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August 23, 2004

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VIA ELECTRONIC FILING

Marlene Dortch, Esq.
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: *Ex Parte Notice* - WT Docket No. 03-103

Dear Ms. Dortch:

On behalf of Verizon Airfone Inc., this is to note that on August 20, 2004, William Pallone and Robert Combs of Airfone, Leslie Owsley of Verizon Communications, Dr. Jay Padgett and Dr. Anthony Triolo of Telcordia, and Tom Dombrowsky of this firm and I met with Shellie Blakeney, Roger Noel, B.C."Jay Jackson, Jr., Richard Arsenault and Tom Derenge of the Wireless Telecommunications Bureau and Julius Knapp, Jim Schlichting, Ira Keltz,, Ron Chase, and Ahmed Lahjouji of the Office of Engineering and Technology and George Sharp of the International Bureau, to discuss technical issues associated with this proceeding.

Drs. Padgett and Triolo summarized their technical papers submitted August 17 in this proceeding and responded to questions from the staff. Copies of the slides from Drs. Padgett and Triolo are attached. In addition, slide 21 from Boeing's April 29, 2004, *Ex Parte* was discussed in connection with data rates to be expected from various proposed approaches.

Please contact me with any questions concerning this matter.

Respectfully,

/s/ *David E. Hilliard*

David E. Hilliard
Counsel for Verizon Airfone, Inc.

Attachments
cc: Shellie Blakeney, Roger Noel, B.C."Jay Jackson, Jr., Richard Arsenault, Tom Derenge, Julius Knapp, Jim Schlichting, Ira Keltz,, Ron Chase, Ahmed Lahjouji, and George Sharp

Response to Recent AirCell Papers and Summary Comments on AirCell Proposals

August 20, 2004

Dr. Jay Padgett
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Telcordia Technologies/ Applied Research
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Summary – Reversed Duplexing Proposal - 1

- AirCell has found no errors in the Telcordia analysis, but merely debated the assumptions (primarily related to the major issue, which is the aircraft transmit power).
- Without a very low limit on aircraft transmit power and textbook-ideal operating conditions, sharing by duplex inversion does not work well, even in theory. Significantly, AirCell has not disputed this, but simply refused to consider conditions outside of its original parameter space, which includes
  - idealized link budget
  - low reverse link transmission rates (48 kb/s average per aircraft)
  - a hard limit of 200 mW on aircraft transmit power.
- AirCell has now acknowledged the base-to-base interference problem, but its proposed antenna-null solution is impractical due to the required antenna pattern rolloff (25 dB with 1° of elevation change).

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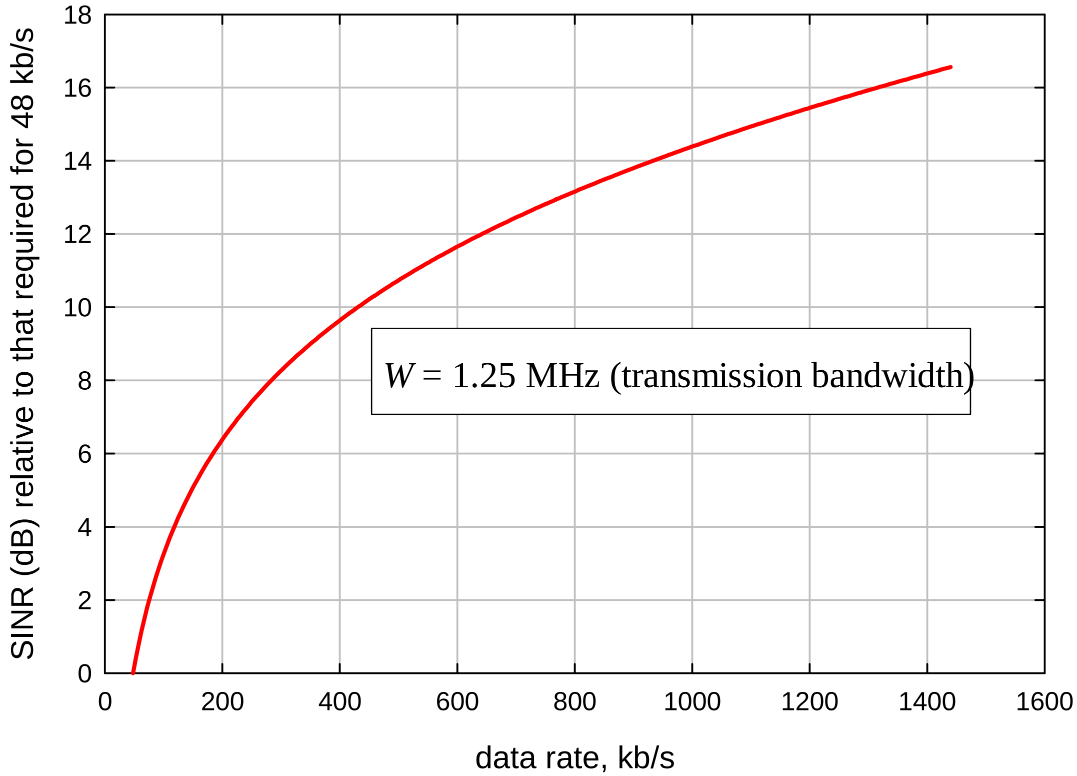
Reversed Duplexing Summary - 2

- AirCell's low aircraft transmit power depends in part on a very limited service model, consisting of an average of 48 kb/s per aircraft on the CDMA reverse link, supporting 10 speech channels.
- True broadband services will requires higher data rates and greater transmit power, but a regulatory structure that relies on duplex inversion will not support this.

Broadband services will require significantly more transmit power from the aircraft than the 200 mW assumed by AirCell



Summary – Crossed Polarization Proposal - 1

- AirCell has proposed, but not analyzed, a four-system sharing approach using both duplex inversion and polarization isolation. However, AirCell has not discussed how base station placement would be managed, coordinated, or regulated in a 4-system scenario.
- AirCell's polarization-isolation analysis suffers from the same deficiencies as its duplex-inversion analysis.
  - unrealistically idealized link budget assumptions
  - a very limited service model
  - a 200 mW hard limit on aircraft transmit power
- There was no analysis of interaction between vertically polarized *incumbent* ATG systems and new cochannel horizontally polarized systems – AirCell states that "more thorough analysis that takes the actual traffic into account should be performed" (p. 23).

