Reply to AirCell September 10, 2004 Response To Telcordia Comments on AirCell Proposals

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Introduction

In [1], AirCell proposed and analyzed a cross-duplexing (or "reverse-banding") scheme for sharing spectrum between two spectrally-overlapping air-to-ground (ATG) service providers. In [2], Telcordia provided additional analysis and simulation results for spectrum sharing using cross-duplexing, demonstrating the potential for substantial performance degradation due to interference between the two systems. AirCell responded in [3], critiquing the assumptions and conclusions of [2]. Shortly thereafter, AirCell proposed a second part to its sharing proposal in [4], suggesting that additional spectrally-overlapping providers could be accommodated using polarization isolation, for a total of 4 providers. In [5], Telcordia responded to the comments in [3] and also provided comments on [4], and AirCell has responded to [5] with [6] . These notes respond to [6].

Summary

Review of [6] reveals that it does not credibly refute even a single point made in [5], and further, it fails even to respond at all to some of the most important points raised in [5]. AirCell's introductory claim to "demonstrate that Telcordia's claims are totally unsubstantiated" ([6], p. 2) is totally unsupported by the discussion that it provides, as is shown here.

This response is organized according to six topic areas. These areas, and the major points relating to them are summarized below, followed by a more detailed discussion of each topic. For completeness, a background summary is provided for each topic.

- ***Air-to-air interference in cross-duplexed systems.*** AirCell has limited aircraft EIRP to 200 mW (23 dBm) in its analysis of aircraft-to-aircraft interference effects in cross duplexed air to ground (ATG) systems, and has assumed an idealized link budget. It has performed no sensitivity analysis to determine the effects of parameter variations. Telcordia has investigated the impact of higher aircraft EIRP levels, which could be necessitated by higher data rates and/or non-idealities in propagation or equipment performance. Telcordia's analyses show that under those conditions, the air-to-air interference would cause significant degradation in forward link performance. AirCell continues in [6] to take issue with Telcordia's allowance for additional link margin. However, in [8] AirCell acknowledges the need to limit, by FCC Rules, the aircraft

EIRP to 200 mW, implicitly agreeing with Telcordia's conclusion that higher aircraft EIRP levels will damage forward link performance. Hence, the debate about the link margin appears largely moot at this point; however, for completeness two plots of received signal strength are provided here from AirCell's own flight test report [7] which clearly show the large variations that can occur.

- ***Base-to-base interference in cross-duplexed systems.*** AirCell has proposed to minimize interference between cross-duplexed base stations by directing deep antenna pattern nulls at the horizon. Telcordia has shown, using AirCell's own geometry and parameters, that this is impractical, and further, that even if it were implemented, reverse link capacity would still be significantly reduced. In [6], AirCell criticizes the geometry used by Telcordia, despite the fact that it came from AirCell's analysis in [4]. AirCell fails to state what it now believes a more reasonable set of parameters might be, and also fails to address the issue of reverse link capacity reduction.
- ***Interference from Naval air search radars to aircraft receivers in cross-duplexed systems.*** Telcordia has noted that the aircraft receivers in a cross-duplexed system (receiving in the 894-896 MHz band) will be more susceptible to interference from the AN/SPS-49 Naval air search radar than are the current base stations which receive in that band, because the radio horizon from the aircraft to the radar transmitter is greater than that from the base station to the radar. AirCell disputed this in [3], but as noted by Telcordia in [5], its argument was flawed due to an incorrect path loss calculation which failed to account for the radio horizon, and a misunderstanding of the rules under which the AN/SPS-49 is operated within 200 nautical miles of the coast. In [6], AirCell fails to either confirm or deny the calculation error, and continues to reiterate its incorrect interpretation of the AN/SPS-49 operating rules.
- ***The relationship between aircraft transmit power and data rate.*** Telcordia pointed out in [5] that the high data rates required to support "broadband services" will require transmit power levels greater than the 200 mW maximum aircraft EIRP which AirCell used in its analyses (and has since proposed be codified in the FCC Rules). In [6] AirCell offers no valid arguments in dispute of this; further, in [8], AirCell endorses the new 1xEV-DO air interface described in [11] with its 1.8 Mbps peak reverse link rate. An example calculation provided here shows that the required aircraft EIRP to support such a rate is on the order of 40 dBm. Clearly, the 23 dBm limit proposed by AirCell is inconsistent with its own vision for broadband services.
- ***Spectrum-sharing using crossed-polarization.*** In [4] AirCell proposed that an additional two providers could share overlapping spectrum by using orthogonal polarization, and provided simulation results assuming a polarization isolation of 12 dB. AirCell claimed that this figure was justified based on measurement results from [7]. In [5], Telcordia reported that a detailed review of [7] revealed no such justification, and further, even if AirCell's simulation results are taken at face value, the severe noise rise problem at airport-scenario base stations would prevent reverse link operation in a real system. In [6], AirCell has not responded to either of these points, but only stated that the 12 dB number is supported by undisclosed proprietary AirCell data.

- ***The CDMA reverse link capacity formula.*** In Annex B of [2], Telcordia pointed out that AirCell had a minor error in its reverse link capacity formulation in [1]. In [3] AirCell took issue with this, providing a definition for the term in question (which had not been defined mathematically in [1]), and claimed that the Telcordia and AirCell formulations were equivalent. In [5] Telcordia showed mathematically that this is not the case. In [6], AirCell merely repeats its material from [3] without addressing Telcordia's point.

