Coexistence Analysis for multiple air-to-ground systems

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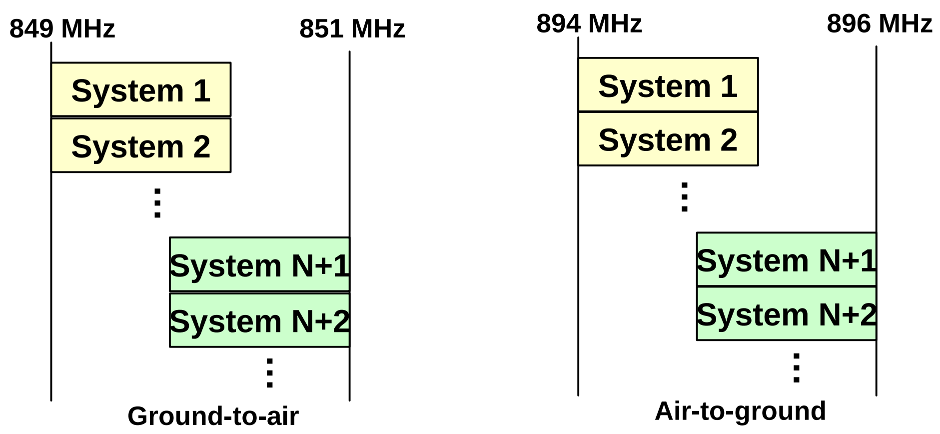
Overview of Proposed Coexistence Plan

- Boeing has proposed use of adaptive antennas on all aircraft and base stations to alleviate interference issues in order to support multiple system sharing of the 850/895 MHz ATG spectrum.
  - The proposed spectrum plan is shown below.
- We will show
  - Unacceptable amounts of interference would result from this plan.
  - Reasonable sized adaptive antennas cannot alleviate this problem.
  - Complexity of proposed adaptive antenna system is much greater than Airfone's proposed switched-beam system.
  - Commercial off-the-shelf systems do not currently exist for air-to-ground applications and the required engineering and testing necessary to develop such a system would lead to significant time-to-market delays.



Observations regarding the proposed layout

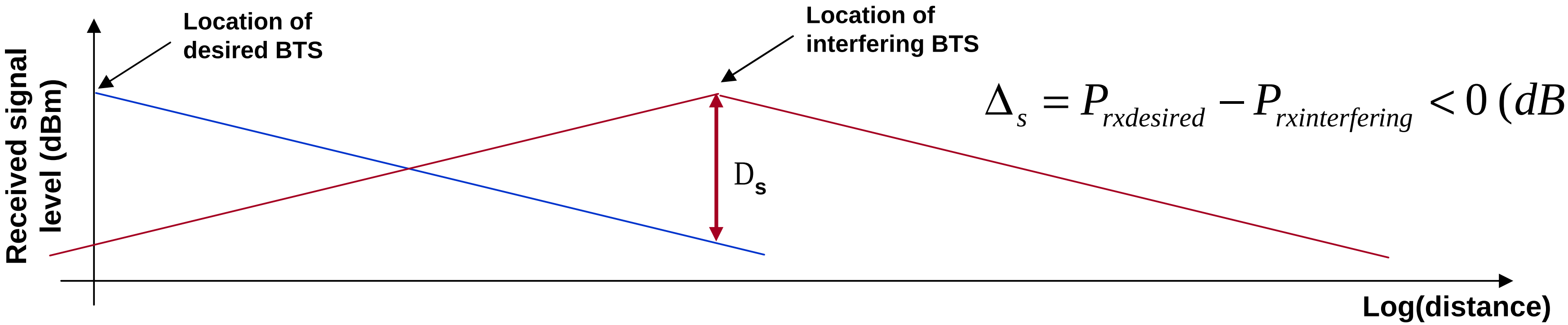
- System #2 base stations are placed where signals from system #1 base stations is weakest, creating severe interference problems.

  Ground-to-air link:

  – Without significant antenna discrimination between the two opposing system's base stations, system #1 aircraft would see a very large signal from system #2 and weak signals from their own base stations.