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Crossed Polarization Proposal Summary - 2

- AirCell has claimed to base its assumed polarization isolation (12 dB) on a 1997 measurement report that in fact contains no data or results about polarization isolation.
- Even taken at face value, AirCell's results show that two cross polarized systems cannot coexist due to excessive noise rise at the reverse link receiver, in the airport environment.
  - CDMA reverse links are typically engineered for a noise rise on the order of 6 dB to maintain front end power within the dynamic range of the base station low-noise amplifier, and to maintain system stability.
  - Admission control mechanisms are used to enforce this, which AirCell seems to have ignored in its simulation, in which the noise rise reached levels up to 25 dB.
  - It is unclear how the noise rise limit would actually be regulated for two cochannel systems.
- In sum, neither duplex inversion nor polarization isolation appears to be viable for actual implementation to support cochannel sharing between broadband ATG systems.

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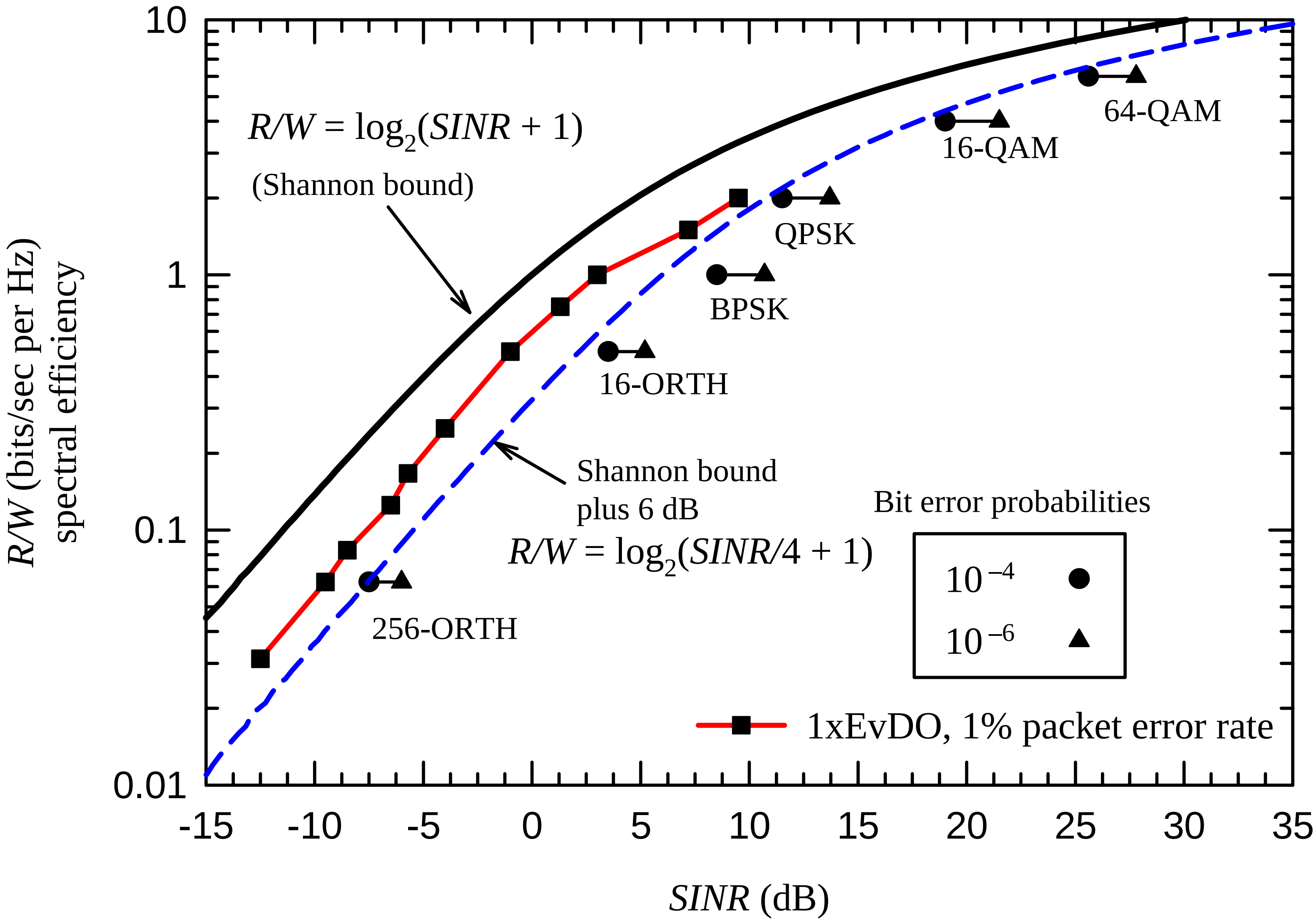
Detailed Comments and Observations

