

Deployment of Two Cross-Polarized Systems in the ATG Band

Presentation to FCC

Prepared by



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Introduction

→ New AirCell-Boeing Proposal:

→ Offers two competitive licenses with:

- broadband service delivery capabilities
- deck-to-deck coverage
- simplified “sharing rules”
- Airfone could keep all existing sites

→ Analysis

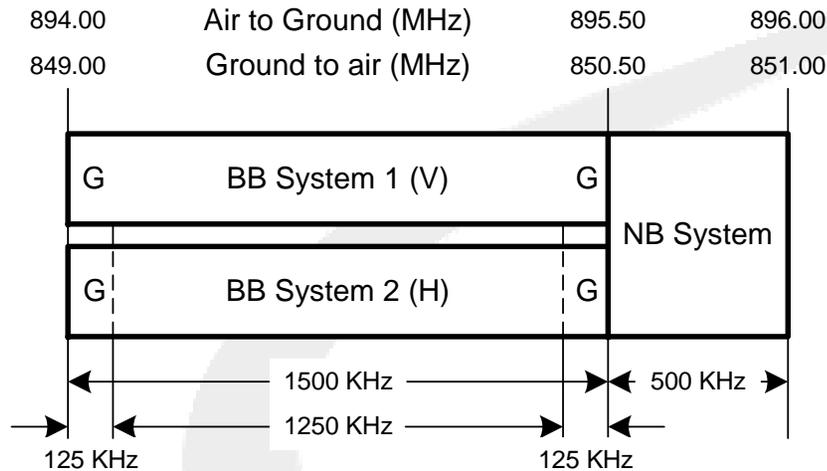
- Monte Carlo approach using sophisticated Matlab-based system simulation tools
- no inter-system interference impact - sites can provide full broadband data rates
- aircraft attitude changes don't have significant impact

Two Carrier Scenario

- Utilizes cross-polarization to provide isolation between carriers
 - AirCell tests and operational experience show 12-15 dB (or more) isolation between horizontally polarized and vertically polarized systems
- Utilize frequency offset isolation, once legacy narrowband system is discontinued
 - Provides additional isolation between the two systems (2.2 dB)
- Isolation sufficient to allow two systems to operate with virtually no intersystem impacts
 - both broadband
 - both deck-to-deck
 - carriers have option to handoff to terrestrial network on landing/departure

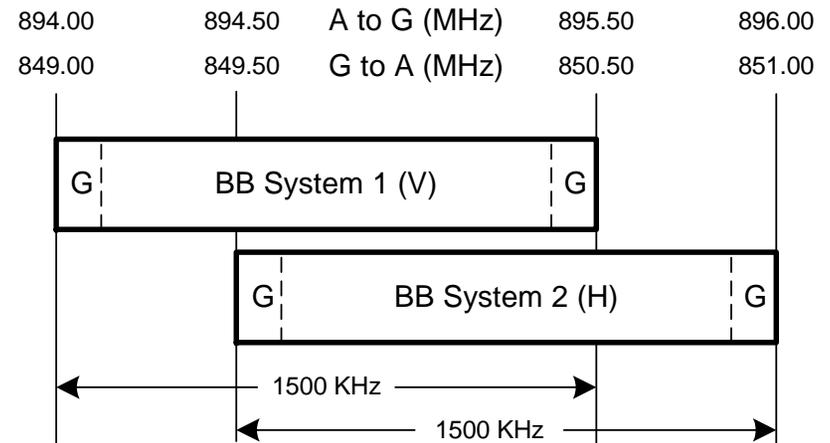
Two Carrier Spectrum Plan

System	Pol	Initial Channels (MHz)		Final Channels (MHz)	
		Ground	Air	Ground	Air
Existing	V	850.50 - 851.00	895.50 - 896.00	-	-
System 1	V	849.00 - 851.50	894.00 - 895.50	849.00 - 851.50	894.00 - 895.50
System 2	H	849.00 - 851.50	894.00 - 895.50	849.50 - 851.00	894.50 - 896.00



