



The Boeing Company Meeting  
with the  
Federal Communication Commission

# ATG TECHNICAL DISCUSSION

August 26, 2004

# Homework Assignments

- Interference Levels & Sharing Rules
- Compatibility with other waveforms
- Aircraft Data Rate & Network Capacity Limitations

# Proposed Sharing Rules

- Very simple
  - Minimal administrative burden
- Technology Independent
  - Compatible with many wireless standards (2G and 3G)
    - CDMA2000, CDMA, GSM, etc.
  - Compatible with many base station antenna types
    - Segmented, non-segmented, smart, etc.
- No performance degradation
  - Rules don't limit or degrade passenger service

# Sharing Rules & Interference Levels

## ▪ Base Station EIRP

- Maximum base station EIRP spectral density = -33 dBW/Hz
- Below 10,000 feet and within 20 miles of airports, maximum EIRP spectral density = -47 dBW/Hz
- Base station antenna gain roll-off with elevation angle,  $\theta$ :  
 $0.225 \theta + 9.75$ , for  $\theta$  between  $10^\circ$  and  $90^\circ$

## ▪ Aircraft EIRP

- Maximum aircraft EIRP spectral density = -71 dBW/Hz
- Below 10,000 feet and within 20 miles of airports, maximum EIRP spectral density = -85 dBW/Hz
- Aircraft antenna gain roll-off of:  
 $0.25 \theta - 2.5$ , for  $\theta$  between  $10^\circ$  and  $90^\circ$

# Maximum Base Station EIRP – Link Budget for Worst Case Scenario

Forward Link		
Boltzman's constant	1.38E-23	J/K
Slant range	160	km
Frequency	0.85	GHz
Wavelength	0.353	m
Path loss	3.08E-14	
Channel bit rate	1000	Kbps
Mobile terminal G/T	-35	dB/K
Operational Eb/No	4	dB
Self + external interference	4	dB
Required base station EIRP	9.5	dBW

**10 W / 1 Mbps channel x 64 channels = 640 W = 28 dBW**  
**Spread over 1.25 MHz channel (61 dB-Hz).**

**Proposed max EIRP spectral density is 28 dBW-61 dB-Hz = -33 dBW/Hz**

# Max. Aircraft EIRP

Return Link		
Boltzman's const	1.38E-23	J/K
slant range	160	km
frequency	0.85	GHz
wavelength	0.35294	m
path loss	3.08E-14	
channel bit rate	1000	Kbps
base station G/T	-14.6	dB/K
threshold Eb/No	4	dB
external + self interference	4	dB
required aircraft antenna EIRP	-12.8	dBW