More on these points is provided in the sections below.

Air-to-Air Interference in Cross-Duplexed Systems

In [1], AirCell proposed the cross-duplexed sharing concept and presented simulation results of the forward link performance degradation due to interference from the airborne transmitters of the "other" system. Total aircraft EIRP was hard-limited to 200 mW (+23 dBm) in all cases, and ideal free-space propagation was assumed with only a 3 dB cable loss. The reverse link payload was ten speech circuits per aircraft, with each circuit at a 9.6 kb/s rate with 50% activity factor (average reverse link aggregate rate of 48 kb/s per aircraft). AirCell performed no sensitivity analysis to explore the impact of different assumptions.

In [2], Telcordia also analyzed cross-duplexed spectrum sharing, but explored the effect of additional loss in the link budget due to non-idealities in the equipment and propagation, and did not limit the aircraft EIRP to 23 dBm. Telcordia found that when the maximum allowed aircraft EIRP was increased (due either to the need to overcome higher link loss, or to transmit at a higher data rate), there was significant performance degradation on the forward link, due to the air–to-air interference.

In [3], AirCell took issue with Telcordia's inclusion of a 10-dB system performance margin in the link budget. In [5], Telcordia responded that the 10 dB was based on Airfone's operational experience, and further noted that in Appendix A of [4], AirCell shows air-to-air propagation data that exhibits a significant variation as shown in Figure 1 (the red line represents free space propagation). The point is that often in real-world environments, there are unexpected losses and that it is not unreasonable to expect that similar imperfect link budgets will occur on the air-to-ground link as well, especially in light of the fact that there is the potential for reflections. Telcordia concluded in [5] (p. 4) that "In sum, AirCell's claim that it is not appropriate to include the additional 10-dB margin in the link budget seems inconsistent with its own recently reported measurement data."

AirCell's response in [6] (p. 2) was "The flaw of such a generalization is obvious, since ATG [air to ground] transmission does not suffer from the aircraft shielding/obstruction losses inherent to ATA [air to air] scenarios with aircraft flying at different altitudes." The problem with this argument is that, as discussed in [5], the aircraft vertical separation was only about 1000 feet during the measurements (see [4], p. 72), so at the large end of the distance range (e.g., 5 km horizontal distance), the elevation angle between the two aircraft is only about 3.5°, and blockage effects should not be significant. AirCell completely ignored this point in [6].

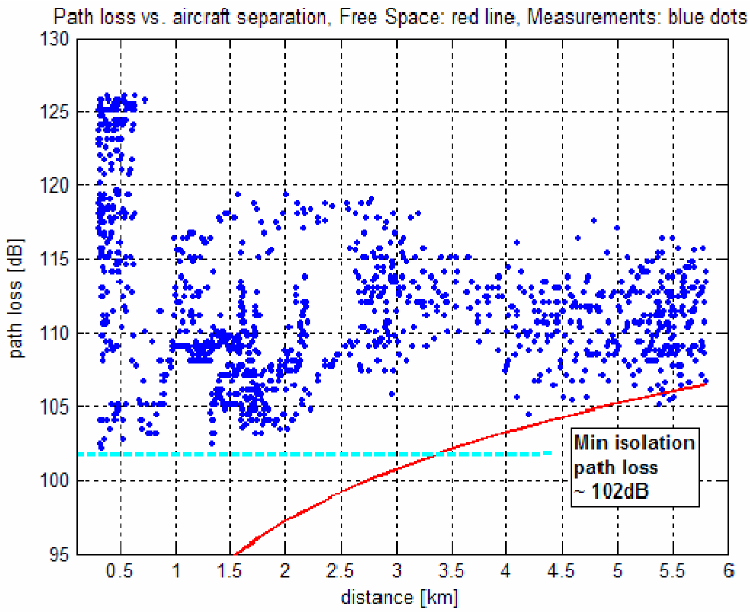

Figure 1: *Measurements of path loss isolation between aircraft, from Figure A3 of [4].*

AirCell further states:

> In supporting it's [*sic*] position regarding the ATG transmission channel, Telcordia does not provide a shred of channel measurement data or any other evidence. Thus, Telcordia's claim for generalization of ATA path loss measurements between two aircraft with belly mounted antennas to the ATG path loss must be regarded as entirelly [*sic*] incorrect. ([6], p. 5).

AirCell, with its operational experience, surely must understand the magnitude of the variations that can occur on an air to ground link. Figure 2 and Figure 3 show received power vs. distance plots for the air-to-ground link from AirCell's own flight test report [7]. These plots show variations on the order of 10 dB along most of the flight path. It therefore is difficult to understand why AirCell insists that the air-to-ground link will exhibit textbook free-space propagation.