G = Guardband BB = Broadband NB = Narrowband

Initial plan, with narrowband system still in operation



G = Guardband BB = Broadband NB = Narrowband

Final plan, after narrowband system operation discontinued

Polarization isolation

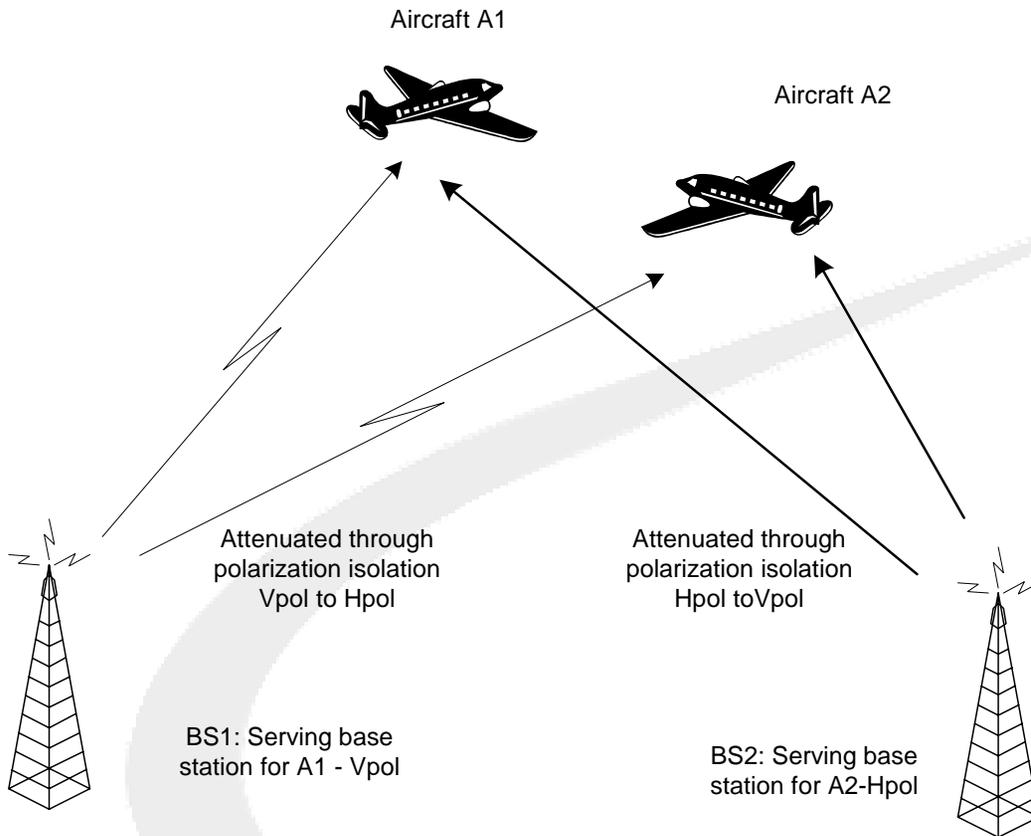


Illustration of forward link interference reduction on cross-polarized systems

- Without isolation technique, interference could occur on both FWD and REV link:
 - FWD to FWD
 - REV to REV
- Interference reduced by polarization isolation
- Effect not the same on FWD link Pilot and Traffic Channels
- REV link interference – “near-far” problem
- Typical aircraft maneuvers have negligible impact

Near-Far Interference

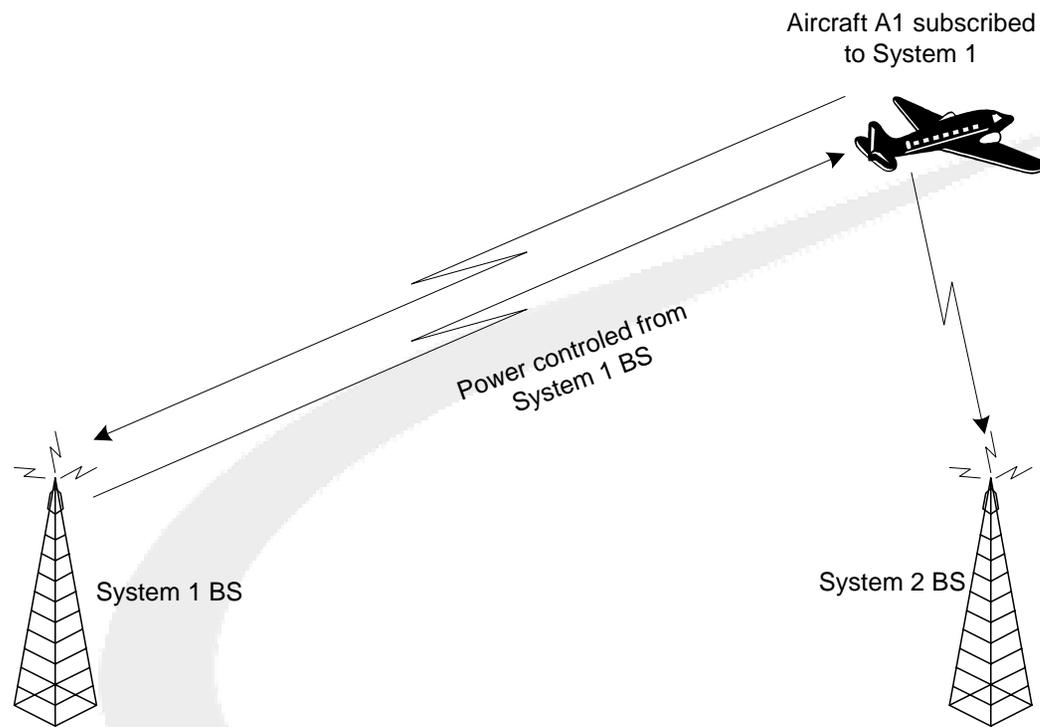
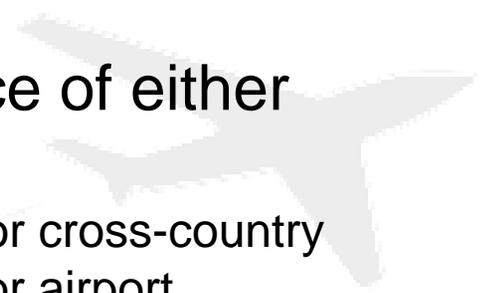


