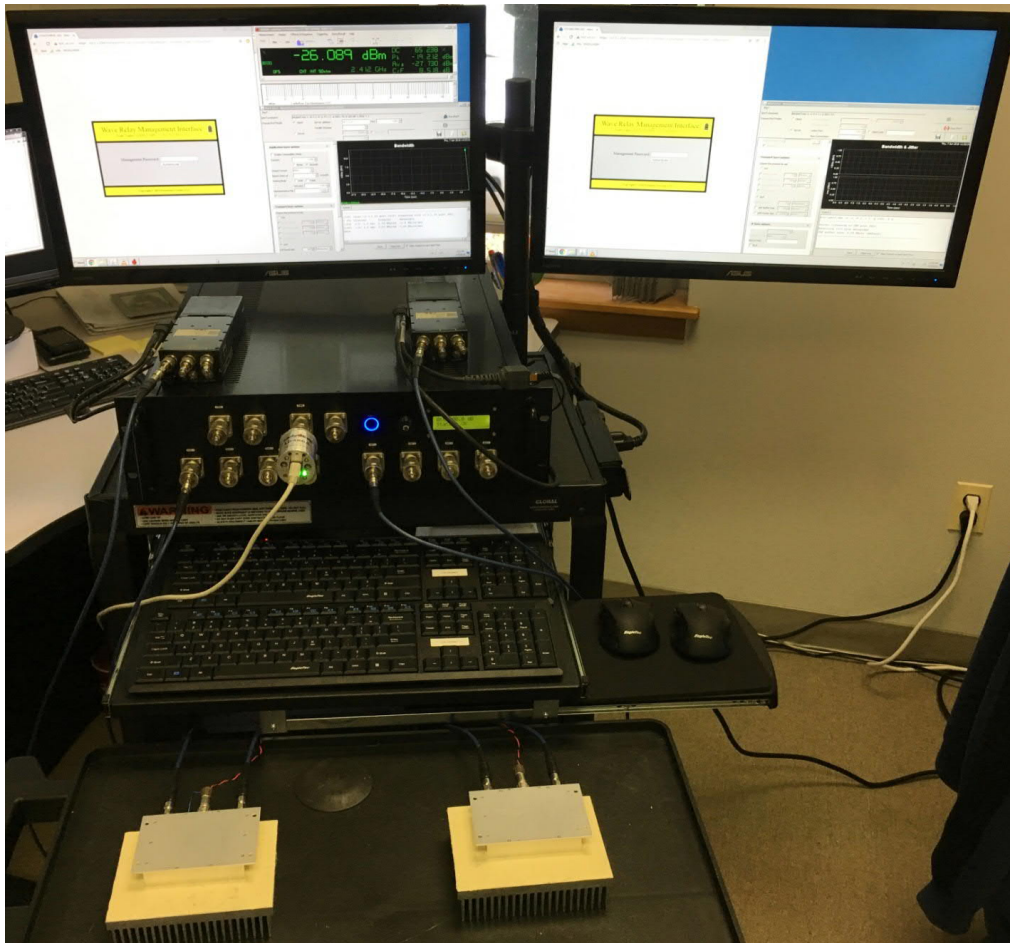


3.3 Persistent MPU5 + Triad 25W S-Band BDA Test Set-up

3.3.1 Block Diagram



3.3.2 Setup Photo



3.4 Test Conditions / Notes

The radios were configured for SISO mode, and a single BDA was attached to that active stream for these tests. Separate tests for 2x2 and 3x3 MIMO are forthcoming, in both bench-test form (as was performed herein) and in real-world “free space” testing. However, this closed loop test very accurately represents the **minimum** link margin increase BDAs can provide.

Adding additional MIMO streams will both increase the throughput of the link and add additional link margin, but the margin contribution that the amplifier(s) will provide is generally the same for both SISO and MIMO cases.

The testing was performed at 2.412 GHz. This frequency was selected arbitrarily, as both the radios and BDAs can operate from 2200-2500 MHz. The edges of this operating band are sufficiently close in frequency such that FSPL calculations will not differ significantly at the low and high ends of this band. In a scenario where the tuning bandwidth was much wider (e.g. 2.2 – 5 GHz) testing at both ends of the operating band would be essential, since FSPL will be much different at the 2.2 GHz and 5 GHz frequencies.

4. Data Link Test Results

The tests in section 4 were performed with the MPU5 radios stand-alone.