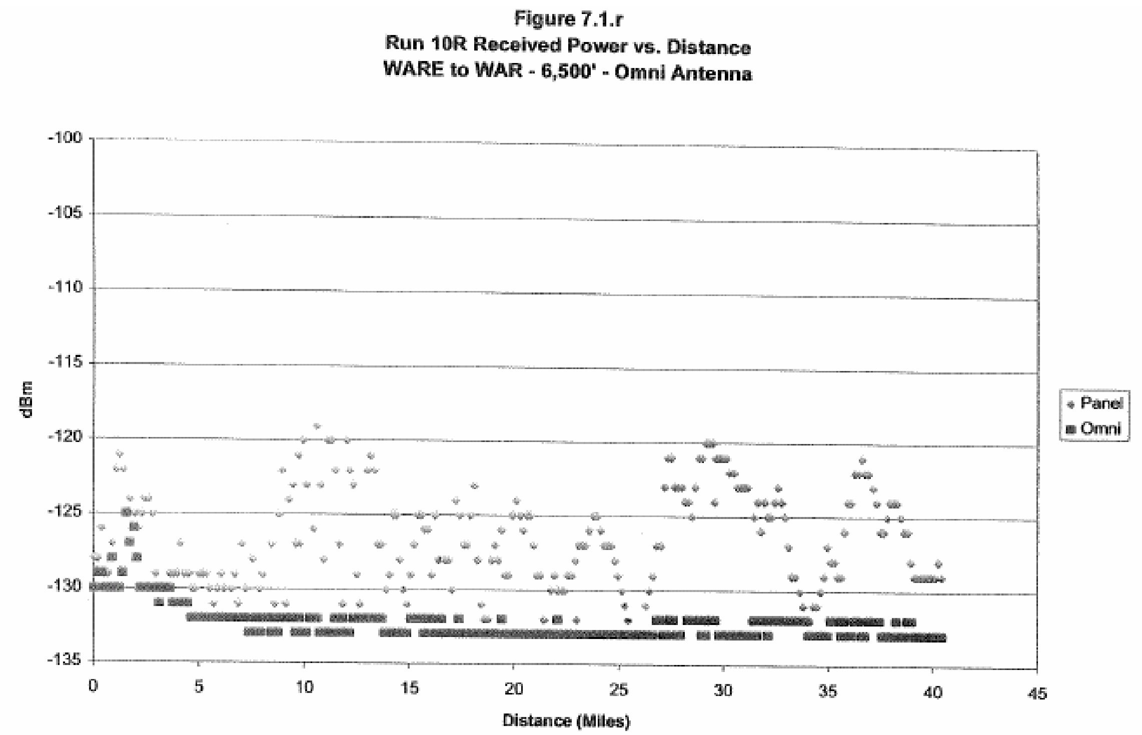

Figure 2: *Figure 7.1.r from the AirCell flight tests [7].*

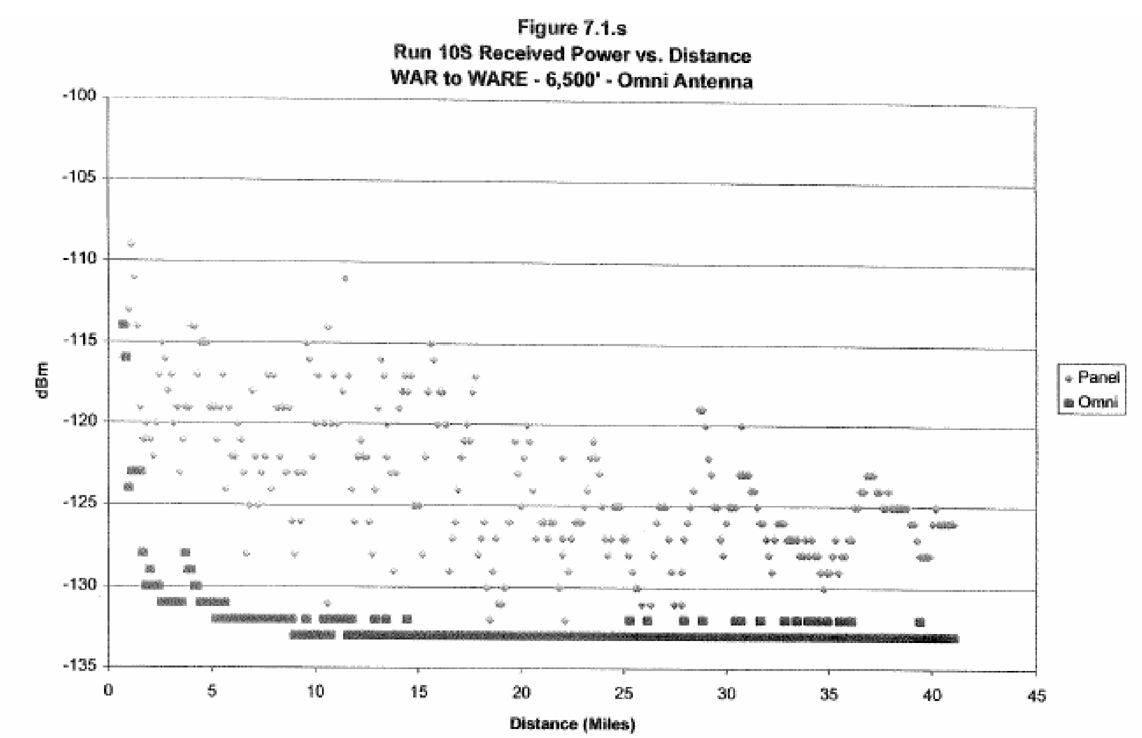

Figure 3: *Figure 7.1.s from the AirCell flight tests [7].*

In sum, Telcordia's main point with respect to air-to-air interference is that the benign results shown by AirCell in [1] are heavily dependent on the assumption of a very limited aircraft transmit power, and that if that assumption is relaxed, whether it be due to extra loss in the link budget that must be overcome, or to the need to achieve greater reverse link throughput, there will be significant performance degradation to the forward link.