Illustration of forward link interference on cross-polarized systems

- Primarily a potential issue on REV link
- Interference minimized
 - if signal levels from “home” and “foreign” aircraft arrive at similar levels, and
 - XP is sufficient to assure that foreign signals do not have interference impact
- When base stations of two systems are located nearby, power control mechanisms maintain similar signal levels

Simulation results

- 
- A faint, light gray silhouette of an airplane is positioned in the upper right quadrant of the slide, behind the main text. The airplane is shown from a top-down perspective, flying towards the right.
- ➔ Negligible overall impact on performance of either system
 - Forward link SINR impact <1.2 dB 99% of time for cross-country
 - Forward link SINR impact <2.0 dB 99% of time for airport
 - Reverse link noise rise <0.5 dB 99% at 50% pole point loading (both scenarios)
 - Reverse link noise rise <2.0 dB 99% at 75% pole point loading (both scenarios)
 - Results conservative - based on 12 dB XP discrimination (vs. 12-15 expected), additional 2.2 dB isolation spectrum isolation offset not modeled)

Rule requirements

- ➔ Sites serving same airspace located within 2 miles of each other at airports, 5 miles for cross-country
 - Licensees can leverage existing reference site list for ATG service to minimize any issues related to agreeing on site locations
 - Airfone can keep all current sites
 - New sites may be added by mutual agreement of licensees
- ➔ Carriers must maintain similar coverage from nearby sites
 - Similar antennas and transmit powers
 - 20 dB discrimination on antennas from 15° to 90°
- ➔ Carriers have option to build/not build any particular site
 - Transmitters control potential for near-far interference from low altitude aircraft
 - cross country split sites do not require nearby site from other system

Observations and conclusions

- ➔ Two systems can operate in ATG band using cross polarization isolation with no impact on either carrier's ability to provide full broadband and deck-to-deck coverage
 - Naval air search radar issues become moot
- ➔ Spectrum offset will provide additional "margin of safety" when narrowband service transition is completed
- ➔ No advanced hardware required
 - v-pol and h-pol antennas already in service for ATG
 - terrestrial mobile data equipment readily adaptable
- ➔ Aircraft maneuvers will not disrupt polarization isolation
- ➔ Minimal, simplified rules

BACKUP SLIDES

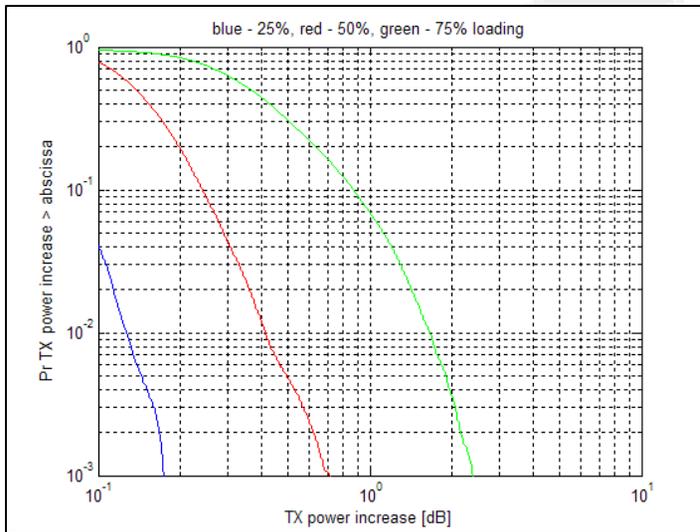
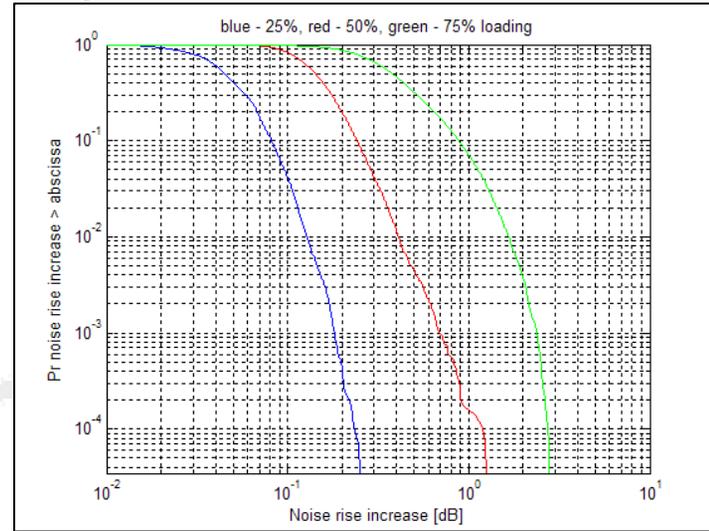
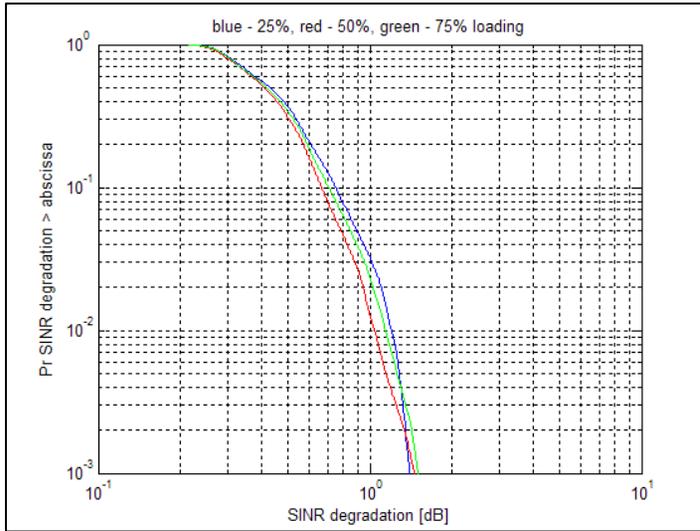