Higher Throughput Requires More Power



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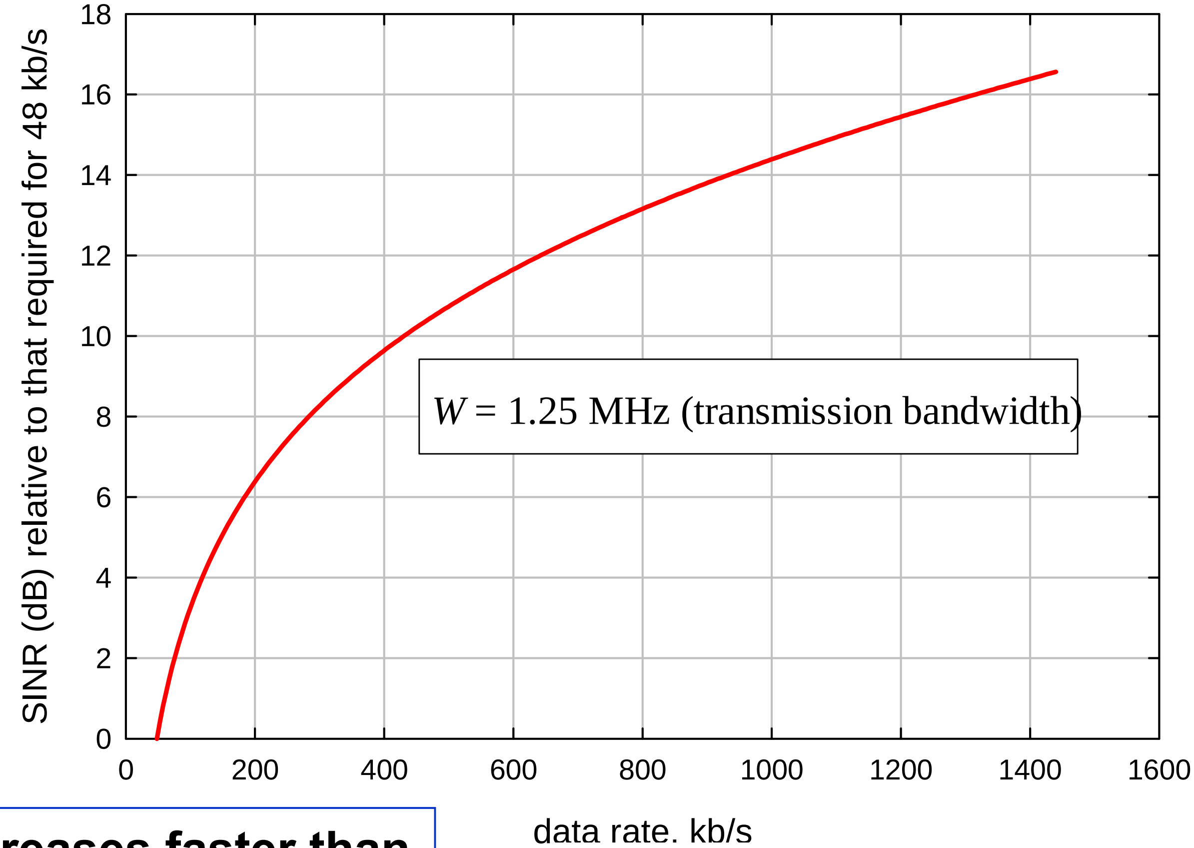
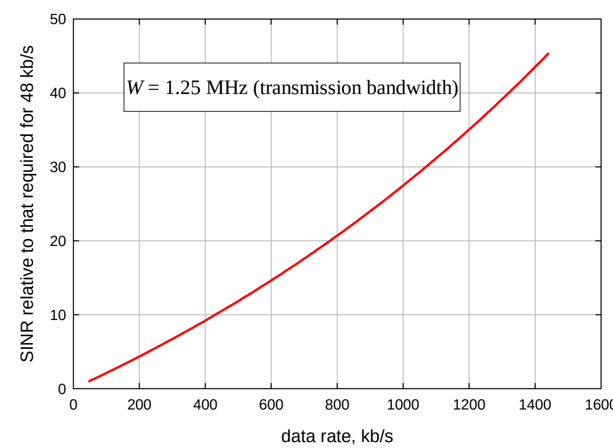
Relative SINR (ref. To 48 kb/s) vs. Rate

$$\frac{SINR_2}{SINR_1} = \frac{2^{R_2/W} - 1}{2^{R_1/W} - 1}$$

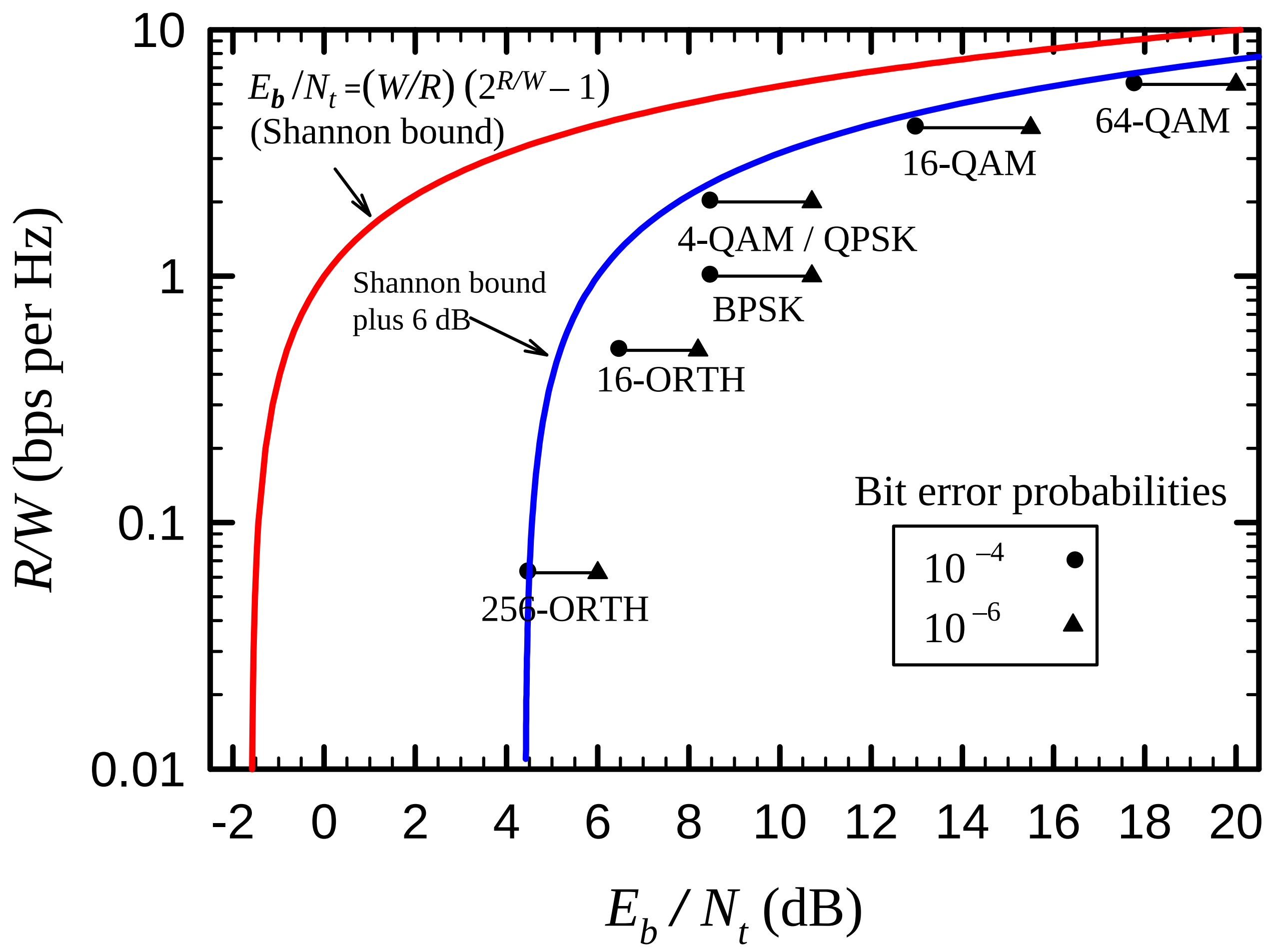
$$SINR_1 = 48 \text{ kb/s}$$
$$SINR_2 = \text{abscissa}$$



- **Required SINR increases faster than linearly with rate →**
- **Broadband services will require significantly more transmit power from the aircraft than the 200 mW assumed by AirCell**



