Report of Working Group A: Compatibility and Interoperability

1. The International Committee on Global Navigation Satellite Systems (ICG) Working Group A (WG-A) on Compatibility and Interoperability met Tuesday through Thursday, October 19-21 under the co-chairmanship of Ms. Tatyana Mirgorodskaya, Russian Federation, and Mr. David Turner, United States of America.

2. After brief welcoming remarks, Ms. Mirgorodskaya explained that she would be acting as co-chair on behalf of Mr. Sergey Revnivykh due to his unavoidable need to return to Moscow. Responding to suggestions from the Providers Forum co-chairs, Mr. Turner then pointed out the spectrum protection and interference detection and mitigation was an area of the groups work plan that has not received as much attention as other areas. As a result, the agenda was modified to cover this area of the workplan first, and the possibility of a subgroup to address this issue was raised. The Russian delegation noted the importance of this topic and stated they would play a strong role. After a discussion regarding the planned coverage of this subject as it applies directly to receivers within the ICG Working Group B (WG-B), the Chairs stated that there would be no duplication of effort and proposed to draft a recommendation to establish a subgroup on interference detection and mitigation under WG-A for final review and approval by the ICG on Thursday, 21 October 2010.

3. The Co-Chairs then turned to the original first item on the agenda, a report of efforts to collect user community and industry views on interoperability. Mr. Turner, presented the work of the group to date in this area, stating that the effort has been part of WG-A's task since before the official formation of the ICG in 2006. However, the focus was changed from the Providers to the User Community, applications and manufacturers. Two workshops were conducted since ICG-3 (2008), giving providers, industry, and user communities the chance to provide their views. Findings from these workshops indicate that there is clear interest in using multiple GNSS.

4. The effort has also focused on the collection of information through questionnaires. To date there have been 34 responses to the questionnaire. From these responses, it is possible to conclude that the ICG Principle of Interoperability and its definition appears to be sufficient and valid from a users perspective. Benefits of interoperability were confirmed, and priorities include common frequencies, common time scale, common reference frames. Service-related assurances were also viewed as important by most respondents. Beyond these statements, it is difficult to draw more detailed conclusions, expect that if decided that this activity should continue, the focus should shift to direct interviews rather than paper questionnaires. These interviews will need to address specific questions that account for the fact that the opportunity for system providers to make significant changes is disappearing very quickly, and the benefits of a common center frequency must eventually be weighed against the benefits of frequency diversity to ensure radio- frequency (RF) compatibility and improved robustness with respect to potential interference.

5. At the conclusion of the presentation, Mr. Turner stated that each system provider should indicate whether or not this or another questionnaire will affect their signal plans, documentation plans, or system commitments and proposed options for the way ahead, including ending the current survey effort or changing the effort and its process to better serve system provider interests.

6. A member of the working group from the Chinese delegation suggested that a decision on this could not be made by them because the presentation material was not provided in advance of the meeting and they would prefer time to translate into Chinese. One of the U.S. representatives then stated that the survey provided value, and recommended that the idea of re-focusing the questionnaire to better account for the likely interests and plans of the Providers. Mr. Chris Rizos, the International GNSS Service (IGS) representative, then suggested that it might be useful to hold a "user summit". Mr. Turner responded by stating that this may be a challenging endeavor, given the experience of the Co-Chairs in attempting to already hold two workshops where it proved difficult to achieve widespread attendance from users all round the world. A Russian member of

the working group then commented that Russia is very interested in the process because they are developing their system to serve users, and receiving additional input from users would be valuable to their design plans. So the process should be continued, but updated. Mr. Turner then stated that it appeared a recommendation for another subgroup to pursue this objective may be in order.

7. Turning to the subject of system time and geodetic reference systems in relationship to interoperability, the Co-Chairs invited Mr. Matt Higgins, the International Federation of Surveyors (FIG), and Ms. Felicitas Arias, International Bureau of Weights and Measures (BIPM), both members of the ICG Working Group D (WG-D), to make short relevant presentations. Mr. Higgins focused on the International Terrestrial Reference Frame (ITRF) and its differences with World Geodetic Systems 84 (WGS84), making the following points:

    - As of 1 January 2002, the two systems agreed to within about a cm in Australia. However, because of plate motion of about 7 cm per year, the difference is now on the order of 63 cm.
    - Between the Geocentric Datum of Australia and WGS84, there is 112 cm of difference.
    - Now that it is becoming possible to achieve point positions in survey and geodesy to millimeter levels of accuracy, these differences become quite visible. However, various organizations are beginning to address the problem.