General simulation parameters

Parameter	Value	Unit	Description
<i>SIM_TIME</i>	7200	Seconds	Duration of the simulation time
<i>TIME_STEP</i>	2	Seconds	Increment of the simulation time
<i>f</i>	870	MHz	Average operating frequency
<i>NumCallsAC</i>	10	-	Average number of voice calls per aircraft of the first
<i>NumCallsAF</i>	10	-	Average number of voice calls per aircraft of the
<i>W</i>	1.2288e6	-	Chip rate for 1xEvDO system
<i>Zmin</i>	0 ¹ , 11000 ²	feet	Minimum aircraft altitude
<i>Zmax</i>	40000	feet	Maximum aircraft altitude
<i>Vmin</i>	380 ² , 180 ¹	knots	Minimum velocity of the aircraft
<i>Vmax</i>	450 ² , 250 ¹	knots	Maximum velocity of the aircraft
<i>MinVerSep</i>	1000	feet	Minimum vertical separation between aircraft
<i>MinHorSep</i>	5	nm	Minimum horizontal separation between aircraft
<i>VAF</i>	0.5	-	Average voice activity
<i>FL_IF_Scaling</i>	1	-	Scaling of the interference due to partial overlap
<i>BS.PA_power</i>	20	W	Base station transmit power
<i>BS.NF</i>	4	dB	Base station noise figure
<i>BS.DL_CL</i>	3	dB	Forward link cable losses
<i>BS.UL_CL</i>	3	dB	Reverse link cable losses
<i>MS.PA_power</i>	23	dBm	Mobile station transmit power
<i>MS.NF</i>	8	dB	Noise figure of the mobile
<i>MS.EbNt</i>	4	dB	Required Eb/Nt for the reverse link
<i>R</i>	100 ²	miles	Cell site radius
<i>Pol_Izol</i>	12	dB	Cross-polarization isolation
<i>AG</i>	9 ² /12 ¹	dB	Antenna gain