Significantly, AirCell seems now to have acknowledged this, because in the Rules it has proposed to the FCC for a two-service licensing plan, AirCell proposes a maximum aircraft EIRP limit of 200 mW ([8], p. 7). Unfortunately, such a low level will not support broadband services on the reverse link, as discussed below.

Base-to-Base Interference in Cross-Duplexed Systems

In [2], Telcordia observed that base stations of cross-duplexed systems will tend to be within the radio horizon of each other in airport scenarios. In fact, in AirCell's "airport scenario" [1], base stations of cross-duplexed systems are about 9.5 miles apart, whereas the radio horizon between base stations will vary between about 18 and 44 miles, depending on their elevations. The radio horizon in miles is $d = \sqrt{2}\left(\sqrt{h_1} + \sqrt{h_2}\right)$ where h_1 and h_2 are the base station antenna elevations in feet and range from 40 to 240 feet. Near airports the elevations are likely to be near the upper end of this range to overcome ambient clutter. In Appendix C of [4], AirCell proposed to use antenna discrimination to control base-to-base interference. As pointed out in [5], AirCell's model would require an antenna gain rolloff of about 25 dB within 1° of elevation change, which is not likely to be commercially feasible with respect to either antenna design or antenna alignment. In presenting this calculation, Telcordia used AirCell's assumptions and geometry from [4], included here for completeness. Figure 4 is reproduced from Figure C.3 on p. 89 of [4], and AirCell states:

> The maximum antenna gain on the TX side should be placed at the elevation of point A. Point A is the edge of the cell for System 1. The horizontal distance from the base station to point A is equal to the cell radius. The elevation of point A is equal to the minimum altitude of served aircraft. ([4], p. 89).

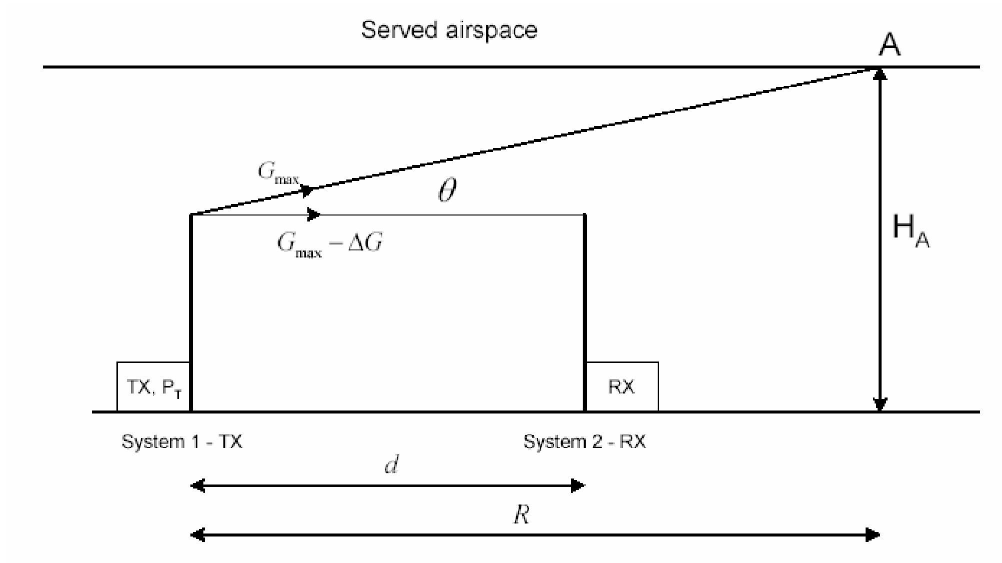

Figure 4: *Geometry for analysis of base-to-base interference for the airport scenario, reproduced from [4], Fig. C.3, page 89.*

In Table 5.1 on p. 25 of [4], the minimum aircraft altitude is given as 1000 feet for the airport scenario, and the cell radius is given as 12.5 miles. Based on those parameters, the angle θ is less than 1 degree. In table C.2 of [4], AirCell gives the required null depth ΔG as a function of base station separation. For a 10-mile separation, ΔG is about 25 dB, leading to Telcordia's conclusion that the antenna gain must roll off by 25 dB within an elevation change of 1°.

In response, AirCell states:

> The flaw in the argument made by Telcordia is obvious. Clearly an aircraft flying at an altitude of 1000 ft is either arriving or departing and is not 12.5 miles away from the airport! Under more realistic circumstances, selection of site locations and antenna patterns will allow coverage to be maintained while the base to base isolations are kept at negligible levels [*sic*] ([4], p. 5).

Presumably, what AirCell actually intended to say here is something like "base to base interference is kept at negligible levels." That aside, however, AirCell completely fails to mention that the geometry and assumptions upon which Telcordia's calculation was based were those provided by AirCell itself in [4], despite the fact that this was clearly explained by Telcordia in [5]. Moreover, AirCell has failed to state what conditions for the aircraft approach might constitute "more realistic circumstances" in terms of approach angle.[1] Further, it should be noted that the 12.5 miles is not necessarily the distance to the runway, but the distance to the base station. In short, AirCell's argument

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[1] If, in fact, different numbers are used, the results are still not comforting. Assume the aircraft is 3 miles from the base station at 1000 feet elevation, and the base station has an elevation of 200 feet. The angle θ is still less than 3°.

in [6] is inconsistent with its own analysis in [4], is incomplete, and mischaracterizes Telcordia's calculation.