8. Mr. Higgins then suggested that each provider in attendance consider completing the geodetic reference frame description template provided by WG-D. These templates had been circulated by WG-D prior to the meeting, but were to be handed out again during their discussions the following day. A Chinese delegate noted that they had completed the template, but had not yet been submitted to WG-D. They planned to present their views on this the next day within WG-D. A member of the working group then suggested that providers include tectonics in maintaining their respective system reference frames or in other words, the time varying aspect of geodetic reference frames should be accounted for by the providers. Mr. Turner stated that there may be a need for further discussion of this aspect of interoperability, but it should be pursued by WG-D rather than WG-A.

9. Ms. Arias then made a presentation that illustrated the differences between Coordinated Universal Time (UTC), International Atomic Time (TAI), Global Positioning System (GPS) time, and Galileo time. She made the following observations:

    - TAI is not a disseminated time reference.
    - GPS is steered to the United States Naval Observatory timescale (UTC USNO), and GLONASS decided to also steer its system time to a national UTC reference time.
    - Compass time is offset from GPS and Galileo.
    - The differences between these time frames should be understood.
    - At the next World Radiocommunication Conference (WRC) it may be decided to eliminate leap seconds from UTC.

10. At the conclusion of the briefing, it was noted that there is also a WG-D time reference template as well as a geodetic reference template from WG-D. The question that remains, is what more can and should be done to support interoperability. As a result, Mr. Turner strongly encouraged representatives of each Global Navigation Satellite System (GNSS) provider to attend the working group on time and on geodesy to address this question.

11. The next topic under the interoperability work area was an update on the Asia-Oceania Multi-GNSS demonstration campaign (MGA) by Mr. Satoshi Kogure of the Japan Aerospace Exploration Agency (JAXA). Moving directly to the next steps chart of the presentation made previously at the Providers Forum, he proposes more frequent activity reports to and discussions

with the ICG and Providers Forum at both annual and intercessional meetings, and invited the co-chairs of ICG WG-A and WG-D to be members of the MGA steering committee. He also requested more participation in the activities of the MGA and contributions to the project from all providers and the GNSS industry.

12. Ms. Ruth Neilan stated that the IGS will participate in the MGA and also expects similar projects focused on multi-GNSS demonstration activities to be in initiated in other parts of the world. Mr. Higgins then mentioned the upcoming MGA workshop in Melbourne associated with the 17th meeting of the Asia-Pacific Regional Space Agency Forum (APRSAF) and offered the support of the Australian Government for hosting and facilitating bilateral discussions during theses events. Co-Chair Mr. Turner then asked if Providers would recommend and support outreach to their industries to request participation in the MGA. Positive responses were received from the European Union (EU), U.S. and Russian Federation working group members.

13. The remainder of the session on interoperability comprised of three presentations from working group members. First, Ms. Xiaochun Lu, National Time Service Center, Chinese Academy of Sciences, presented a perspective on interoperability beginning with the ICG definition and moving quickly to signal design issues, and an algorithm developed to quantitatively evaluate interoperability based on weighing receiver cost against improvement in performance. Regarding signal design, she discussed carrier frequency, modulation, code, and message. Using the algorithm, Ms. Lu illustrated that signals from two different systems with all parameters in common had the best interoperability rating, whereas uncommon carrier frequencies had the lowest ratio. In every case, however, the ratio appeared to be positive.

14. The next presentation, focused on GNSS Time Interoperability, was made by Dr. Arcady Tyuylyakov & Dr. Alexey Pokhaznikov of the Russian Institute of Radionavigation and Time. They discussed efforts that are under way to reduce the offset between GLONASS time and the Russian realization of UTC, known as UTC(SU). They also characterized the current difference between GLONASS time and GPS time which is 30 ns, and plans to eventually reduce this to 2 ns. Mr. Tyuylyakov and Mr. Pokhaznikov also expressed the view that progress is being made in this area of interoperability, although it is currently necessary to have multiple offset corrections for the several GNSS. Their last chart illustrated a possible future scenario where a virtual (hypothetical) UTC based on a large ensemble of time standards of various types exists, which each individual national system time could be aligned to. Therefore, all corrections to on-board clocks would be calculated relative to a single time scale and transmitted synchronously by multiple spacecraft belonging to multiple constellations.