  Air-to-ground link:

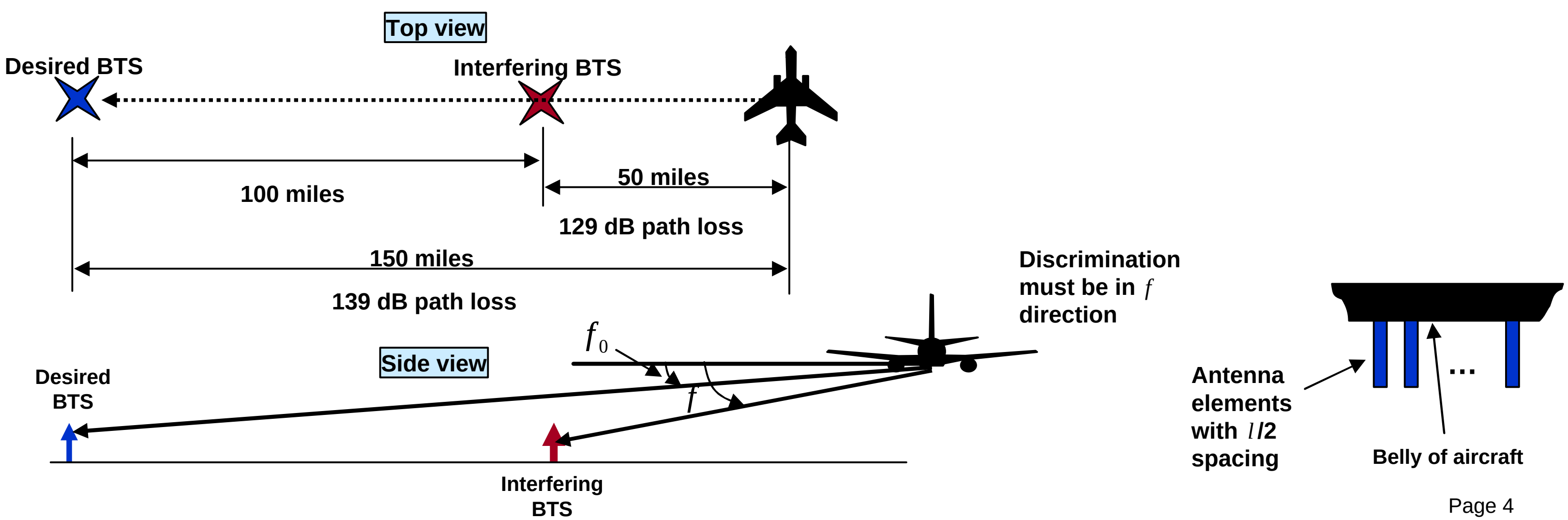
  – Base stations from system #1 could have aircraft belonging to system #2 very close while trying to communicate with system #1 aircraft that are very far (classic near-far problem).



$$\Delta_s = P_{rxdesired} - P_{rxinterfering} < 0\ (dB)$$

Observations regarding the proposed layout (cont.)

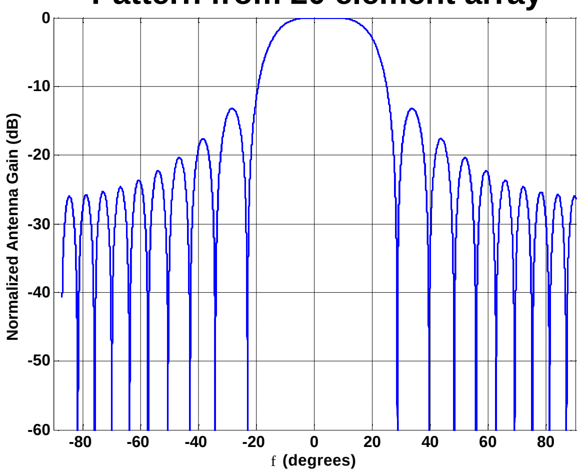
- The only way to deal with this interference problem, as was proposed, is to install adaptive antennas on both ends of the link that can form beams which aim at the desired base station, while attenuating the signal from the interfering base station through pattern roll-off.
- As we will see however, for cases where interfering and desired BTS are not separated by reasonable angles, a prohibitively high number of antenna elements is required to form a beam that is narrow enough to aim at the desired BTS, while attenuating the interferer.
  - These cases occur where the serving BTS is angularly very close to an interfering base station.
    - Airport approach and climb-out, when both systems have base stations near the airport.
    - Edge-of-network areas, such as coastal regions.