Finally, in [5] Telcordia pointed out that even if the antenna discrimination specified by AirCell could somehow be achieved, its goal would be to reduce the base-to-base interference to a level that is 3 dB below the noise floor of the victim receiver ([4], p. 90). Interference from two base stations would equal the noise floor and would reduce the capacity of the victim receiver reverse link by about 30% ([5], pp. 15-16). In [6], AirCell neglects to comment at all on this important point.

Interference from Radar to Cross-Duplexed Aircraft Receivers

In [2] (p. 53), Telcordia explained that Airfone's base stations in some coastal areas experience interference from the AN/SPS-49 Naval Air Search Radar with some regularity (the base stations receive in the 894-896 MHz band). Telcordia also explained that the aircraft receivers of a cross-duplexed system, which would also receive in that band, would be more susceptible to this interference. As summarized in [5], there are three factors that lead to this conclusion:

1. Operation of the radar within 200 nm (230 statute miles) of land is limited to channels within the 902-928 MHz band.
2. An aircraft is much more likely to "see" the radar transmitter due to its greater radio horizon (about 250 miles for an aircraft vs. about 30 miles for a base station, depending on its elevation).
3. A receiver in the 894-896 MHz band will be more strongly affected by sidebands of a radar signal in the 902-928 MHz band than will a receiver in the 849-851 MHz band.

AirCell disputed this claim in [3], but as explained in [5], its conclusion was based on: (1) a misunderstanding of the operating rules for the radars; and (2) a flawed interference calculation that failed to account for the radio horizon (curvature of the Earth).

AirCell stated that "ships turn off their AN/SPS-49 radar about 200 nm from the shore." ([3], p. 15). Telcordia explained in [5] that this is not true; and that as was clearly stated in [2], operation within 200 nm of shore is limited to the 902-928 MHz band. This is explained in [9], which was referenced as the source of the information in [2], which explained the rules (and was also referenced by AirCell in [3]). There is no information in [9] which suggests that the radars are turned off within 200 nm of shore, and AirCell offers no support for the statement. It is difficult to understand why AirCell at this point still does not seem to understand the AN/SPS-49 operating rules; however, in [6], AirCell continues to reiterate the misconception that "ships typically turn off their AN/SPS-49 radar about 200 nm from shore."

AirCell also made a critical error in [3] in computing interference from radars to coastal base stations, in its attempt to show that interference from the radars could be as damaging to existing base stations as to cross-duplexed aircraft receivers. In its calculations, AirCell neglected the effect of the radio horizon ([3], p. 15). This was pointed out by Telcordia in [5], but in [6] AirCell has neither confirmed nor denied its error, and in fact has not mentioned those calculations at all.

What AirCell does state is:

> Telcordia fails to present any data for interference levels seen at an aircraft today and it fails to provide concrete data and explain why Airfone's base stations do not regularly experience radar interference if its claims for propagation protection are true ([6], p. 6).

This statement makes no sense, and suggests that AirCell is confused. First, neither Airfone nor Telcordia have claimed that aircraft today (which receive in the 849-851 MHz band) suffer interference from the AN/SPS-49. The concern is that a *cross-duplexed* aircraft receiving in the high band (894-896 MHz) will suffer the interference, as has already been explained in [2] and [5]. Second, as explained in [2], Airfone's base stations do in fact experience interference from the AN/SPS-49. AirCell has not made clear what it means by "propagation protection," but presumably it refers to the fact that base stations will have a smaller radio horizon with respect to the radar transmitter than will aircraft, but that is a fact rather than a claim. The authors of [3] and [6] should be familiar with radio horizon effects, as they have been discussed in AirCell's own documents in this proceeding (see, *e.g.,* [1], pp. 97-99).

In summary, AirCell has failed in [6] to take advantage of the opportunity to correct the errors in [3] that were pointed out in [5], has offered no new information, has continued to stand by its erroneous contentions, and has provided only a confusing and logically inconsistent critique of Telcordia's assessment in [2] of the potential for interference to cross-duplexed aircraft from the AN/SPS-49 radars.

Transmit Power and Data Rate

Telcordia observed in [5] that, regardless of technology, increasing the data rate with a fixed transmission bandwidth and a given path loss requires an increase in transmit power. This was supported with the relationships shown in Figure 5. Telcordia then used these relationships to demonstrate the increase in the aircraft EIRP that would be required to support broadband services on the reverse link, compared to the EIRP needed to support the 48 kb/s average throughput in AirCell's analysis.

In [6], AirCell responded that

> The power level of 200 mW (23 dBm) is accepted in terrestrial 1x EvDO application [*sic*] as the value that balances forward and reverse communication paths. ([6], p. 6).

While 200 mW may be adequate as a terminal power limit *per user channel* in the current instantiation of 1xEV-DO, it is not true that the forward and reverse links are balanced, as can be seen from [10] (p. 5), which gives average throughput for the forward and reverse link per 3-sector cell. For the reverse link the average throughput is 600 kbps/cell or 200 kbps/sector (see also [10], p. 17), and for the forward link the throughput depends on the speed of the user and the number of receive antennas. For pedestrian speeds with a single antenna or high speeds with a dual antenna, the average throughput is 3.1 Mbps/cell or about 1 Mbps/sector, a factor of five higher than the reverse link.