Modulation Efficiency vs. E_b/N_t



$$\frac{E_b}{N_t} = \frac{W}{R} \cdot SINR$$

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References for Discussion of Recent AirCell Submittals

1. **Ivica Kostanic and Dan McKenna, "Evaluation of the ATG Spectrum Migration Concept," March 10, 2004, AirCell report to the FCC, WT Docket 03-103.**
2. **Anthony A. Triolo and Jay E. Padgett, "Coexistence Analysis for Multiple Air-to-Ground Systems," June 3, 2004, Verizon Airfone report to the FCC, WT Docket 03-103.**
3. **V. Tarokh and A. Varadachari, "Response to Telcordia Technologies Comments on AirCell Proposal," June 17, 2004, AirCell report to the FCC, WT Docket 03-103.**
4. **Ivica Kostanic, "Evolution of the ATG Migration Concept (Part 2)," June 29, 2004, AirCell report to the FCC WT Docket 03-103.**
5. **C. J. Hall and I. Kostanic, *Final Report of AirCell Flight Tests,* TEC Cellular, July 10-11, 1997. (Reference 6 of [4])**

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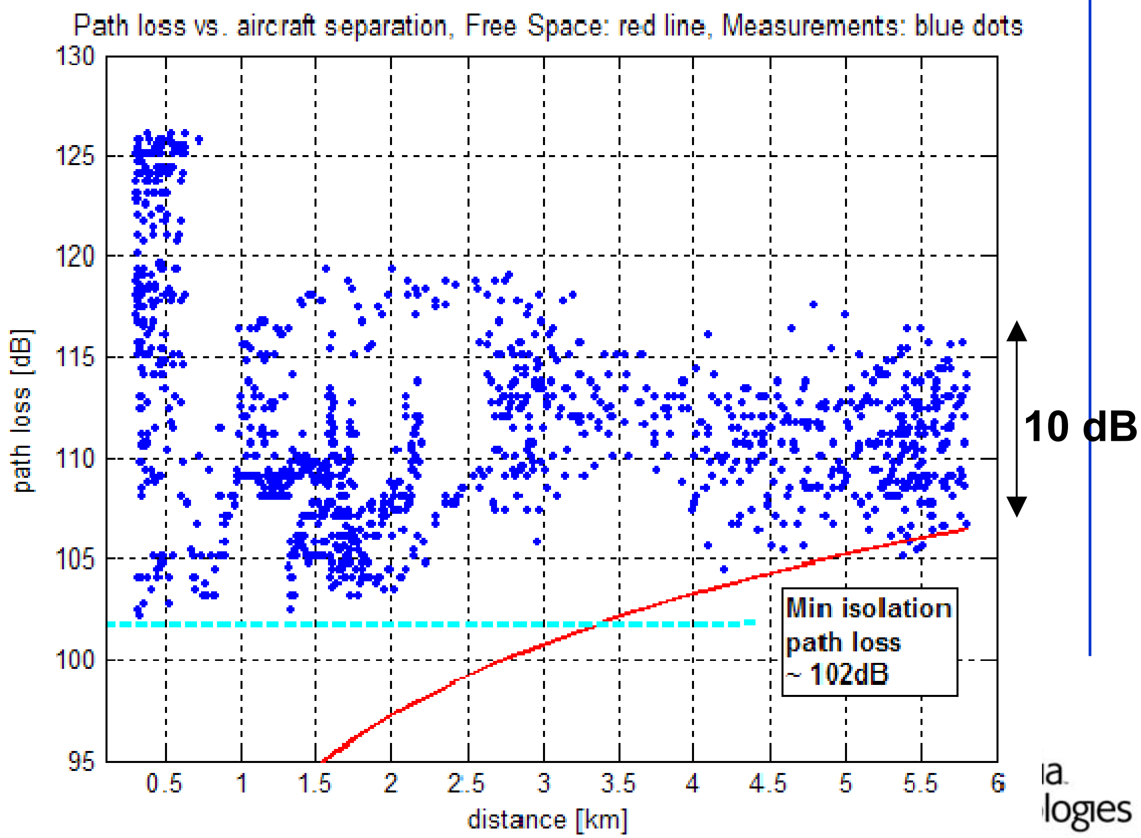
Areas of Major AirCell Comments [3] on Telcordia Paper [2]

- **10 dB system implementation margin.**
- **Base-to-base cross-duplex interference.**
- **Increased susceptibility of reverse-duplexed aircraft (receiving at 894-896 MHz) to interference from offshore Naval air search radars (AN/SPS-49).**
- **The unrealistically limited service model used by AirCell (48 kb/s per aircraft on the reverse link, supporting ten low-rate speech channels).**

System Implementation Margin

- **In [4] AirCell provides results of air-to-air propagation measurements; shows about 10 dB variation in path loss above free space.**
- **Air-to-ground can be worse due to potential for ground reflection.**
- **Based on these data and Airfone's experience, Telcordia continues to believe that 10 dB is a reasonable implementation margin to account for non-idealities in propagation and equipment.**

From Figure A3 of [4]