Two use cases were tested; the testing in sections 4.1.1 and 4.2.1 determined how much attenuation could be inserted in the radio link, without and with the BDAs, before it became unusable. The testing in section 4.1.2 determined how much attenuation could be inserted until the radio link no longer operated at its maximum data rate

An “equivalent link distance” was calculated in the second column of each chart. This link distance was backwards-calculated from the free space path loss equation. This column represents the physical distance required for the same attenuation level to be experienced by the wireless link in line of sight conditions. Since actual link distance depends on a great many factors, this distance number’s main purpose is to compare how much more range can be achieved using a BDA, keeping all other link factors constant and controlled.

4.1 Persistent MPU 5 Stand-Alone Radio Testing

4.1.1 Test to Link Failure

The table below outlines the data rate, SNR and other radio parameters across an increasing attenuation level between the radios during an active link. The radio power was set the maximum setting.

The Stand-Alone MPU5 radio pair lost link at approx 122 dB of attenuation.

Radio Power Setting: 29 dBm

Attenuation	Equivalent Link Distance (km)	Radio 1 Rx SNR (dB)	Radio 2 Rx SNR (dB)	Output Power (Pk)	Output Power (avg)	Modulation	Data Rate (Mbps)
82.2	0.13	40	41	34.1	26.1	MIMO 7:1	33.11
87.3	0.23	36	37	33.5	24.6	MIMO 7:1	34.62
92.3	0.41	32	32	34.2	25	MIMO 7:1	34.55
97.4	0.73	27	27	34.8	25.1	MIMO 7:1	31.86
101.9	1.23	23	23	34.3	26	MIMO 7:1	21.97
107	2.22	19	18	34.5	27.1	MIMO 4:1	19.58
112.1	3.99	14	13	34.5	26.8	MIMO 3:1	14.20
112.6	4.22	14	12	34.2	26.5	MIMO 3:1	13.74
113.1	4.47	13	12	34.8	27.1	MIMO 3:1	12.30
113.6	4.74	13	11	34.2	26.6	MIMO 2:1	10.85
114.1	5.02	12	11	34.5	26.6	MIMO 2:1	11.30
114.6	5.32	11	11	34	26.7	MIMO 2:1	11.62
115.1	5.63	11	11	34.6	26.2	MIMO 2:1	11.20
115.6	5.97	11	10	34.3	26.1	MIMO 2:1	11.95
116.1	6.32	10	10	34.3	26.3	MIMO 2:1	11.06
116.5	6.62	10	10	34.4	26.4	MIMO 2:1	11.05
117.3	7.25	9	9	34.5	26.4	MIMO 2:1	10.71

Attenuation	Equivalent Link Distance (km)	Radio 1 Rx SNR (dB)	Radio 2 Rx SNR (dB)	Output Power (Pk)	Output Power (avg)	Modulation	Data Rate (Mbps)
117.8	7.68	9	9	34.4	26.6	MIMO 2:1	11.06
118.3	8.14	9	8	34.3	26.3	MIMO 2:1	10.27
118.8	8.62	8	7	34.2	26.5	MIMO 1:1	7.84
119.3	9.13	7	7	34.3	26.7	MIMO 1:1	7.33
119.8	9.67	6	6	34.5	37	MIMO 1:1	7.54
120.3	10.25	6	6	34.4	26.6	MIMO 1:1	6.31
120.8	10.85	5	6	34.5	26.6	MIMO 1:1	4.44
121.3	11.50	4	5	34.7	26.6	OFDM_9	3.20
121.8	12.18	5	4	34.6	27.1	OFDM_9	2.37
122.2	12.75	Link Failed					

4.1.2 Test to Maintain Maximum Data Rate

The table below outlines the data rate, SNR and other radio parameters across an increasing attenuation level between the radios during an active link. **In this test, the radio power was set to the maximum output power where the radio module was still linear enough to maintain the max data rate / modulation level.**

In this test, the Stand-Alone MPU5 radios moved to a lower order modulation (and lower data rate) at approx 92 dB of attenuation.