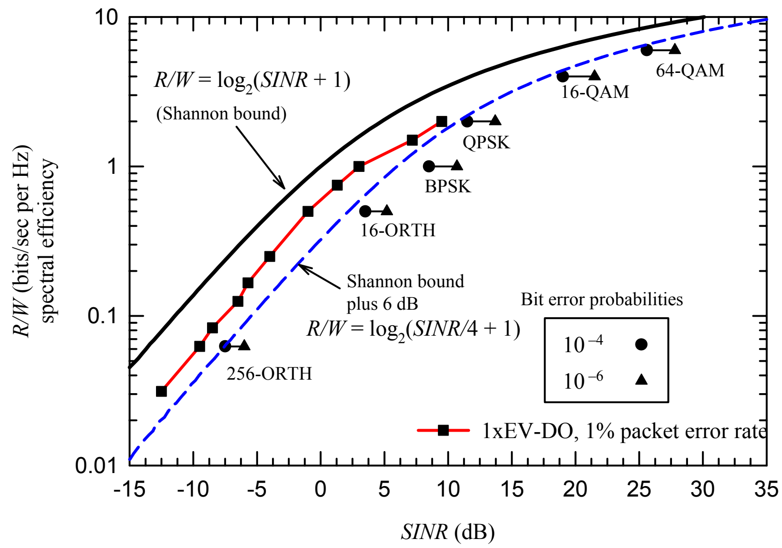

Figure 5: *Modulation efficiency vs. SINR.*

The maximum reverse link rate per subscriber in the original 1xEV-DO air interface is about 153 kbps. Qualcomm has proposed enhancements (1xEV-DO rev A), which would include a peak reverse link rate of 1.8 Mbps [11]. AirCell endorses this technology for ATG, stating:

> 1xEVDO Rev A is the most recent version of EVDO, offering 3.1 Mbps throughput on the forward link and 1.8 Mbps on the reverse link, with low data latency support. This represents a significant improvement over the earlier version (rev 0), which had been used for AirCell's earlier performance analysis ([8], p. 4).

AirCell also states in [8] (p. 4) that "AirCell regards CDMA 1xEVDO Rev A as the primary candidate for ATG broadband services."

It is useful to calculate the aircraft EIRP required to support 1.8 Mbps on the reverse link in an ATG application. Table 2 of [12] gives the SINR required to support the various data rates in the original 1xEV-DO forward link at a 1% packet error rate. For 1843.2 kbps, the required SINR is 7.2 dB. With a 4 dB noise figure the noise floor is −109 dBm. In addition, there will also be interference from other aircraft. Clearly, the traditional CDMA reverse link interference and capacity analysis cannot be applied here, because even two users cannot share a sector at this rate due to the SINR requirement (they each cannot be 7.2 dB above the other at the receiver). It is therefore assumed here (arbitrarily) that there is no same-sector interference and that the other-sector interference is equal to the thermal noise, making the noise plus interference –106 dBm. The received signal power therefore must be –98.8 dBm. The free space path loss for 200 miles is 141.3 dB. Assuming a 9 dB base station antenna gain, 2 dB diplexer loss, and 3 dB cable loss gives a required aircraft EIRP of 38.5 dBm, or about 7 watts. If the link loss increases due to fading and other non-idealities, the required aircraft EIRP might exceed 45 dBm.

This is consistent with a simple extrapolation of a 23-dBm EIRP to support a reverse link rate of 48 kbps per AirCell [1], to 1.8 Mbps using

$$EIRP = 23 + 10\log\left(\frac{2^{R/W}-1}{2^{48/W}-1}\right) \text{ dBm}$$

where $W = 1250\,\text{kHz}$ and R is the throughput in kbps. This follows from the same reasoning as eq. (12) of [5]. The result is shown in Figure 6; note that an aircraft EIRP of 41 dBm would be required to support a reverse link rate of 1.8 Mbps, according to this calculation.

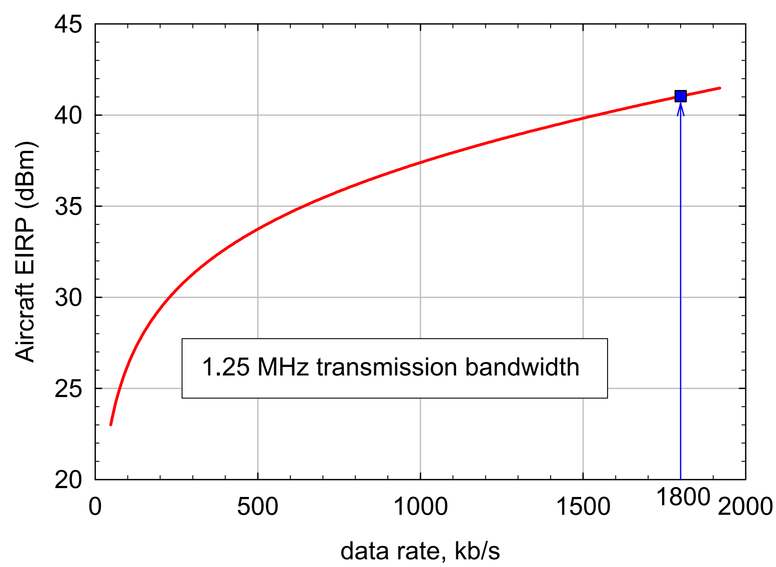

Figure 6: *Required reverse link EIRP vs. data rate, assuming 23 dBm is required to support 48 kbps.*

Clearly, a hard limit of 23 dBm (0.2 watts) on the aircraft EIRP is inadequate to support broadband transmissions on the reverse link, and in particular, to support the 1.8 Mbps peak reverse link rate of 1xEV-DO rev A. Thus, AirCell's unqualified endorsement of 1xEV-DO rev A for ATG applications is inconsistent with its proposal to limit the aircraft EIRP to 23 dBm.