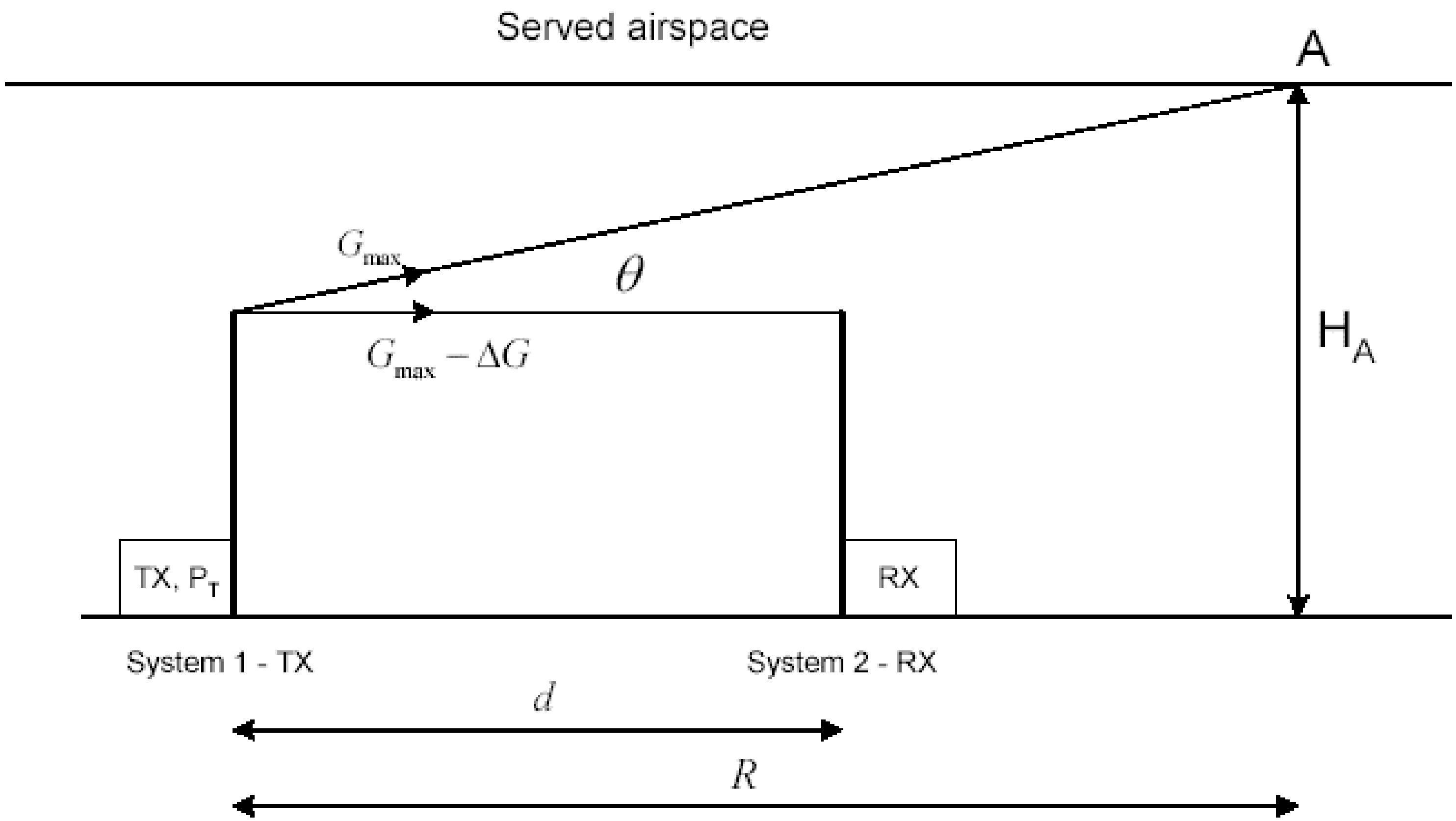


ia.
logies

Base-to-Base Interference with Duplex Inversion

- AirCell ignored base-to-base interference in [1].
- Telcordia observed in [2] that in the airport scenario, base stations were closer together than the radio horizon.
- AirCell claimed in [3] that Telcordia unrealistically modeled base-to-base interference in [2] using free space propagation (not true; Telcordia merely observed that base station separation was less than the radio horizon).
- In [4], Appendix C, AirCell provides base-to-base interference calculations (using free space propagation) and proposes to mitigate it using deep antenna nulls aimed at the interfering base station.
- This would require a rolloff of about 25 dB with a 1-degree elevation change, which is not practical from the perspectives of design, installation, or operation (tower sway > 1 degree).
- Even if it were, it would effectively double the noise floor and reduce the reverse link capacity to 2/3 of its baseline value.

Base Station Antenna Geometry from [4]



G_{max} is gain to aircraft

A is minimum-altitude location of aircraft (1000 feet)

ΔG is null depth (e.g., 25 dB)

θ is elevation angle difference between aircraft and cross-duplexed base station

Impact of AN/SPS-49 Naval Radar

Review of Major Points

1. **Operation within 200 nm (230 mi) of land is limited to 902-928 MHz band.**
2. **An aircraft is much more likely to see radar transmitter due to its larger radio horizon (~250 mi) compared to a base station (~30 mi).**
3. **A receiver at 894-896 MHz will be more strongly affected by sidebands of a radar signal at 902-928 MHz than will a receiver at 849-851 MHz.**

- **AirCell disputes this in [3] but has neglected the effect of the radio horizon in its calculations, so the resulting conclusions are not valid.**
- **AirCell also mistakenly claims that the ships turn off the radars 200 nm from shore, which is not true (see point 1 above). Also, Airfone regularly experiences radar interference to its coastal base stations.**

Aircraft Transmit Power and Technology Evolution

- **AirCell's coexistence results rely on very low aircraft transmit power (hard limited to 200 mW, the RF power output of a digital cellular handset).**
- **The reverse link in AirCell's model supports 48 kb/s (ten speech channels with a voice activity factor of 50%).**
- **Broadband services will require higher rates, which in turn will require higher reverse link (aircraft) transmit power as shown on previous slides.**
- **AirCell continues to insist that the very limited service model (ten speech channels) used in its analyses is the appropriate one.**
- **Telcordia believes that whatever ATG rules are adopted must allow flexibility for evolution and advancement in technology and applications.**
- **Sharing by duplex inversion does not meet this criterion because it would not accommodate higher throughput on the reverse link.**

AirCell's Polarization-Isolation Proposal [4]

- **AirCell now proposes four-system sharing of the ATG bands using duplex inversion plus polarization isolation (see table below).**
- **AirCell has not analyzed or simulated the coexistence of all four systems together; [4] only simulates a pair of cross-polarized but co-duplexed systems (i.e., systems 2 and 4 or 1 and 3).**
- **AirCell assumes that if a single pair of cross-duplexed systems can coexist, and a single pair of cross-polarized systems can coexist, then all four systems can coexist.**
- **This ignores coupling (e.g., reverse link noise rise, causing high aircraft transmit power) and joint planning issues (e.g., base station locations).**

	duplexing	
pol	*normal*	*reversed*
V	System 2	System 1
H	System 4	System 3

AirCell's Polarization-Isolation Proposal (cont'd)

- **AirCell assumes a fixed 12 dB polarization isolation based on a reference to a test report [5] which does not provide any data or conclusions about polarization isolation.**
- **AirCell's analysis suffers from the same flaws as its duplex-inversion analysis (limited service model, artificially limited aircraft EIRP, and idealized link budget assumptions).**
- **Even taking AirCell's results at face value, coexistence using polarization isolation is not feasible due to the extremely high interference (noise rise) at the base stations.**
- **CDMA reverse links are typically engineered for a noise rise on the order of 6 dB to maintain front end power within the dynamic range of the low-noise amplifier, and to maintain system stability.**
- **Admission control mechanisms are used to enforce this, which AirCell seems to have ignored in its simulation, in which the noise rise reached levels up to 25 dB (see graph on next slide). It is unclear how the noise rise limit would be regulated for two cochannel systems.**