Radio Power Setting: 17 dBm

Attenuation	Equivalent Link Distance (km)	Radio 1 Rx SNR (dB)	Radio 2 Rx SNR (dB)	Output Power (Pk)	Output Power (avg)	Modulation	Data Rate (Mbps)
82.2	0.13	29	29	23.8	16.9	MIMO 7:1	34.09
87.3	0.23	25	25	23.2	16.7	MIMO 7:1	32.47
88.3	0.26	24	23	23	17.9	MIMO 7:1	33.26
89.3	0.29	24	22	23.4	17.5	MIMO 7:1	33.51
90.3	0.32	23	22	23.7	16.8	MIMO 7:1	32.98
90.8	0.34	22	21	23.3	17.3	MIMO 7:1	28.66
91.3	0.36	21	21	23	18.6	MIMO 7:1	25.42
91.8	0.39	20	20	22.9	14	MIMO 6:1	28.58
92.3	0.41	20	20	23.6	17	MIMO 6:1	26.01
92.8	0.43	20	19	22.5	17.3	MIMO 5:1	22.23
93.3	0.46	19	19	23.5	16.7	MIMO 4:1	20.8
93.8	0.48	19	18	23.2	17.6	MIMO 4:1	20.92
94.3	0.51	18	18	23.5	16	MIMO 4:1	20.79
94.8	0.54	18	17	23	17.4	MIMO 4:1	18.25
95.3	0.58	17	17	22.7	16.5	MIMO 4:1	19.89

4.2 Persistent MPU5 with Triad 25W S-Band BDA Testing

The tests in section 4.1.1 and 4.1.2 were repeated with the addition of 2x TTRM1004 BDA modules to the link.

4.2.1 Test to Link Failure

In this test, the MPU5 radio pair used in conjunction with Triad BDAs lost link at approx 137 dB of attenuation. This represents an additional 15 dB in link margin, and an approximate 6x increase in wireless range.

Radio Power Setting: 29 dBm

BDA Power Output: 44dBm

Attenuation	Equivalent Link Distance (km)	Radio 1 Rx SNR (dB)	Radio 2 Rx SNR (dB)	Output Power (Pk)	Output Power (avg)	Modulation	Data Rate (Mbps)
107	2.22	40	40	44.9	42.3	CCK_11	1.55
112.1	3.99	35	36	44.9	41.9	MIMO 4:1	15.59
117.4	7.34	30	30	45	41.9	MIMO 4:1	15.51
122.2	12.75	25	25	44.9	42.1	MIMO 3:1	10.45
127.3	22.94	20	20	44.9	42	MIMO 2:1	8.63
132.4	41.27	15	16	44.9	42	MIMO 2:1	7.85
133.4	46.30	14	14	44.9	42.2	MIMO 1:1	5.69
134.4	51.95	13	14	45	42	MIMO 1:1	5.06
135.4	58.29	11	12	44.9	41.9	MIMO 1:1	3.58
136.4	65.41	11	11	45	43.1	OFDM_6	2.49
137.4	73.39	10	11	44.8	43.5	CCK_5	1.85
138.4	82.34	Link Failed					

4.2.2 Test to Maintain Maximum Data Rate

In this test, the MPU5 radio pair used in conjunction with Triad BDAs moved to a lower order modulation (and lower data rate) at approx 108dB of attenuation. This represents an additional 17 dB in link margin, and an approximate 7x increase in wireless range.