15. Finally, Mr. Matteo Paonni of the Institute of Geodesy and Navigation, University FAF Munich, Germany, presented a perspective on the sharing of a common frequency among multiple GNSS using the multiplexed common baseline signal (MBOC) modulation focused on impacts to the spectrum band noise floor. Through simulation, his research group weighed the value of multiple constellations broadcasting the same signal based on improving geometry (DOP or dilution of precision) against increases in interference.

16. Mr. Paonni concluded that there is only a small improvement in DOP for more than 3 constellations, yet the increase in the noise floor could cause harmful problems for the acquisition of many satellites. To limit this problem, he and his colleagues propose that apportionment of the noise floor is an important criterion that should be discussed, since compatibility is a fundamental prerequisite to achieving interoperability.

17. At the conclusion of the presentation, Mr. Greg Turetzky of CSR noted that manufacturers may be forced to track every satellite in view in order to compensate for cross-correlation interference, even if some of the signals are not actually of interest. Another member of the U.S. delegation then asked if the simulation and analysis addressed the scenario where a user is in a difficult sky view situation where significant signal blockage exists. Multiple interoperable systems would be especially beneficial in this scenario. Mr. Paonni stated that this situation will be considered.

18. This final presentation and the subsequent discussion created an excellent natural transition to the next topic area on the agenda, focused on GNSS compatibility. Mr. Turner began this session by providing the group with a brief report on the June Compatibility Workshop conducted on behalf of the system providers. He mentioned the following results:

    - Workshop participants concurred with the current ICG Principle of Compatibility and its definition without change
    - A Subgroup of WG-A (Providers-only) was formed to investigate organizational models relevant to multilateral coordination of GNSS compatibility. Examples include the Space Frequency Coordination Group (SFCG) and the Mobile Satellite Service (MSS) Operators Review Meeting
    - A system assumptions template was discussed and possible criteria and methodology for multilateral compatibility analysis presented. The Co-chairs of the workshop welcomed informal inputs from each Provider on the template, but the subgroup will be the focus of WG-A compatibility activity in preparation for ICG-5 (2010).

19. The report of the Sub-group on Organizational Models and Procedures for Multilateral Coordination of GNSS Compatibility was then presented by Mr. Takahiro Mitome and Mr. Fredric Bastide. They covered the following main points:

    - The main question is whether frequency coordination should be conducted only on a bilateral basis, as now, or should also be a multilateral process.
    - The scope of a possible multilateral process should be limited to civil signals such as those in the L1/B1/E1 and L5/B2/E5 bands.
    - Should ICG agreements be binding on the participants?
    - It may be desirable to study the appropriate limit on increasing the noise floor and potentially avoid an unnecessary increase in the number of satellites.
    - An international regulatory body is also, by definition, a standards-setting body.
    - A definitive conclusion on a multilateral coordination framework has not been reached.
    - International Standard have “power”. Some standards are de facto and others are de jure.

        - De jure standards can be treaty based. Forum standards can be based on industry agreements. A de facto standard can be established by one entity on its own, such as “Windows”.

    - In the International Telecommunication Union (ITU), all coordination is conducted on a bilateral basis and ITU Radiocommunication Sector (ITU-R) recommendations establish an international standard for coordination.
    - The question remains as to whether there should be a mandate for additional regulation.

20. The presenters concluded by proposing that before any decisions are taken, a more detailed investigation should be conducted on the need and scope of a multilateral coordination process. A member from the Russian Federation then commented that WG-A should use the term “Consultations” rather than “Coordination” when discussing a possible multilateral process. Hearing that there is really no distinction between the two words when translated into Chinese, the working group settled on the term “discussions”.