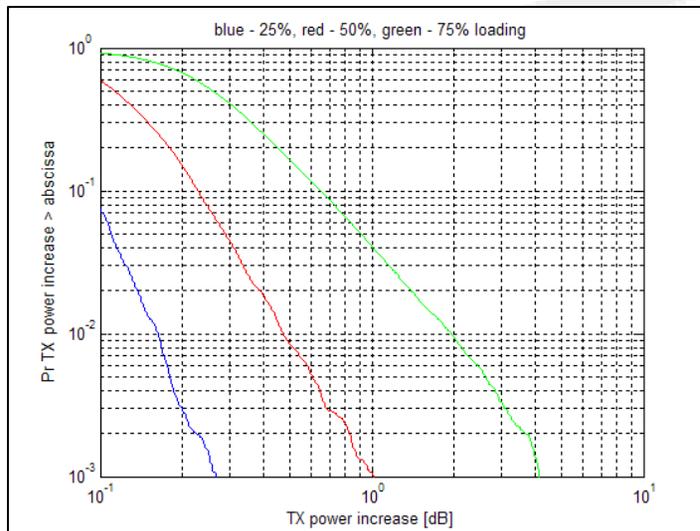
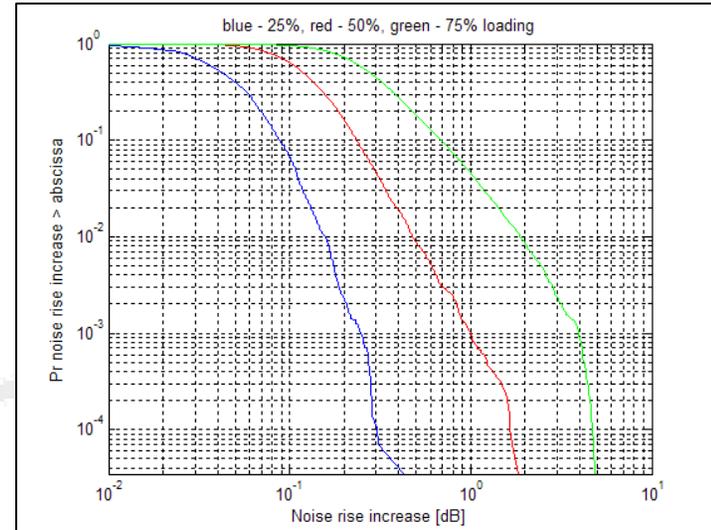
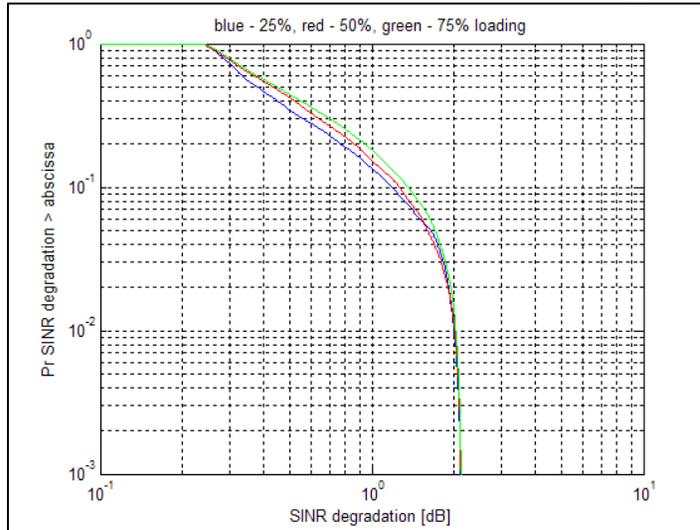
¹ airport scenario; ² cross-country scenario

Results – cross country scenario



Percent of time	10 %			1%		
	25%	50%	75%	25%	50%	75%
Degradation in SINR [dB]	0.7	0.70	0.7	1.1	1.2	1.2
Increase in TX power [dB]	0	0.25	0.9	0.13	0.4	1.8
Increase in the NR [dB]	0.08	0.25	0.9	0.13	0.4	1.8

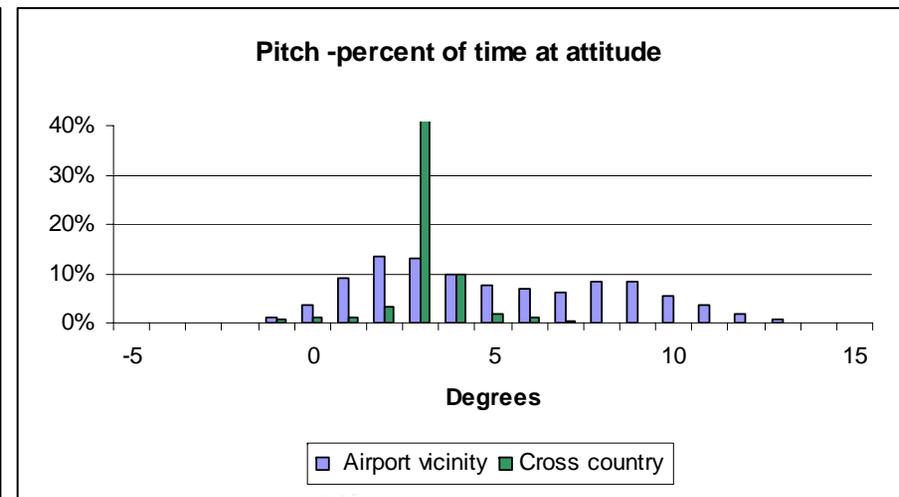
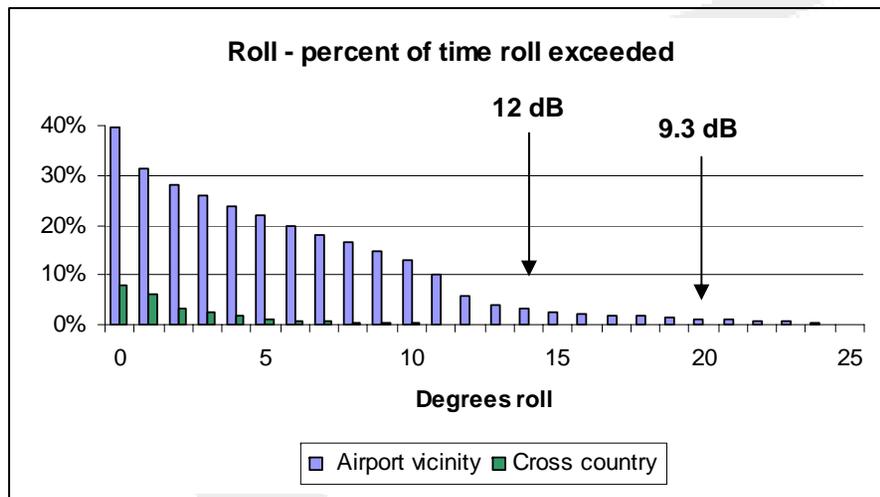
Results – Airport scenario