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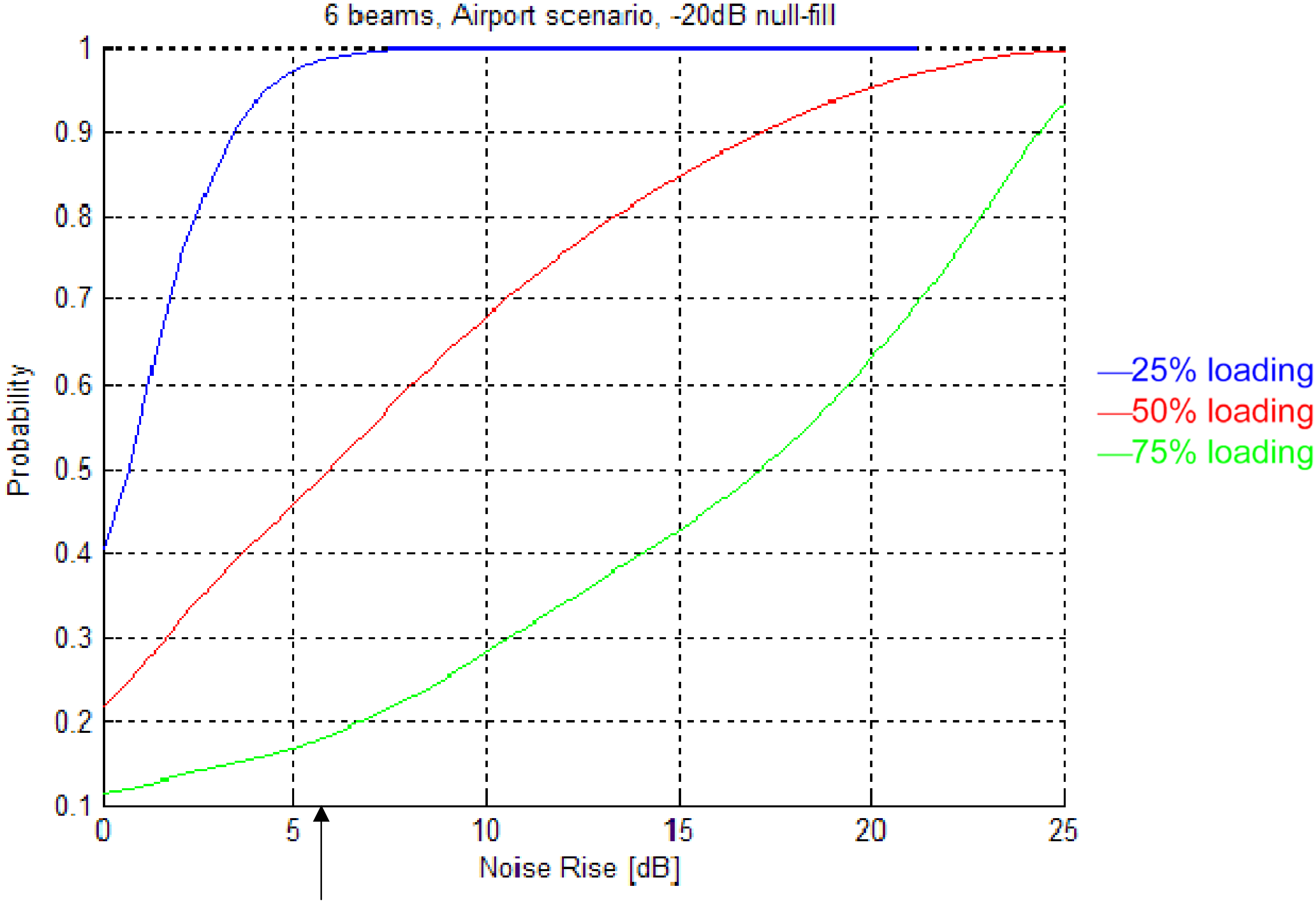
Noise Rise CDF (AirCell [4] Fig. 6.23, p. 54)



typical maximum-load design point (~6 dB)

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AirCell Proposals – Summary

- **ATG sharing using duplex inversion is not technically feasible:**
  - Aircraft-to-aircraft interference will degrade forward link performance significantly with broadband services and realistic link conditions.
  - Base-to-base interference will occur in high-density situations (near airports) and will severely degrade the reverse link.
  - Aircraft receiving at 894-896 MHz will suffer interference from Naval air search radars.
- **ATG sharing using polarization isolation is not technically feasible:**
  - There is no evidence that the assumed isolation can be achieved in the ATG environment (AirCell assumed a fixed 12 dB in its analysis, which is unsupported by the 1997 measurement report cited).
  - Even taking AirCell's simulation results at face value, the extreme "noise rise" at the base station receivers in the airport scenario cannot be tolerated on the CDMA reverse link.
- **AirCell has proposed (but not analyzed) 4-system sharing using both duplex inversion and polarization isolation.**
- **AirCell has not provided any sensitivity analysis of a cross-duplexed sharing scenario to demonstrate feasibility with high-rate reverse link transmissions and non-ideal link conditions.**

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Reply to Boeing ATG Update Report

