RADIO FREQUENCY INTERFERENCE ANALYSIS REPORT

Emerald

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Table of Contents

1.0 Executive Summary

This report presents a radio frequency interference (RFI) analysis which was performed on the Emerald site. The RFI analysis consists of transmitter noise, receiver desensitization, intermodulation, harmonic and transmitter spurious output interference. The report consists of Sections that provide details of the communications site, antenna systems, operational frequencies and each interference analysis mode.

A summary of the interference analysis results is depicted in the following Table.

Interference Analysis Mode	Type Mix	Status	Summary	Worst-Case Margin (dB)
Transmitter Noise	N/A	Passed	No Interference was predicted	42
Receiver Desensitization	N/A	Passed	No Interference was predicted	6
Transmitter Intermodulation	1 Tx	Passed	No Interference was predicted	N/A
Transmitter Intermodulation	2 Tx	Passed	No Interference was predicted	N/A
Transmitter Intermodulation	3 Tx	Passed	No Interference was predicted	N/A
Transmitter Intermodulation	4 Tx	N/A	No Analysis performed	N/A
Transmitter Intermodulation	5 Tx	N/A	No Analysis performed	N/A
Receiver Intermodulation	1 Tx	Passed	No Interference was predicted	N/A
Receiver Intermodulation	2 Tx	Passed	No Interference was predicted	N/A
Receiver Intermodulation	3 Tx	Passed	No Interference was predicted	N/A
Receiver Intermodulation	4 Tx	N/A	No Analysis performed	N/A
Receiver Intermodulation	5 Tx	N/A	No Analysis performed	N/A
Transmitter Harmonics	N/A	Passed	No Interference was predicted	N/A
Transmitter Spurious Output	N/A	Passed	No Interference was predicted	N/A
Interference Level Summing - C/(I+N)	N/A	Passed	No Interference was predicted	N/A
Wideband IM Spectral Analysis	N/A	N/A	No Analysis performed	N/A

The analysis was performed with the setup options depicted in the Table below.

Analysis	Description
Receiver Performance	Receiver Sensitivity Threshold
Receiver Bandwidth	Receiver Dependent
Antenna Patterns Considered	No (Worst Case)
Measured Antenna Isolation Data	No
Filters/Multicouplers Considered	Yes
Number of Simultaneous Transmitters Mixed	3
Highest Intermodulation Order Tested	3
Condense Intermodulation Hit Quantity	No
TX IM Bandwidth Multiplication	Yes
Tx/Rx Systems Excluded	None
Site File Name	Emerald.dta
Report File Name	Emerald_draft9.docx
WirelessSiteRFI Software Version	10.0.11

2.0 Site Description

The communication systems located at this site are described in this section as well as the configuration of the antenna systems.

The site parameters are:

Site Name: Emerald
Owner:
Site Description:
Address: 38400 Blackmer Dr
Latitude: 40:27:44.1 N
Longitude: 106:51:02.4 W
Elevation: 8250
Notes:

2.1 Communications Systems

System	Provider	Technology	Frequency Band
1	State of Colorado	SMR	806 - 896 MHz - Land Mobile
2	Routt County	SMR	806 - 896 MHz - Land Mobile
3	State of Colorado	Microwave	5925 - 6875 MHz - 5 GHz Microwave
4	YVEA	Microwave	10700 - 11700 MHz - 11 GHz Microwave
5	Routt County	Microwave	10700 - 11700 MHz - 11 GHz Microwave
6	YVEA	SMR	150 - 174 MHz - Land Mobile
8	State of Colorado	Microwave	10700 - 11700 MHz - 11 GHz Microwave
9	Routt County	SMR	150 - 174 MHz - Land Mobile
10	L3 Harris	WAM	1030 SSR 1090 ADS-B 978 UAT