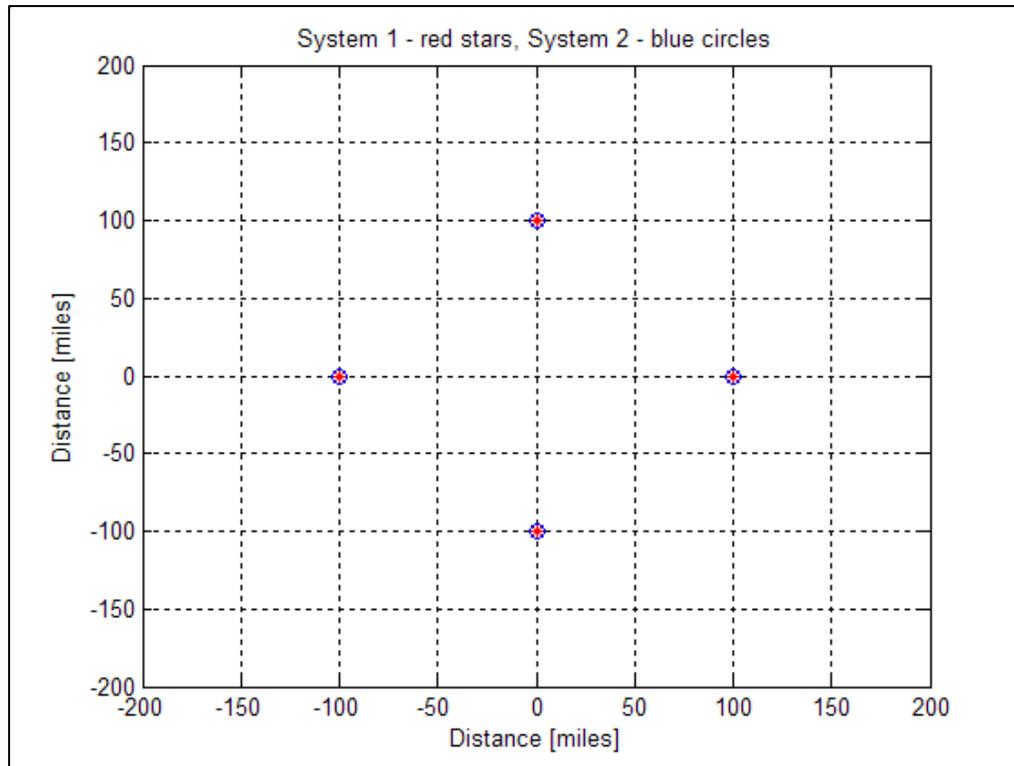
Percent of time	10%			1%		
Loading	25%	50%	75%	25%	50%	75%
Degradation in SINR [dB]	1.3	1.3	1.3	2.0	2.0	2.0
Increase in TX power [dB]	0.0	0.25	0.65	0.17	0.5	2.0
Increase in the NR [dB]	0.09	0.25	0.65	0.17	0.5	2.0

Impact of aircraft maneuvers

- ➔ **Analysis by Boeing for sample of aircraft over variety of airports**
 - Evaluated pitch and roll for cross country routes and for vicinity of airports
 - greatest orientation change will be from roll in vicinity of airports - roll is less than 14° 97% of the time, less than 20° 98.8% of the time.
 - Polarization isolation of 12 dB or more is achieved for more than 99% of time