Anthony A. Triolo, Ph.D.
20 August 2004

Overview

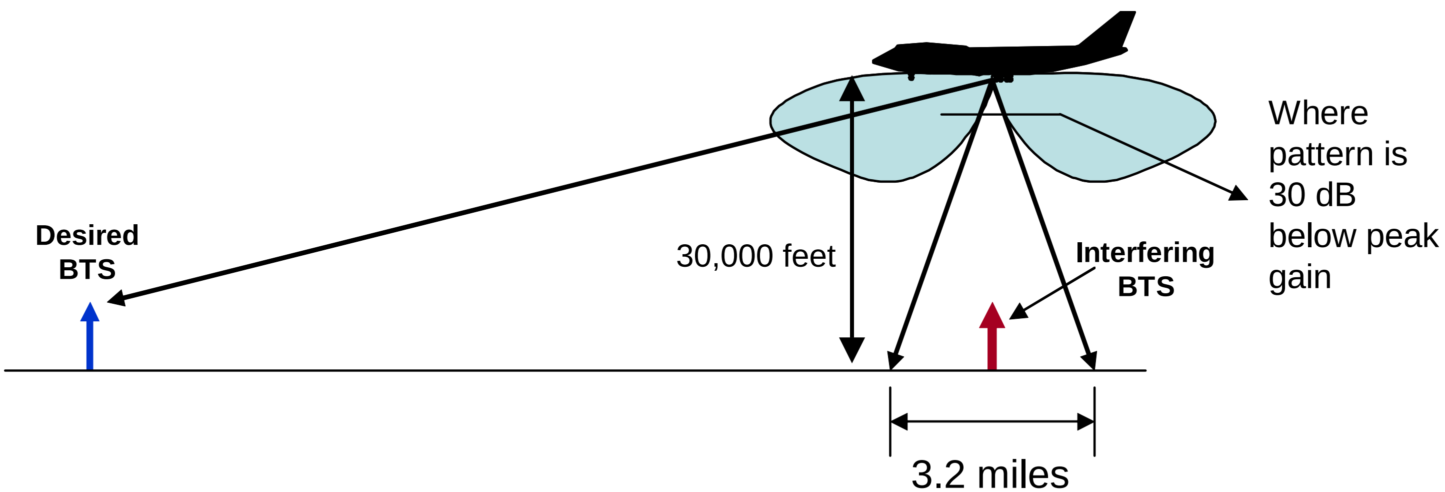
- Boeing states that Telcordia ignored the April 29th Boeing submission, since Telcordia proposed that the only feasible method of combating co-duplexed interference was through the use of large adaptive arrays.
  - It was not clearly stated in the April 29th Boeing submission that the *only* way Boeing's co-duplex spectrum sharing might work is if all providers place base stations on a uniform grid across the entire country.
  - Since the uniform grid did not seem like a workable solution in a real market, Telcordia assumed that the uniform grid was a simplifying assumption that Boeing used for their simulations.
  - The uniform grid model has many associated problems that we are prepared to discuss in detail.
  - When the more reasonable assumption is made that providers would all like to be located near major airports, all of the problems associated with spectrum sharing using clustered base stations would exist (as put forth in the previous Telcordia submission).

Summary of Problems Associated with a Uniform Grid

- The uniform grid constraint is unfair and not workable due to the following factors:
  - Since the density of aircraft near the airports is high, there would exist an unfair advantage for those providers on the grid that are located near major airports, i.e., these close-in providers would have better signal **coverage** to larger numbers of aircraft.
  - More importantly, each provider would likely need more than one base station near each airport to provide the required **capacity** to serve ground (runway) and air based users.
  - There is a potential near-far problem associated with this scenario.
  - Since base stations located far from airports would not be able to communicate with approaching aircraft below certain altitudes (due to the radio horizon), this would eliminate the possibility of aircraft monitoring links over the broadband connection. At the least, this would provide an additional unfair service advantage to base stations near the airports.
  - It is difficult to maintain the uniform grid along the irregular coastlines; an area where a large majority of air traffic resides.

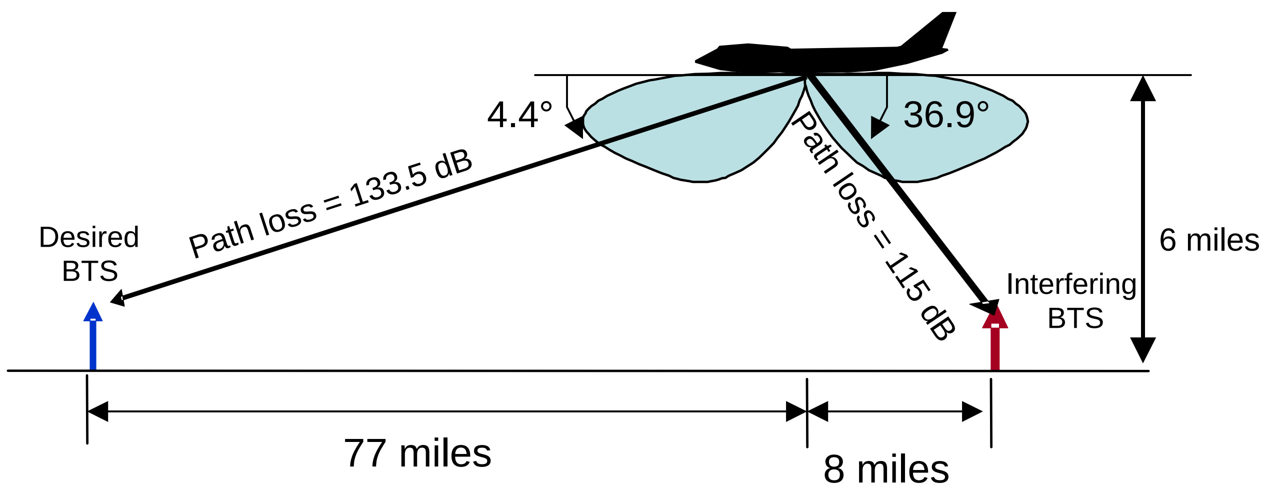
Worst-Case Near-Far Problem

- Boeing provides an example of a worst-case near-far scenario showing that the aircraft antenna pattern provides enough discrimination to combat the interference.
  - The scenario that was chosen as their worst-case is not actually the worst case, given the antennas they assume.
- Boeing claims >30 dB of interference rejection is possible, since the aircraft antenna has a null in the downward direction.
  - However, if the aircraft is just slightly out of this null (>1.6 miles from the interfering base station), a significant reduction in interference rejection occurs.



Worst-Case Revisited

- Using antenna patterns and inter-base station distances (85 miles) from Boeing's document, the case shown below leads to interference problems.
- In the situation below (just slightly modified from the Boeing example):
  - The interfering signal is 18.5 dB higher than the desired signal.
  - The aircraft antenna only provides 3 dB of rejection (from Boeing's antenna pattern @ 32.5° below the pointing angle).
  - The base station antenna may provide 3 dB of rejection.
  - Resulting in a -12.5 dB signal-to-interference ratio. This would represent an outage for a 1xEvDO based system.
- An elevation null could not be steered in the direction of the interfering base station with a switched beam (in azimuth) antenna system.
  - A fully adaptive 2-D array would be needed to steer a null in this direction.



Boeing Simulations from 4/29/04

- The original Boeing simulations of April 29th show that multiple provider spectrum sharing would not lead to a significant number of "broken links" when provider's base stations are constrained to a regular grid.
  - The simulations did not address the data throughput reduction that would be experienced by all carriers when multiple systems are present.
- These simulations* do not seem to take into account true broadband services, since the peak per-aircraft aggregate data demand seems very low.
  - It is not fully clear what assumptions were made, but Boeing's slide presentation depicted:
    - An aggregate air-to-ground data rate of 45 kbps per aircraft (3 kbps per user per aircraft).
    - An aggregate ground-to-air data rate of 180 kbps per aircraft (12 kbps per user per aircraft).
    - The time-varying rate chart for the cross country flight showed a maximum of 160 kbps ground-to-air aggregate rate.
- Airfone is planning initially to provide a maximum of
  - ~2.5 Mbps ground-to-air shared among aircraft in a sector.
  - ~900 kbps air-to-ground shared among aircraft in a sector.
- The use of higher data rates would lead to increased interference with Boeing's proposed solution.
  - Higher data rates require higher Ec/Io target, and hence increased transmit power.
  - Less coding/spreading gain is available when trying to achieve high data rates in a fixed bandwidth, leading to less interference tolerance.
  - Both of these factors would lead to increased cross-system interference.
- The off-grid simulations allow for only 20 mile off-grid placement.
  - This is not enough flexibility to allow all providers airport coverage.