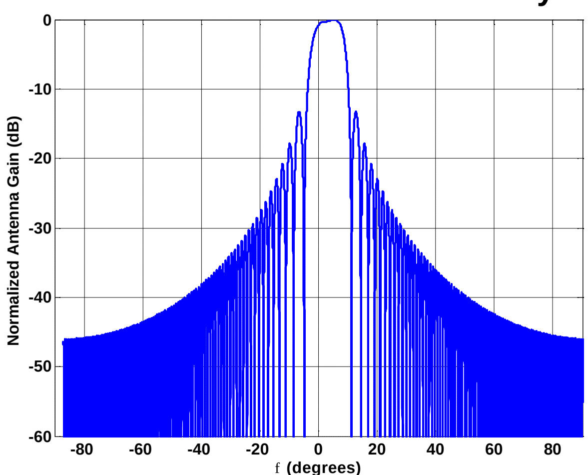
Co-linear interfering BTSs example (cont.)

- Because of the path loss difference in the case shown on the previous slide, the interfering signal must be attenuated by 10 dB + minimum SINR required to complete call.
- We can form a beam toward the desired base station that will also attenuate the signal to the interferer.
- The question is: how many elements do we need in order to attenuate the interfering signal enough?
- Assume we only need 0 dB SIR to complete the call (this will result in very low data rates, but the call will be connected).
  - We must find the number of elements that make: $20\log_{10}\left(G\left(f;N\right)\right)=-10$
  - We need 190 elements in the dimension along the wing to achieve this.
  - We must maintain this performance regardless of the aircraft azimuthal orientation, so we need a square array.
  - This results in a square array with 190^2 = 36,100 elements.
  - This array would be 100 feet on a side at 895 MHz and would require 36,100 receiver chains.
- The absurd number of elements required show that it is clearly very difficult to form a narrow enough beam to attenuate a near co-linear interfering BTS using a belly mounted array.