**Max. aircraft EIRP = -10 dBW**  
**Spread over 1.25 MHz channel (61 dB-Hz).**

**Proposed max aircraft EIRP spectral density is -71 dBW/Hz**

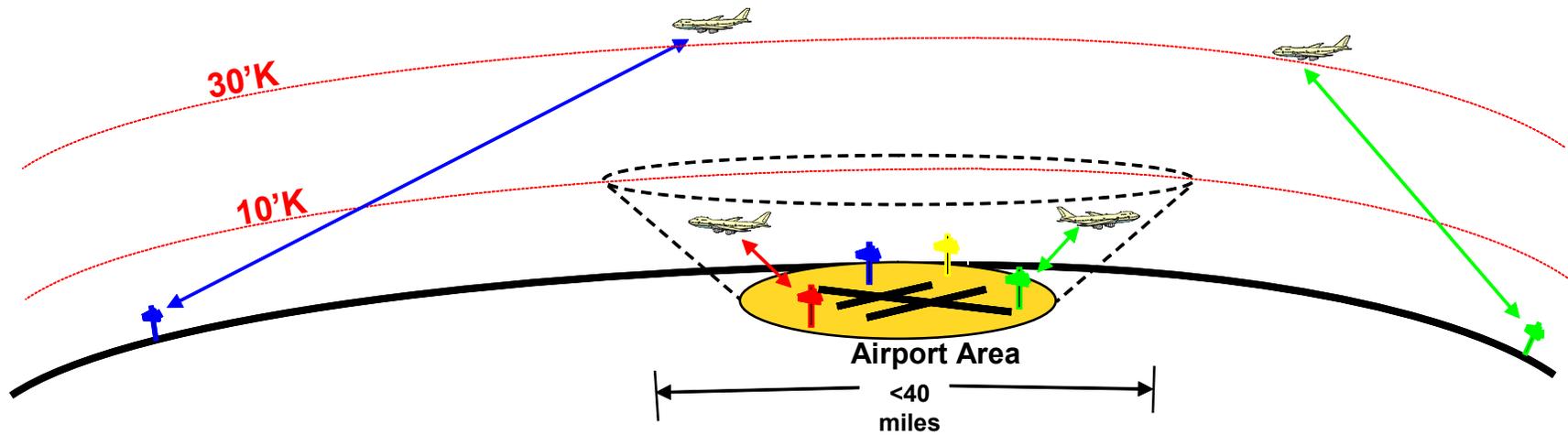
## Data Rate to Aircraft

- The proposed rules don't limit the data rate (pipe size) to an aircraft.
  - No restrictions on data rate to passengers
- The base station may use as much EIRP as desired to communicate with an aircraft, but must stay below an aggregate limit of 640 W.
- Link budget shows that up to 10W required for 1 Mbps.
- Therefore up to 64 Mbps of capacity per sector with 640W limit.
  - CDMA, FDMA, TDMA, etc. it does not matter.
- Base station capacity is scaled by number of sectors.

# Impact of Multiple ATG Systems

- Multiple systems do not limit data rate to aircraft
- Multiple systems do not limit data rate to passenger
- Multiple systems increase capacity of ATG spectrum
  - Up to 4x frequency reuse

# Airport Scenario



**14 dB reduction of max EIRP is proposed for base stations and aircraft within airport area.**

# Base Station Separation

## Original Boeing Proposal

- Inter-System >102 miles
- Intra-System > 227 miles
- Service providers choose locations.