*Boeing's Proposed ATG Sharing Rules with Supporting Analyses, Filed with the FCC on April 29, 2004 (slide #21).

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Increasing Capacity Through a Denser Grid

- Boeing claims that capacity can be increased by reducing the inter-base station separation.
  - Boeing's simulations show a 2x capacity increase when the inter base station separation is reduced from R_{max} to $R_{max}/2$.
- There are two major problems with this solution
  - Capacity/coverage is needed in certain closely spaced areas, as was shown with the NY/NJ/PA/MD example on an earlier slide.
    - Making the grid denser only somewhat alleviates this situation. As Airfone's current base station deployment shows, 3 base stations are needed within 10 miles of Manhattan to provide the necessary capacity/coverage. A grid with 10 mile spacing between base stations is prohibitively costly.
  - The provider with the largest market share dictates the grid density.
    - This provider will need a certain capacity (and associated number of base stations) to serve its customers. In order to maintain the signal to interference ratio, all other providers must have approximately the same number of base stations.
    - Those providers that do not match this increased infrastructure will provide degraded service due to the reduced signal to interference ratio. This will create coverage holes for such providers.

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Summary

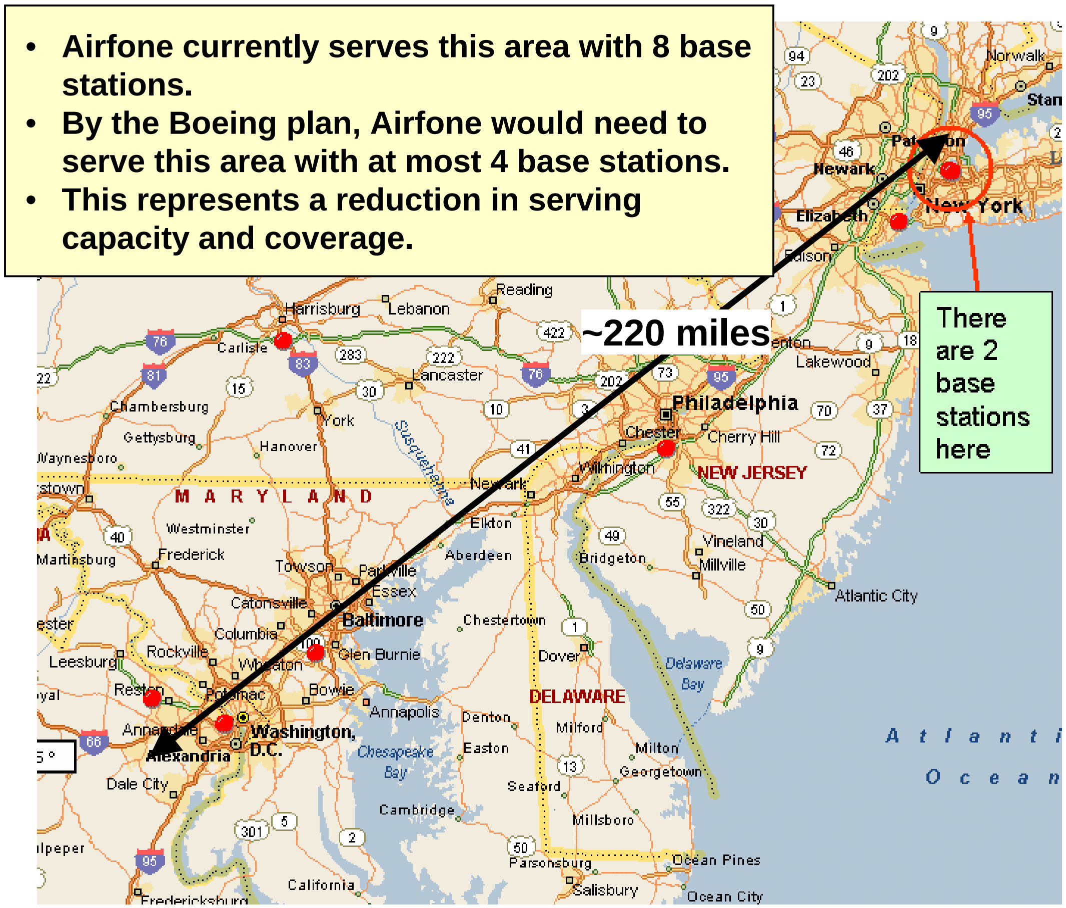
- Boeing's simulations seem to show that it is possible to share spectrum among multiple providers when all providers are constrained to a uniform grid.
- This grid-based system proves to be unfair and may be difficult to manage.
  - It eliminates the possibility of aircraft monitoring applications by providers distant from airports.
  - It penalizes providers far from airports through inferior coverage in high density areas and eliminates the possibility of runway to runway service (aircraft monitoring applications).
  - It limits capacity growth in the highest density areas by limiting the number of base stations a single provider can place near airports.
  - Increasing capacity through closer inter base station separation places a burden on the provider with the smallest market share.
- Boeing's proof-of-concept simulations do not take into account the high data rates possible with broadband operation.
- A slightly modified version of Boeing's worst-case example shows that the near-far problem can still exist with a grid-based system.
  - A problem that switched beam (azimuth) antennas cannot alleviate.

Backup Material

Current Non-Uniform Spacing

- **Airfone's current base station locations are not uniformly distributed.**
- **Shown below are two examples.**

- **Airfone currently serves this area with 8 base stations.**
- **By the Boeing plan, Airfone would need to serve this area with at most 4 base stations.**
- **This represents a reduction in serving capacity and coverage.**



Endfire Array Problem

- When multiple providers place base stations near an airport, the aircraft array must form an endfire narrow beam.
  - This requires a large number of elements.
- It is true that if *all* providers were constrained to a grid, this situation would not occur, but that would be impractical because:
  - The grid based solution would need central planning and management, would preclude aircraft monitoring applications, and would severely constrain the capacity of each provider.
  - The grid based solution can lead to a near-far interference problem (as explained on slide #5).