2.2 Antenna Systems

Ant #	Mfg	Antenna Model	Gain (dBd)	Hgt (ft)	Orient (deg)	Sec-tor	Ant Use	Transmission Line Type	Line Loss (/100')	Line Length (ft)
1	Antenna Products	CAT10-188199T0	10	81.3	0		Tx/Rx	1-1/4 in. Foam	3	111.3
2	Antenna Products	150D7-12-25	11.32	82.8	0		Tx	1-1/4 in. Foam	3	112.8
3	RFS	PAD 6 - W59 B USA 970728-VV	39.1	75.4	0		Tx/Rx	1-1/4 in. Foam	3	105.4
4	Andrew	PX4-127	38.8	63.3	0		Tx	1-1/4 in. Foam	2	93.3
5	Andrew	VHP4-107	38.2	56.8	0		Tx/Rx	1-1/4 in. Foam	2	86.8
6	Telewave	150D7-12-50	11.21	60.2	0		Tx	1-1/4 in. Foam	2	90.2
8	RFS	SU 3 - 127 B FRT	38.8	40.1	0		Tx/Rx	1-1/4 in. Foam	2	70.1

		980619E-HH								
9	Telewave	150D7-12-25	11.32	52	0		Tx	1-1/4 in. Foam	2	82
10	Antenna Products	DB Systems 5100A	9	65	0		Tx/Rx	1-1/4 in. Foam	2	95

3.0 Transmitter Frequencies

Freq #	Ant #	Provider	Model	Technology	Channel Label	ID	Frequency	Power (Watts)	BW (KHz)
1	1	State of Colorado	Motorola	SMR	TX A	A	851.237500	75	20
2	1	State of Colorado	Motorola	SMR	TX B	B	851.850000	75	20
3	1	State of Colorado	Motorola	SMR	TX C	C	852.725000	75	20
4	1	State of Colorado	Motorola	SMR	TX D	D	853.137500	75	20
5	1	State of Colorado	Motorola	SMR	TX E	E	853.312500	75	20
6	1	State of Colorado	Motorola	SMR	TX F	F	857.662500	75	20
7	2	Routt County	Motorola	SMR	TX G	G	155.370000	75	11.2
8	2	Routt County	Motorola	SMR	TX H	H	155.925000	75	11.2
9	2	Routt County	Motorola	SMR	TX I	I	154.370000	75	11.2
10	3	State of Colorado	Other	Microwave	TX J	J	6004.500000	.63	30000
11	4	YVEA	Generic	Microwave	TX K	K	10805.000000	50	10000
12	5	Routt County	Generic	Microwave	TX L	L	10705.000000	.63	10000
13	6	YVEA	Harris	SMR	TX M	M	153.515000	35	11.2
14	6	YVEA	Harris	SMR	TX N	N	158.130000	35	11.2
15	8	State of Colorado	Generic	Microwave	TX Q	Q	11095.000000	.63	30000
16	9	Routt County	Motorola	SMR	TX R	R	155.370000	100	11.2
17	9	Routt County	Motorola	SMR	TX S	S	155.925000	100	11.2
18	10	L3 Harris	Generic	FM Land Mobile	TX T	T	1030.000000	10	1600
19	10	L3 Harris	Generic	FM Land Mobile	TX U	U	1090.000000	58	110
20	10	L3 Harris	Generic	FM Land Mobile	TX V	V	978.000000	35.5	815

4.0 Receiver Frequencies

Freq #	Ant #	Provider	Model	Technology	Channel Label	ID	Frequency	Sen (dBm)	BW (KHz)
1	1	State of Colorado	Motorola	SMR	RX A	A	806.237500	-116	20
2	1	State of Colorado	Motorola	SMR	RX B	B	806.850000	-116	20
3	1	State of Colorado	Motorola	SMR	RX C	C	807.725000	-116	20
4	1	State of Colorado	Motorola	SMR	RX D	D	808.137500	-116	20
5	1	State of Colorado	Motorola	SMR	RX E	E	808.312500	-116	20
6	1	State of Colorado	Motorola	SMR	RX F	F	812.662500	-116	20
7	3	State of Colorado	Other	Microwave	RX J	J	6256.540000	-68	30000
8	5	Routt County	Generic	Microwave	RX L	L	10735.000000	-74	10000
9	8	State of Colorado	Generic	Microwave	RX Q	Q	11585.000000	-66	30000
10	10	L3 Harris	Generic	FM Land Mobile	RX T	T	1030.000000	-100	1600
11	10	L3 Harris	Generic	FM Land Mobile	RX U	U	1090.000000	-100	110
12	10	L3 Harris	Generic	FM Land Mobile	RX V	V	978.000000	-100	815