This inconsistency is also reflected in [6], which states:

> Telcordia then argues that this power limitation [200 mW] makes it impossible to provide truly broadband services to airplanes. Telcordia cites AirCell's own

> results [1], which were presented to the commission [*sic*] solely to demonstrate that two cross-duplexed systems deployed according to AirCell's proposal [1] do not interfere with each other. **In fact, in the framework of AirCell's proposed system, by means of straightforward network engineering, it is possible to achieve greater capacity per aircraft and approach the maximum speeds of 1xEvDO systems.** ([6], p. 6, emphasis in original).

What this seems to say is that AirCell used the 200-mW limit in its analyses to demonstrate to the FCC the feasibility of cross-duplexed spectrum sharing, but actual implementation for broadband services is another matter.[2]

Unfortunately, the explanation is once again incomplete, as [6] fails to explain what "straightforward network engineering" measures would be used to achieve the higher rates. Moreover, AirCell does *not* claim here that the 200 mW EIRP would be adequate to support 1xEV-DO rev A.

Again, Telcordia's point is that (1) high speed data transmissions will require significantly higher reverse link EIRP than the 200 mW assumed and proposed by AirCell, and (2) higher reverse link EIRP will increase air-to-air interference with cross-duplexed systems and cause forward link degradation as shown in [2]. AirCell has effectively conceded the second point with its proposed limits in [8], and the first point is easily verified with simple calculations such as that given above.

Spectrum Sharing using Polarization Isolation

In [4], AirCell proposed polarization isolation as an additional spectrum sharing scheme for the ATG bands, whereby one system would use vertical polarization and the other would use horizontal polarization. AirCell proposed in [4] that by using both cross-polarization and cross-duplexing, four ATG providers could share the bands. AirCell provided an analysis of two cross-polarized ATG systems in [4], assuming that the polarization isolation between the two systems was 12 dB, and justifying this number by referring to a flight test report [7].

In [5], Telcordia noted that a detailed review of [7] "revealed no basis whatsoever for assuming 12 dB polarization isolation, or any other value. . . . The report does not provide any data about polarization isolation, nor are any conclusions about polarization isolation values given in the text, summary, or conclusions" ([5], p. 15).

This is a key issue, in that the degree of polarization isolation that can be achieved in practice determines whether or not the concept is even worth considering. The only mention of this issue in [6] is a single sentence: "In fact measurements performed by AirCell [reference to Proprietary Data, AirCell, Inc.], clearly shows that the 12 dB cross-polarization isolation is valid." Skepticism toward this claim, based on proprietary AirCell data that apparently exists but has not been disclosed, might be considered

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[2] This naturally raises the question of why realistic implementation parameters should not be incorporated into the interference analysis.

understandable, given AirCell's earlier claim that the 12 dB isolation was supported by [7], which now does not seem to be the case.

While orthogonal polarizations can be used in some controlled-path situations such as fixed terrestrial microwave radio, the aeronautical propagation path is affected by the climbing, descent, and turning of the aircraft, as well as ground reflections. These factors can alter the polarization of the signal being transmitted, as well as the polarization discrimination of the receiver, reducing or eliminating the polarization isolation. Further, it is impractical to reduce transmit power to compensate for a loss in polarization isolation as suggested by AirCell [8]. This would require a mechanism for monitoring the polarization isolation and feeding the monitored level back to transmitters. The base stations and aircraft receivers themselves could be used as monitors, but then each would need to receive both polarizations and generate a power control feedback signal based on the comparison of the power received on the two polarizations. Even with such an arrangement, the polarization isolation as seen by a victim receiver generally will be different than that seen by a monitoring receiver, which is at a different location and has a different "view" of the transmit antenna.

Telcordia also noted that:

> Even taking AirCell's results at face value, those results show that with two cross-polarized systems sharing the ATG bands, the reverse link noise rise can be extremely large (up to 25 dB), whereas normal system design practice would limit it to around 6 dB for dynamic range and system stability reasons. ([5], p. 3)

AirCell's response in [6] does not address this issue at all, even though it seems to make implementation of crossed-polarization sharing completely impractical, and the results cited are based on AirCell's own analysis.

Telcordia also observed in [5] that although AirCell proposed a four-system sharing scenario in [4], it only actually analyzed the coexistence of two systems using crossed polarization, leaving some significant questions about a four-system scenario unanswered, such as interference interactions among the four systems, and four-system base station placement and coordination ([5], pp. 2, 10-13, 19-20). On pp. 11-12 of [5], Telcordia provided a specific example of the potential for four-system interaction, and concluded:

> It is clear from this example that the potential for coexistence of four systems under AirCell's most recent proposal cannot adequately be evaluated by pairwise analysis (one pair of cross-duplexed, co-polarized systems and a separately-analyzed pair of co-duplexed, cross-polarized systems), because that approach ignores coupling effects. The interactions of all four systems must be considered jointly. ([5], p. 13).