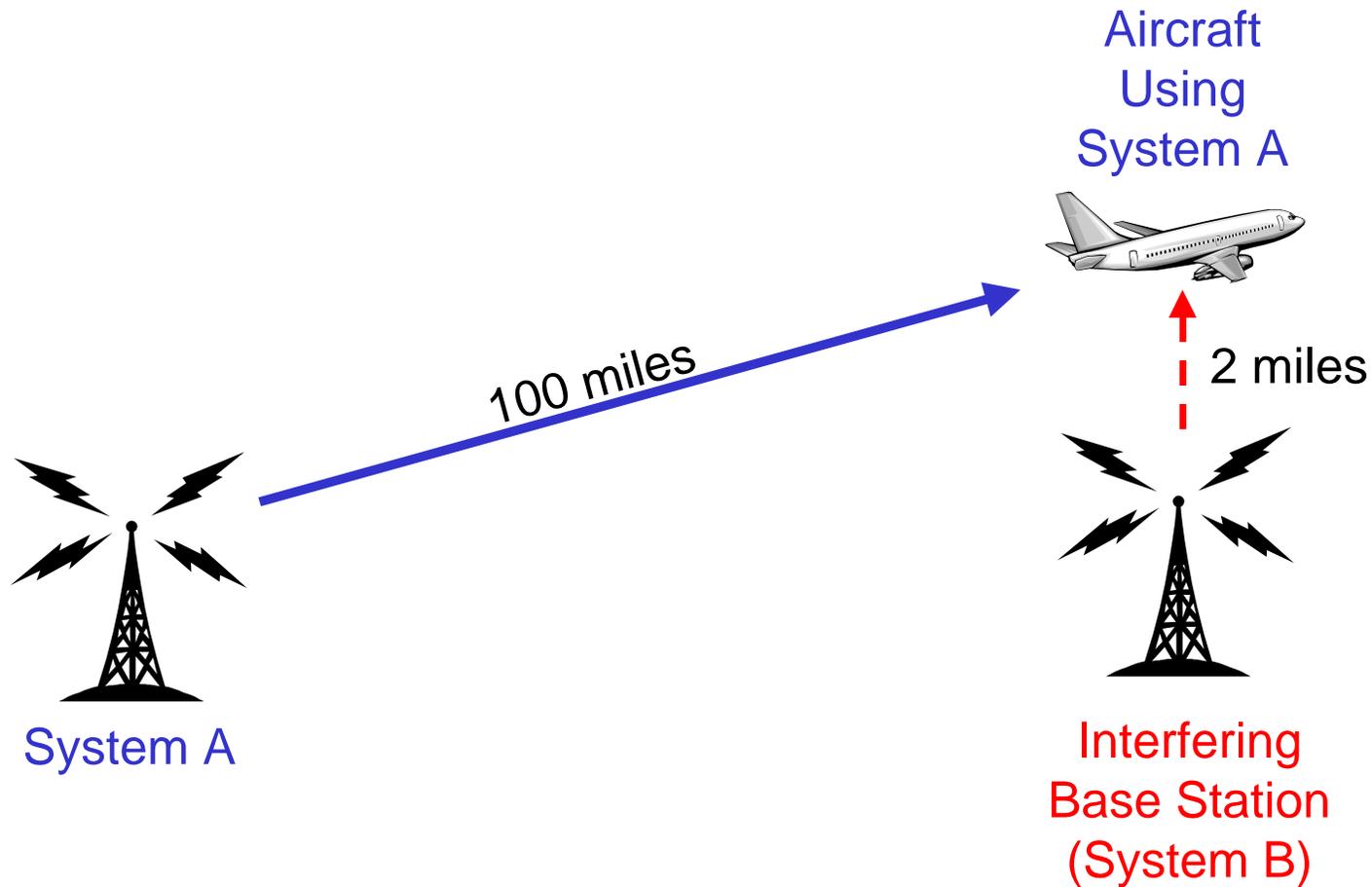
## Option of FCC assigned grid centers

- Proposed because it was the legacy method.
- Maximizes the number of potential competitors.

# Technology Compatibility

- Proposed sharing rules are technology independent.
- Compatible with:
  - AirCell's non-directional aero-antenna
  - Airfone's and Boeing's proposed directional antennas.
  - Simple or complex base station.
    - Segmented/non-segmented
    - Smart/conventional antennas
- Rules allow any communication standard compatible with 1.25 MHz channel:
  - Any of the CDMA2000 variants.
  - 2G cellular standards (GSM, CDMA, etc.)
- Only requirement is to stay below EIRP limits.

# Forward Link Interference Scenario



# Return Link Interference Scenario

Aircraft  
Using  
System A

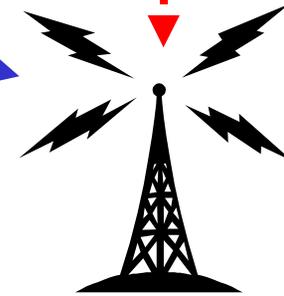


100 miles

Interfering  
Aircraft  
(System B)