5.0 Transmitter Noise Analysis

Transmitter noise interference occurs because a transmitter radiates energy on its operating frequency as well as frequencies above and below the assigned frequency. The energy that is radiated above and below the assigned frequency is known as sideband noise energy and extends for several megahertz on either side of the operating frequency. This undesired noise energy can fall within the passband of a nearby receiver even if the receiver's operating frequency is several megahertz away. The transmitter noise appears as "on-channel" noise interference and cannot be filtered out at the receiver. It is on the receiver's operating frequency and competes with the desired signal, which in effect, degrades the operational performance.

The analysis predicts each transmitter's noise signal level present at the input of each receiver. It takes into account the transmitter's noise characteristics, frequency separation, power output, transmission line losses, filters, duplexers, combiners, isolators, multi-couplers and other RF devices that are present in both systems. Additionally, the analysis considers the antenna separation space loss, horizontal and vertical gain components of the antennas as well as how they are mounted on the structure. The gain components are derived from antenna pattern data published by each manufacturer.

The analysis determines how much isolation is required, if any, to prevent receiver performance degradation caused by transmitter noise interference. The Table below depicts the results of this analysis. For each receiver, the transmitter that has the worst-case impact is displayed. The Signal Margin represents the margin in dB, before the receiver's performance is degraded. A negative number indicates that the performance is degraded and the value indicates how much additional isolation is required to prevent receiver performance degradation.

Receiver Provider	Receive Channel	Receive Frequency (MHz)	Transmitter Provider	Transmit Channel	Transmit Frequency (MHz)	Attn Required (dB)	Attn Provided (dB)	Signal Margin (dB)
None								

No transmitter noise interference problems were predicted.

6.0 Receiver Desensitization Analysis

Receiver desensitization interference occurs when an undesired signal from a nearby "off-frequency" transmitter is sufficiently close to a receiver's operating frequency. The signal may get through the RF selectivity of the receiver. If this undesired signal is of sufficient amplitude, the receiver's critical voltage and current levels are altered and the performance of the receiver is degraded at its operating frequency. The gain of the receiver is reduced, thereby reducing the performance of the receiver.

A transmitter can be operating several megahertz away from the receiver frequency and/or its antenna can be located several thousand feet from the receiver's antenna and still cause interference.

The analysis predicts each transmitter’s signal level present at the input of each receiver. It takes into account the transmitter’s power output, frequency separation, transmission line losses, filters, duplexers, combiners, isolators, multi-couplers and other RF devices that are present in both systems. Additionally, the analysis considers the antenna separation space loss, horizontal and vertical gain components of the antennas as well as how they are mounted on the structure. The gain components are derived from antenna pattern data published by each manufacturer.

The analysis determines how much isolation is required, if any, to prevent receiver performance degradation caused by receiver desensitization interference. The Table below depicts the results of this analysis. For each receiver, the transmitter that has the worst-case impact is displayed. The Signal Margin represents the margin in dB, before the receiver’s performance is degraded. A negative number indicates that the performance is degraded and the value indicates how much additional isolation is required to prevent receiver performance degradation.

Receiver Provider	Receive Channel	Receive Frequency (MHz)	Transmitter Provider	Transmit Channel	Transmit Frequency (MHz)	Attn Required (dB)	Attn Provided (dB)	Signal Margin (dB)
None								

No receiver desensitization interference problems were predicted.