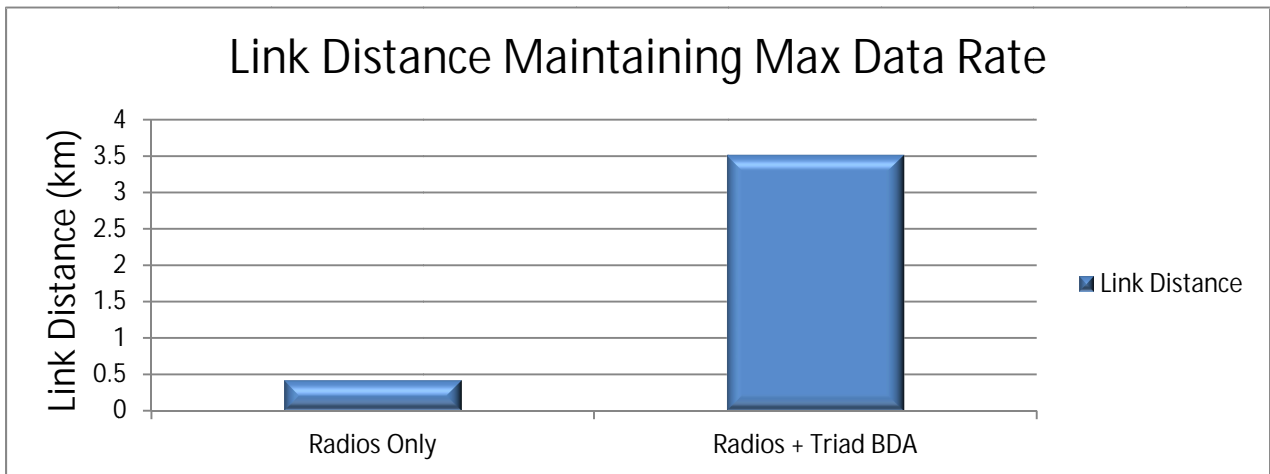
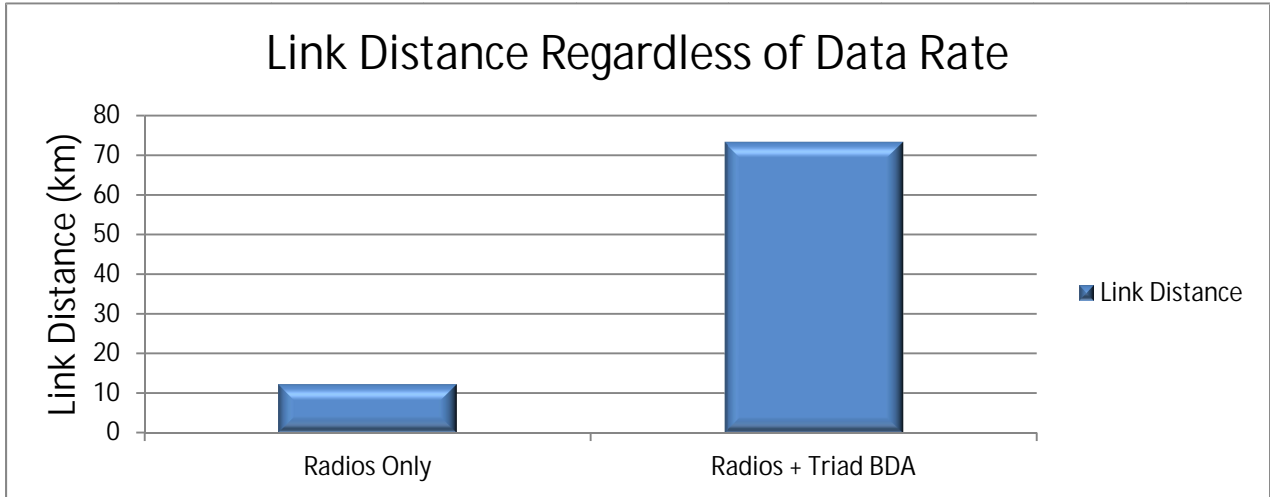
Radio Power Setting: 17 dBm

BDA Power Output: 44 dBm

Attenuation	Equivalent Link Distance (km)	Radio 1 Rx SNR (dB)	Radio 2 Rx SNR (dB)	Output Power (Pk)	Output Power (avg)	Modulation	Data Rate (Mbps)
96.3	0.65	39	39	44.3	30.5	MIMO 7:1	25.36
97.4	0.73	38	38	44.4	30.7	MIMO 7:1	27.96
98.4	0.82	38	38	43.7	30.95	MIMO 7:1	31.67
99.4	0.92	37	37	44.3	30.9	MIMO 7:1	34.52
100.4	1.03	36	31	43.7	30.7	MIMO 7:1	27.04
101.4	1.16	35	35	44.2	31.1	MIMO 7:1	30.73
101.9	1.23	34	33	43.9	30.8	MIMO 7:1	32.15
102.9	1.38	33	32	44.6	30.7	MIMO 7:1	32.14
103.9	1.55	32	32	44	31	MIMO 7:1	31.14
104.9	1.74	31	30	44.1	30.8	MIMO 7:1	32.88
105.9	1.95	30	30	44.3	30.8	MIMO 7:1	32.13
107	2.22	29	28	43.7	30.7	MIMO 7:1	30.52
108	2.49	28	27	43.9	30.8	MIMO 7:1	28.86
109	2.79	26	26	44.4	30.8	MIMO 6:1	22.85
110	3.13	26	26	44.2	31.1	MIMO 5:1	25.51
111	3.51	24	25	44.2	31.2	MIMO 4:1	22.05
112.1	3.99	24	24	44.4	31	MIMO 4:1	21.21

5. Summary: Radios only vs. Radios + 25W S-Band BDA

All tests assume 0dBi Tx and Rx antenna.



6. Conclusions

BDAs are able to provide increased link performance in specific use cases of the MPU5 radios.

These cases include:

- System implementations where extra node-to-node link distance from the MPU5 is required and the internal radio module does not have the linear RF power capability to close the link,
- System implementations where the wireless link is functioning between nodes, but a higher data rate than is currently being achieved is desired.