Pattern from 20 element array

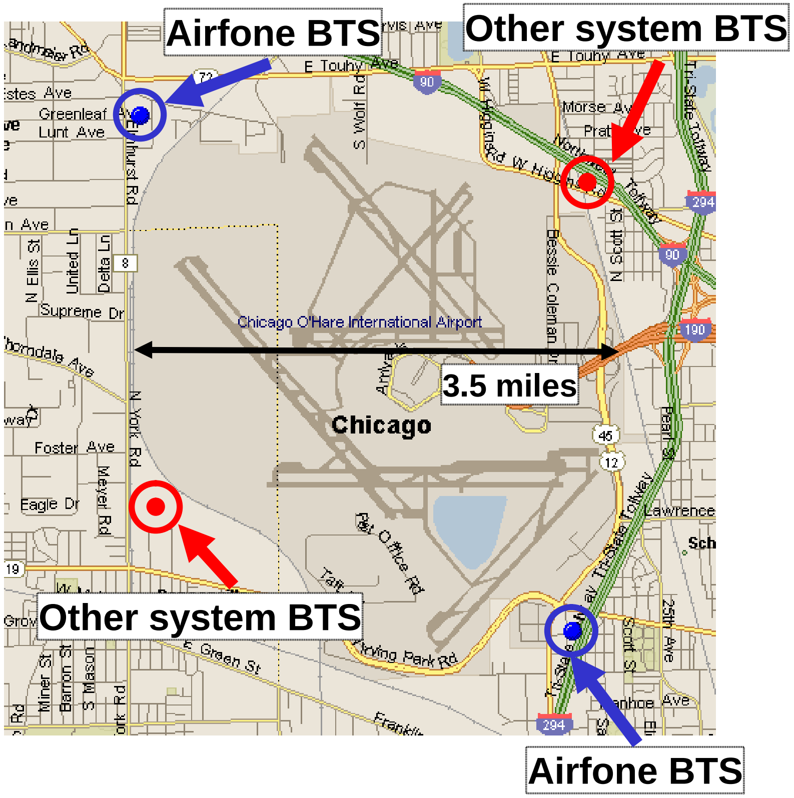


Pattern from 200 element array

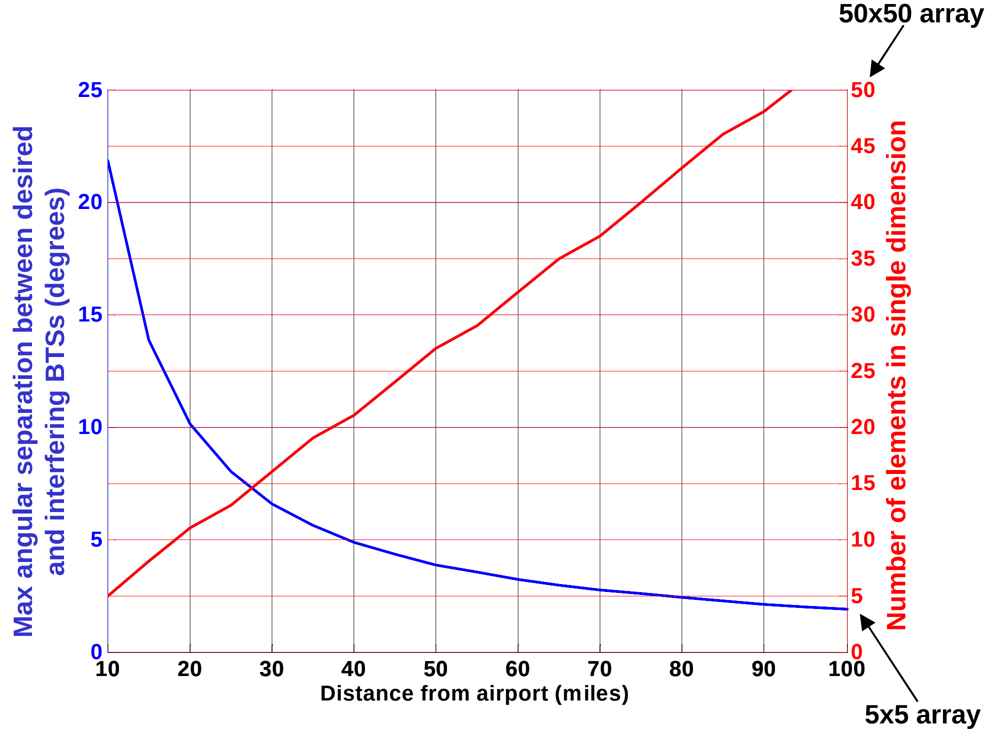


Both aimed at 3° from horizon

Chicago O'Hare example

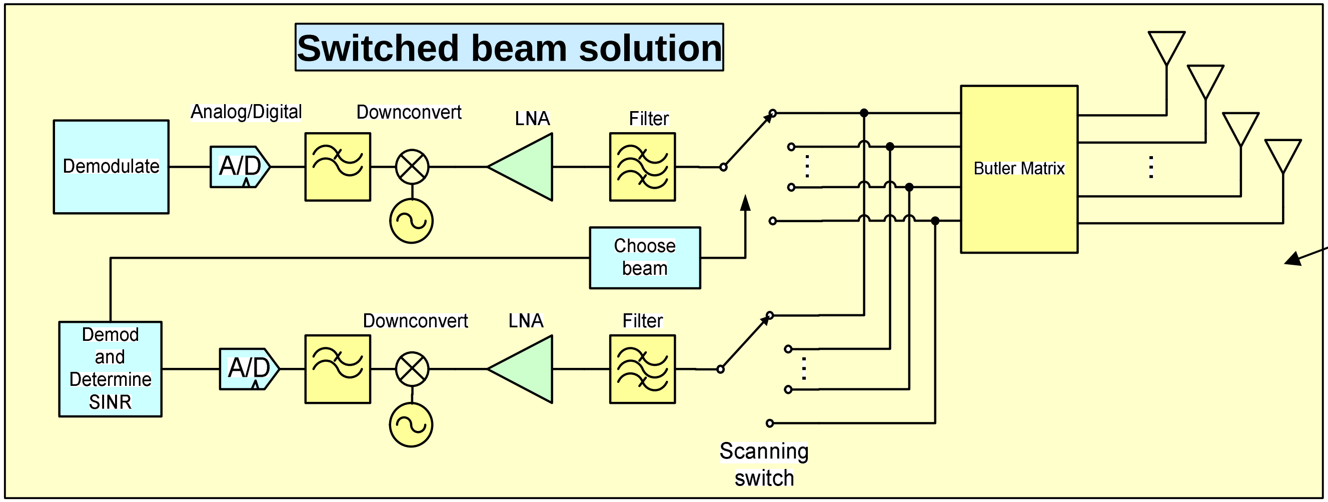


- In this specific example, we can use angular separation in azimuth to discriminate between desired and interfering BTSs (no longer an endfire array).
- We determine the number of elements necessary to put the interferer outside the 3 dB beamwidth (may not be enough attenuation, but is best case).
- As we get farther from the airport, all base stations (desired as well as interfering) look as if they are co-located.