Cross Country XP simulator



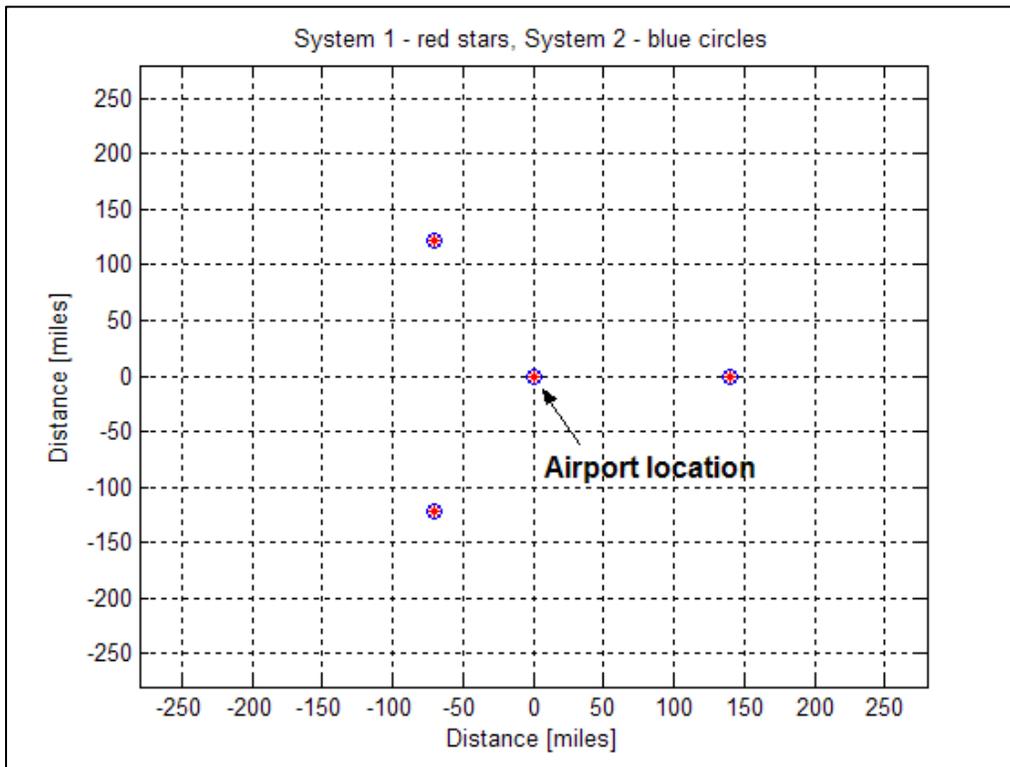
Topology of the inter-system test bed for cross-country scenario

Simulation parameters

- Omni-directional sites
- One network H-pol, other network V-pol
- Antenna patterns with envelope of current aircell antenna
- Altitudes 18,000 – 40,000 feet
- Average of 10 voice calls per plane
- Three different loading scenarios

Loading [%]	Number of aircraft
25	4
50	8
75	12

Airport Scenario XP simulator



Simulation parameters

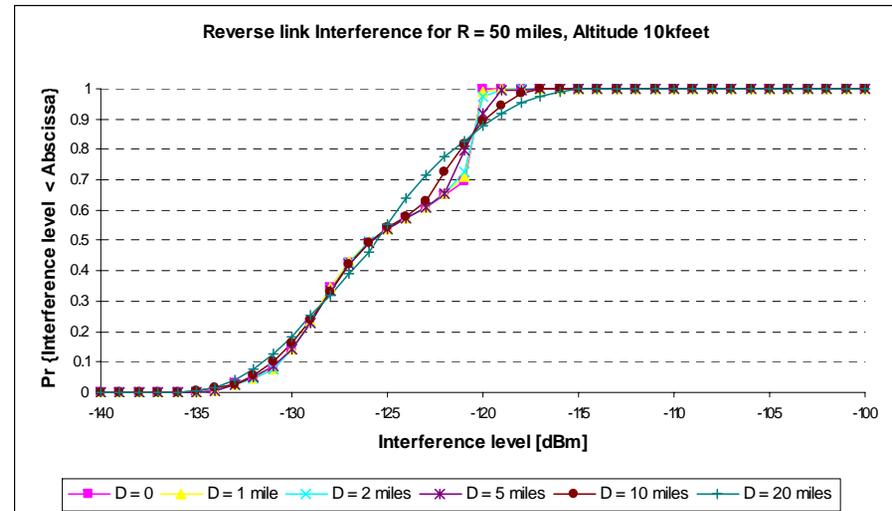
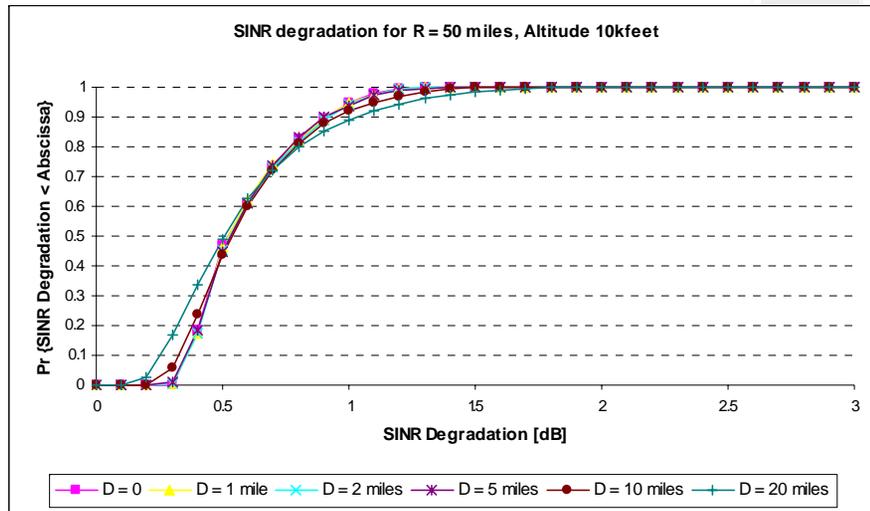
- Omni sites
- One network H-pol, other network V-pol
- Antenna patterns with envelope of current aircell antenna
- Altitudes 0 – 40,000 feet, constrained by approach/departure routes
- 10 voice calls per plane
- Three different loading scenarios:

Loading [%]	Number of aircraft
25	4
50	8
75	12

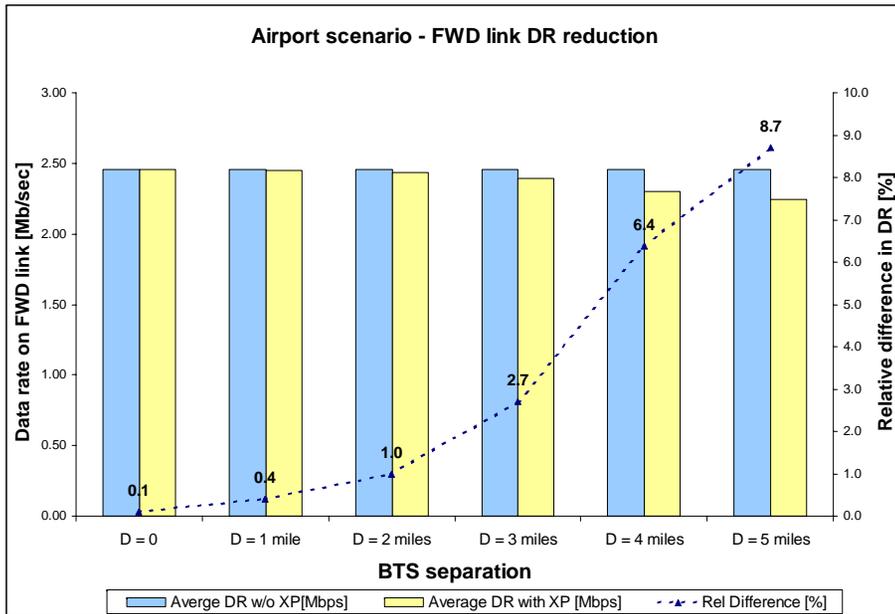
Topology of the inter-system test bed for
airport scenario

Cross country site spacing

- **5 mile intersystem spacing recommended for cross country sites**
 - based on geometry for 50 mile cell and 10,000 aircraft altitudes - more constraining that larger cells or higher altitudes
 - virtually no impact on forward and reverse link, compared to collocation
 - “soft” constraint - can be relaxed if required

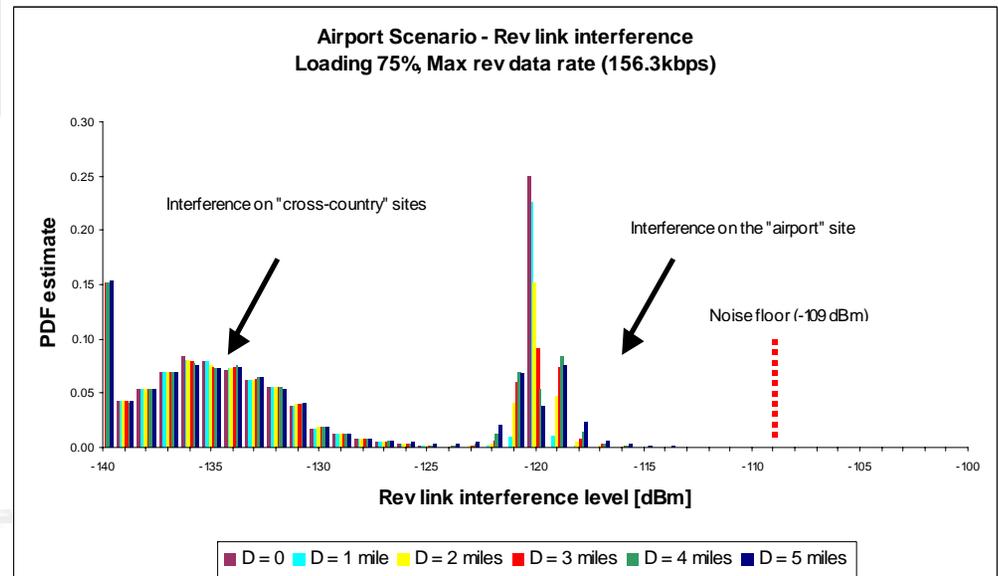


Airport cell spacing



✈ **2 mile intersystem spacing recommended for airports**

- limited impact on forward link data rate in vicinity of sites
- no impact on reverse link - well below thermal noise floor



Cross country split cells

- ➔ **Split sites do not require matching site from other system**
 - Antenna discrimination provides adequate isolation to minimize near-far degradation of isolation