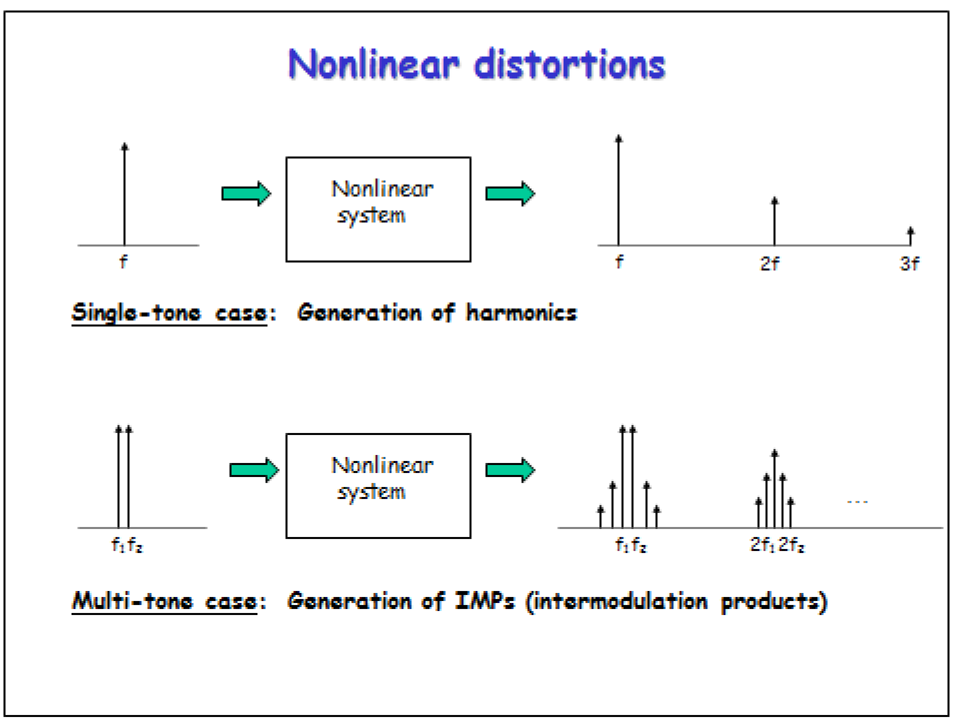
7.0 Intermodulation Interference Analysis

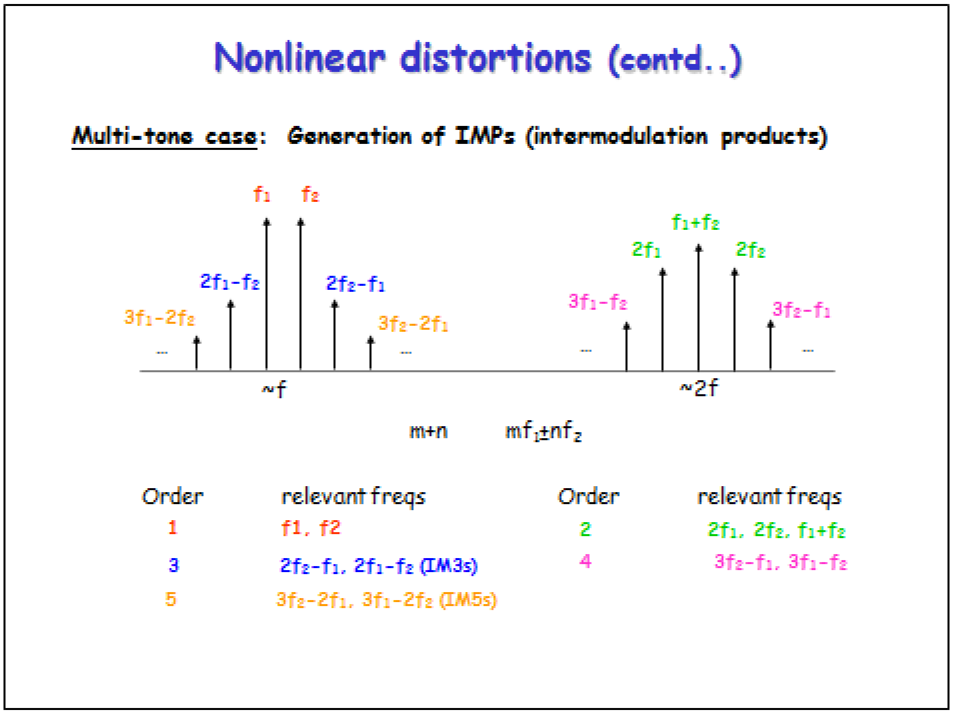
There are three basic categories of Intermodulation (IM) interference. They are receiver produced, transmitter produced, and "other" radiated IM. Transmitter produced IM is the result of one or more transmitters impressing a signal in the non-linear final output stage circuitry of another transmitter, usually via antenna coupling. The IM product frequency is then re-radiated from the transmitter's antenna. Receiver produced IM is the result of two or more transmitter signals mixing in a receiver RF amplifier or mixer stage when operating in a non-linear range.