AirCell's only response in [6] on this issue is the unsupported statement:

> The interaction between systems is minimal. For the sake of clarity the results are presented just for pair [*sic*] of systems operating as co-duplexed and cross-polarized. AirCell simulator [*sic*] simulates all four systems and it was used to determine that the coupling is essentially non-existent. ([6], pp. 8-9).

AirCell does not address the example of four-system interaction provided by Telcordia.

In summary, [6] provides no new information at all on viability of ATG spectrum sharing using crossed polarization, and does not address the points raised by Telcordia in [5].

CDMA Reverse Link Capacity Formula

In Annex B of [2], Telcordia developed the relationship between CDMA reverse link capacity and the noise rise, and noted in passing that the reverse link capacity relationship developed by AirCell in [1] had a minor error. In [3], AirCell responded that Telcordia's interpretation of the parameter I_{adj} in the AirCell formula was incorrect (AirCell had not provided a mathematical definition of this term in [1]). In [3], AirCell proposed a mathematical definition of I_{adj} and stated that with this definition, "the analysis of the pole point provided by Telcordia is accurate and essentially identical to AirCell's analysis." ([3], p. 7). In [5] Telcordia showed that in fact the AirCell and Telcordia formulations are not equivalent, because I_{adj} as defined in [3] is not a constant, but depends on the reverse link load. Telcordia showed that "when the final steps of the analysis (omitted by AirCell in [3] are taken, it is clear that the AirCell formulation is not equivalent to the Telcordia formulation." ([5], p. 9).

Instead of responding to Telcordia's analysis in [5], AirCell in [6] has simply repeated its material from [3], but adding a pair of equations in an intermediate steps that admittedly involve "trivial algebraic manipulations that can be easily reconstructed." ([6], p. 6). Telcordia's comment, as was explained quite clearly in [5], applied to *additional* steps in the analysis that would occur *after* AirCell's final equation in [3] (eq. 3.10), which is the same as AirCell's final equation of [6] (eq. 13). Telcordia's eq. (6) in [5] is identical to these two equations, but then Telcordia extends the analysis beyond that point with eqs. (7) – (9) in [5], to demonstrate its point, which AirCell has failed to address in [6].

Conclusion

While [6] purports to refute Telcordia's conclusions, the detailed examination provided here shows that in fact, it does not. The concluding section of [6] attempts to make three summary points (shown here in italics):

- "*Telcordia has failed to point out and subsequently substantiate any flaws in the AirCell two systems [sic] proposal in [1] and the AirCell four-system proposal in [[4]].*" **As can be seen by reading [2] and [5], as well as the discussion above, this statement is completely untrue. Telcordia has pointed out and substantiated a number of flaws in AirCell's proposals.**
- *"Telcordia has been repeating its unsubstantiated claims many times without providing any evidence/data/simulations to back up its position."* **Again, this is**

obviously false, as detailed simulations were documented in [2]. To help remind AirCell about the ATG path variability, some of its own "data" have been reproduced here.

- *"Telcordia has failed to support Airfone's claim to providing truly broadband systems under Airfone's proposed one service provider model using details simulations/data."* **This comment suggests that AirCell did not understand Telcordia's simulations, which showed performance degradation to one system as a function of the aircraft transmitter deployment on the other system. The one-provider case corresponds to the baseline (no interfering aircraft), which is clearly shown on the graphs presenting the results.**

AirCell's purported refutations of [5] are groundless.

It also is worth noting that AirCell has failed to answer a number of key questions, including:

- How can broadband ATG transmissions can be supported on a reverse link that is limited to 200 mW EIRP?
- How can the problem of interference between cross-duplexed base stations in the airport scenario be solved?
- What measurement data support the contention that a 12 dB polarization isolation can be reliably maintained?
- How would base station locations and coordination be managed in a 4-provider sharing scenario?
- How can the excessive noise rise (indicated by AirCell's own results in [4]) at the base stations with crossed polarization sharing be realistically managed in the airport scenario?

Even though these issues were raised in [5], AirCell in [6] failed to take the opportunity to add meaningful information to the record by addressing them.

In sum, Telcordia has shown that the multi-system sharing schemes proposed in this proceeding are not practical. These proposals would subject users to extensive interference and fail to provide reliable broadband service.

References

[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] Jay E. Padgett, "Response to Recent AirCell Filing and Summary Comments on AirCell Proposals, August 16, 2004, WT Docket 03-103.

[6] A. Chari and V. Tarokh, "Response to Telcordia Technologies Comments on AirCell Proposal, September 10, 2004, WT Docket 03-103.

[7] C. J. Hall and I. Kostanic, *Final Report of AirCell Flight Tests,* TEC Cellular, July 10-11, 1997.

[8] "AirCell Response to FCC Questions," September 9, 2004, WT Docket 03-103.

[9] FCC Public Notice, DA 98-2394, November 25, 1998, pp. 3-6.

[10] Qualcomm, Inc., "1xEV: 1xEVolution, IS-856 TIA/EIA Standard Airlink Overview," rev. 7.2, Nov. 7, 2001, www.qualcomm.com/technology/1xev-do.

[11] Qualcomm, Inc., "IS-856 Revision A and EV-DO Enhancements," available at www.qualcomm.com/technology/1xev-do/enhancements.html.

[12] P. Bender, *et al*, "CDMA/HDR: A Bandwidth-Efficient High Speed Wireless Data Service for Nomadic Users," *IEEE Communications Magazine*, July 2000, pp. 70-77.