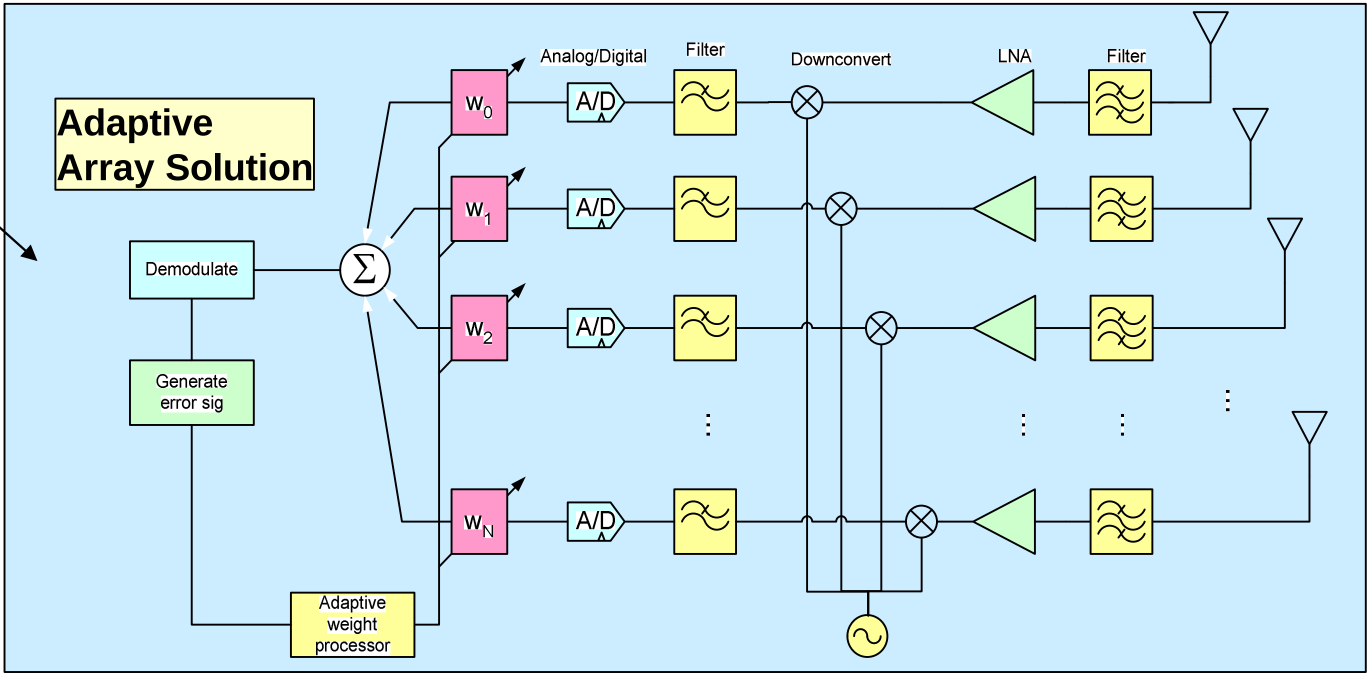
- Even at the closest reasonable point (10 miles), where azimuthal angular separation is greatest, a 5x5 array is needed to reduce the interferer by 3 dB.

Simplified block diagram comparison



2 receiver chains

N receiver chains



More costly and more complex solution

Summary and conclusions

- When the serving and interfering base stations are not well separated angularly, the adaptive antenna cannot attenuate the interferer.
  - The only way to accomplish the required attenuation is to use an unreasonably large and expensive array to achieve the required narrow beam width.
- Even for moderately sized arrays (5x5), the required design, system engineering, and flight testing of these arrays would lead to increased cost, weight, power consumption (over a switched beam system) and time-to-market delays.

Additional technical information

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Proposed physical layout of coexisting systems