"Other" radiated IM is the result of transmitter signals mixing in other non-linear junctions. These junctions are usually metallic, such as rusty bolts on a tower, dissimilar metallic junctions, or other non-linear metallic junctions in the area. IM products can also be caused by non-linearity in the transmission system such as antenna, transmission line, or connectors.

Communication sites with co-located transmitters, usually have RF coupling between each transmitter and antenna system. This results in the signals of each transmitter entering the nonlinear final output (PA) circuitry of the other transmitters. When intermodulation (IM) products are created in the output circuitry and they fall within the passband of the final amplifier, the IM products are re-radiated and may interfere with receivers at the same site or at other nearby sites. Additionally, these strong transmitter signals may directly enter a receiver and drive the RF amplifier into a nonlinear operation, or if not filtered effectively by the receiver input circuitry, these signals could mix in the nonlinear circuitry of the receiver front-end or mixer, creating IM products directly in the receiver.

The frequencies of IM mixing are known as nonlinear distortions. The images below depict how these IM products are derived when passing through a nonlinear junction/system.





Not all of the mixing possibilities are significant in creating interference signals. Some fall "out-of-band" of the receiver and the higher order IM products are usually weaker in signal strength.

7.1 Transmitter Generated Intermodulation Analysis

Intermodulation in transmitters occurs when a signal from another transmitter is impressed on the nonlinear final output stage circuitry, usually via antenna coupling. The power level of the IM product is determined by the power level of the incoming extraneous signal from another transmitter and by a conversion loss factor. The conversion loss factor takes into account the mixing efficiency of the transmitter's final output stage. Conversion loss differs with transmitter design, adjustment, frequency separation of the source signals, and with the order of the IM product.

The analysis calculates all possible IM product frequencies that could potentially interfere with receivers at the communications site based on each receiver's individual bandwidth. It then predicts each IM signal level present at the input of each affected receiver. For each IM frequency, the analysis considers all possible sources of IM generation in the transmitters. For example, if there are four transmitters involve, the analysis will calculate the IM signal level that would be generated in each transmitter. For this example, that would be four possible mixing conditions.

The analysis takes into account the transmitter's power output, modulation bandwidth, conversion losses, transmission line losses, filters, duplexers, combiners, isolators, multi-couplers and other RF devices that are present in each system. Additionally, the analysis considers the antenna separation space loss, horizontal and vertical gain components of the antennas as well as how they are mounted on the structure. The gain components are derived from antenna pattern data published by each manufacturer.

The analysis determines how much isolation is required to prevent receiver performance degradation for each IM interference signal that occurs. Receivers experiencing transmitter generated intermodulation interference are depicted in the following Table.

Tx 1 Source Mix Tx		Tx 2 Source		TX 3 Source		Tx 4 Source		Tx 5 Source		Intermod Hit		Affected Receiver		Attn Need
ID	Freq (MHz)	ID	Freq (MHz)	ID	Freq (MHz)	ID	Freq (MHz)	ID	Freq (MHz)	Freq (MHz)	Ord	ID	Freq (MHz)	
None														

No transmitter generated intermodulation interference problems were predicted.

7.2 Receiver Generated Intermodulation Analysis

Within a receiver, when two or more strong off-channel signals enter and mix in the receiver and one of the IM product frequencies created coincides with the receiver operating frequency, potential interference results. This internal IM mixing process takes place in the receiver's RF amplifier when it operates in a nonlinear range and/or in the first mixer, which, of course, has been designed to operate as a nonlinear device.

Receivers have a similar conversion loss type factor and receiver performance is commonly described in terms of conversion loss with respect to the 2A - B type products. Here, conversion loss is the ratio of a specified level of A and B to the level of the resulting IM product, when the product is viewed as an equivalent on-channel signal. Receiver conversion loss varies with input levels, AGC action, and product order.

The analysis calculates all possible IM product frequencies that could potentially interfere with receivers at the communications site based on each receiver's individual bandwidth. It then predicts each IM signal level present at the input of each affected receiver. For each IM frequency, the analysis considers that the IM signal is generated directly in the receiver.