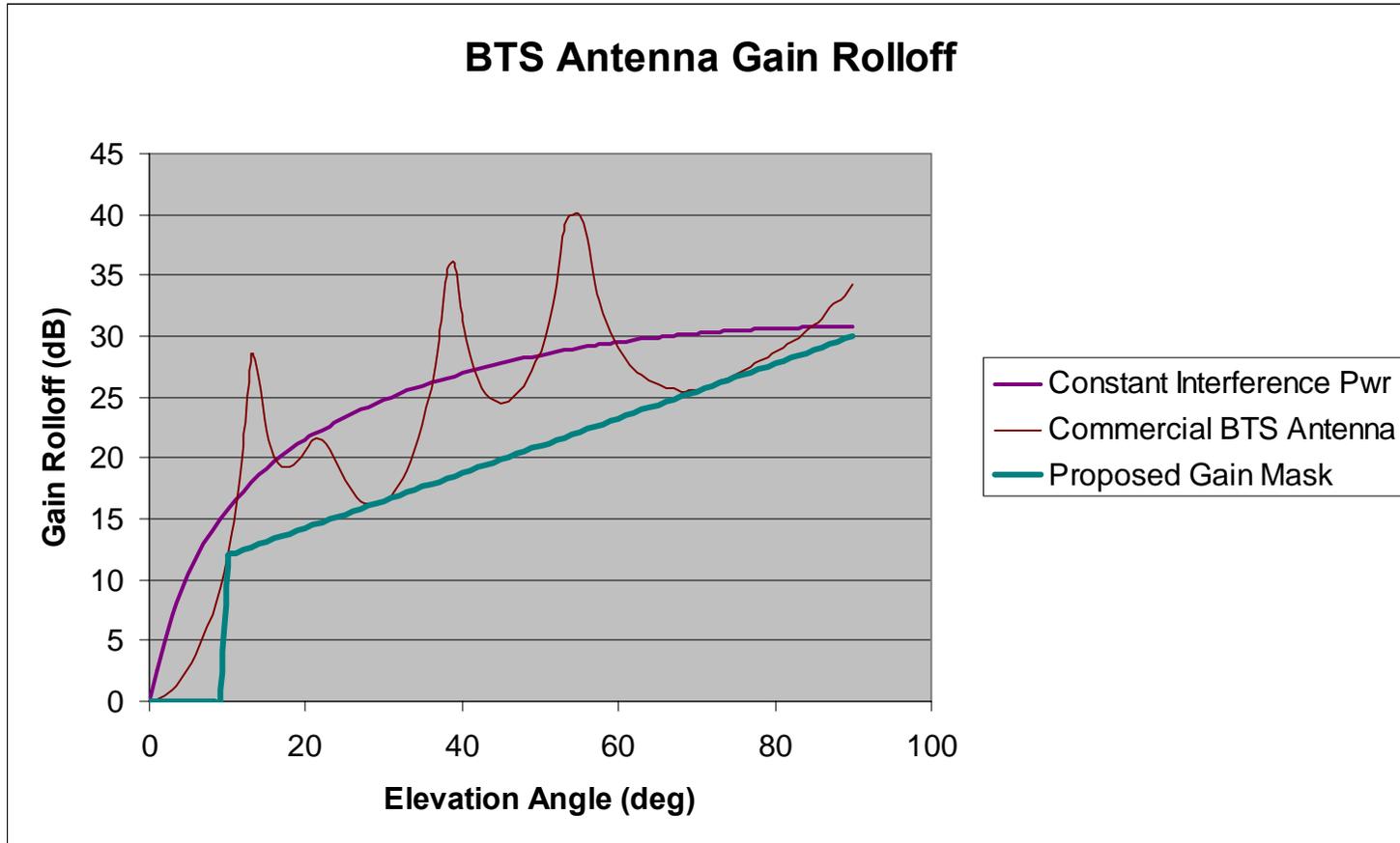
2 miles



System A

- Reciprocal of forward link scenario
- Previous SINR budget applies
- Some additional spreading gain

# Base Station Gain Roll-Off Requirement



**This eliminates the near-far problem for all scenarios.**

# SINR Budget

Worst case ratio of ranges squared = $(100/2)^2 =$	-34 dB
Worst case interfering to signal EIRP = $640 / 10 =$	-18 dB
Proposed BTS gain roll-off near zenith	>30 dB
Proposed aero antenna roll-off @ nadir	>20 dB
Polarization/Duplex isolation (AirCell)	>10 dB
<u>Directional antenna isolation (Boeing)</u>	<u>&gt;15 dB</u>
Total	>23 dB

$$E_b/I_o = \text{SINR} (W/R) = \text{SINR}$$

Spreading gain  $W/R \approx 1$  for 1.25 MHz channel and 1 Mbps information rate.

We need  $E_b/I_o > 4$  dB to close link. Therefore:

>19 dB margin for Boeing + AirCell proposal

>9 dB margin for Boeing proposal alone

>4 dB margin for AirCell proposal alone

## 1.25 MHz is Minimum Necessary

- We need a minimum of 1.25 MHz each way to provide a broadband data service.
  - 1 Mbps is minimum requirement to aircraft.
  - Not practical to provide this data rate with less than 1.25 MHz
    - Would require higher order modulations
    - Or less FEC
- We want to use a commercial standard for our ATG service.
  - Reduced hardware cost.
  - Reduced development cost.
- Channel BW for CDMA2000 is 1.25 MHz.

# Summary of all Rules

## (1) Base Station EIRP

- Maximum base station EIRP spectral density = -33 dBW/Hz
- Below 10'K and within 20 miles of airports, max EIRPSD = -47 dBW/Hz
- Base station antenna gain roll-off with elevation angle,  $\theta$ :
  - =  $0.225 \theta + 9.75$ , for  $\theta$  between  $10^\circ$  and  $90^\circ$

## (2) Aircraft EIRP

- Maximum aircraft EIRP spectral density = -71 dBW/Hz
- Below 10'K and within 20 miles of airports, max EIRPSD = -85 dBW/Hz
- Aircraft antenna gain roll-off
  - =  $0.25 \theta - 2.5$ , for  $\theta$  between  $10^\circ$  and  $90^\circ$

## (3) Base Station Separation Distance

- Inter-System >102 miles
- Intra-System > 227 miles

## (4) Band Plan

- 1.25 MHz per system (each direction)
- Overlapped by 0.75 MHz in 2 MHz ATG band (each direction)

# Summary

- Proposed sharing rules are simple.
- Sharing does not limit bandwidth to passenger or aircraft.
  - >64 Mbps/sector forward link for each base station
- Network capacity is scalable
  - By increasing base station sectorization.
- >50% of addressable market is served with “plain-old” base stations having 3 to 9 sectors.
- Rule proposals from AirCell and Boeing are similar and compatible.
  - Similar EIRP limits have been proposed.
  - Polarization and duplex assignments are acceptable