The analysis takes into account the transmitter's power output, modulation bandwidth, conversion losses, transmission line losses, filters, duplexers, combiners, isolators, multi-couplers and other RF devices that are present in each system. Additionally, the analysis considers the antenna separation space loss, horizontal and vertical gain components of the antennas as well as how they are mounted on the structure. The gain components are derived from antenna pattern data published by each manufacturer.

The analysis determines how much isolation is required to prevent receiver performance degradation for each IM interference signal that occurs. Receivers experiencing receiver generated intermodulation interference are depicted in the following Table.

Tx 1 Source		Tx 2 Source		TX 3 Source		Tx 4 Source		Tx 5 Source		Intermod Hit		Affected Receiver		Attn Need
ID	Freq (MHz)	ID	Freq (MHz)	ID	Freq (MHz)	ID	Freq (MHz)	ID	Freq (MHz)	Freq (MHz)	Ord	ID	Freq (MHz)	
None														

No receiver generated intermodulation interference problems were predicted.

8.0 Transmitter Harmonic Output Interference Analysis

Transmitter harmonic interference is due to non-linear characteristics in a transmitter. The harmonics are typically created due to frequency multiplers and the non-linear design of the final output stage of the transmitter. If the harmonic signal falls within the passband of a nearby receiver and the signal level is of sufficient amplitude, it can degrade the performance of the receiver.

The analysis takes into account the transmitter's harmonic characteristics, output level, transmission line losses, filters, duplexers, combiners, isolators, multi-couplers and other RF devices that are present in each system. Additionally, the analysis considers the antenna separation space loss, horizontal and vertical gain components of the antennas as well as how they are mounted on the structure. The gain components are derived from antenna pattern data published by each manufacturer.

The analysis determines how much isolation is required to prevent receiver performance degradation for any harmonics that fall within a receiver's passband. Receivers experiencing transmitter harmonic interference are depicted in the following Table.

Transmitter		Harmonic		Affected Receiver		Attn Needed
ID	Frequency (MHz)	Frequency (MHz)	Order	ID	Frequency (MHz)	
None						

No transmitter generated harmonic interference problems were predicted.

9.0 Transmitter Spurious Output Interference Analysis

Transmitter spurious output interference can be attributed to many different factors in a transmitter. The generation of spurious frequencies could be due to non-linear characteristics in a transmitter or possibly the physical placement of components and unwanted coupling. If a spurious signal falls within the passband of a nearby receiver and the signal level is of sufficient amplitude, it can degrade the performance of the receiver.

The analysis takes into account a transmitter's spurious output specification, output levels, transmission line losses, filters, duplexers, combiners, isolators, multi-couplers and other RF devices that are present in each system. Additionally, the analysis considers the antenna separation space loss, horizontal and vertical gain components of the antennas as well as how they are mounted on the structure. The gain components are derived from antenna pattern data published by each manufacturer.

The analysis determines how much isolation is required to prevent receiver performance degradation for any transmitter spurious signals that fall within a receiver's passband. Receivers experiencing transmitter spurious output interference are depicted in the following Table.

Transmitter		Affected Receiver		Attn Needed
ID	**Frequency (MHz)**	**ID**	**Frequency (MHz)**	
None				

No transmitter generated spurious interference problems were predicted.

10.0 Interference Power Level Summing Analysis

This section of the report provides a simulation of Intermodulation (IM) interference, transmitter wideband noise and receiver desensitization interference occurring on each individual receiver when all transmitters at the site are active at the same instance in time. Even though individual interference modes may not be reported in other report sections, this summing analysis represents a worst-case interference scenario.

However, the probability of this interference occurrence for an individual receiver could be low since it depends on the utilization of the transmitters involved in the interference generation.

The carrier-to-noise C/(I + N) ratio for each receiver is based on the aggregate of interference power levels. A negative C/(I + N) ratio indicates that the performance of the receiver could possibly be degraded by the value shown.

The following Table presents this data:

Receiver		Interference Power Level (dBw)				
Channel Label	**Freq (MHz)**	**Tx Noise**	**Rx Desense**	**IM Power**	**Aggregate**	**C / (I+N)**
None						