21. Mr. Attila Matas, observer from the ITU radio bureau staff, noted that the ITU would not likely recognize an input from the ICG, but later noted that this may be slightly overstated, since as other working group members pointed out, other informal inputs are considered in certain circumstances. After further discussion and viewpoints expressing concern over prematurely endorsing the need for multilateral compatibility discussions, Mr. Turner proposed that a

recommendation be drafted for further WG-A consideration before adoption that would simply continue the subgroups investigation focusing on defining the needs and the scope of multilateral discussions on GNSS compatibility, continuing the study of appropriate organizational models and assessing their applicability to GNSS, and then selecting the most relevant models and the appropriate role of the ICG.

22. Next several presentations were made by members focused on their delegations views of compatibility or specific aspects of compatibility. First, views on multi-lateral compatibility coordination were provided by Dr. Lu Jun of the China Satellite Navigation Office. Her presentation included the following points:

- GNSS compatibility is critical and the ICG is seeking its role and a way forward. The purpose of ICG is to promote cooperation related to civil GNSS
- Furthermore, it is a voluntary body and recommendations will be decided on a consensus basis, not on a legal basis or in pursuit of mandates
- Discussions should be focused on open signals and other signals should be addressed through bilateral discussions.
- The use of similar link budgets, common max and min received power, receiver models, minimum receiver C/N0 and reasonable protection thresholds for compatibility analysis is recommended, and international standards could be of general benefit.
- Multilateral coordination could complicate the issue.

23. The presentation also included some numerical values for contributions to the noise floor made by GPS, Galileo, and COMPASS, with the conclusion that each system makes comparable contributions within 0.7 dB of each other. Furthermore, having three full constellations versus one or two adds significant value from the perspective greater satellite visibility and signal availability, according to figures presented.

24. The presentation spurred a healthy debate within the working group, focused primarily on the European delegations view that multilateral compatibility discussions should include consideration of authorized signals and their concern that authorized signals were excluded from the noise floor calculations shown. While not directly taking sides in the debate, other members of the working group pointed out that all signals are addressed in bilateral compatibility coordination completed through the ITU process, and what is important is for all providers to share the correct signal parameters for their systems with all other providers.

25. The next presentation was from Dr. John Betz of the U.S. delegation, focused on GNSS compatibility link budget conventions. He made the following points:

- Each GNSS is a potential source of interference to other systems
- Maximum received signal power is the critical parameter to evaluating compatibility
- Agreement on the same parameters for defining maximum received power is recommended

26. Dr. Betz moved quickly through the detail in his briefing and skipped a number of charts in order to quickly present the conclusion that the proposed link budget convention for compatibility analysis can be expressed by a simple equation based on maximum RF transmit power, satellite antenna gain, and free space loss. Nevertheless, a number of fairly specific questions about the technical assumptions made were asked working group members. These were addressed to the apparent satisfaction of most members, with the exception of the European delegates, who stated that compatibility can only be assessed by considering both maximum and minimum received power levels. Mr. Turner closed this discussion by proposing that an attempt be made to draft a recommendation on common assumptions for compatibility analysis that would receive further discussion before a decision is made to propose it to the full committee.

27. Finally, the EU's views of GNSS Compatibility were presented by Mr. Frederic Bastide of the European Commission. His briefing included the following highlights:

    - Interoperability should only be promoted if compatibility is assured
    - Compatibility should respect national security concerns
    - The EU has not been able to achieve enough spectral separation in the E1/L1 and E6 frequency bands. Because of many systems in these bands, there are compatibility concerns.
    - When considering a hypothetical relationship between systems A, B, and C, what happens if A and B and A and C achieve coordination, but B and C do not? What happens if coordination is not possible?
    - It is recommended that the ICG decide how to resolve the problem, as the only forum where all parties can meet together.
    - ITU regulations suggest that multilateral discussions may be needed or useful.
    - Should a "code of good conduct" be promoted by the ICG that could be employed with future system requests?

28. The presentation initiated a healthy debate with members of the European delegation, members of the Chinese delegation, and Mr. Matas of the ITU Radio Bureau all weighing in, but without a clear consensus on the questions raised by the EU. Eventually, Mr. Turner suggested that the group should review the current language in the WG-A work plan with respect to compatibility, and proceed accordingly. He then closed the day's meeting by encouraging members to attend the WG-D meeting on the following day, and reminded the group that they would also convene later that afternoon.

29. On the next day, 20 October 2010, the session on GNSS compatibility continued when the group reconvened and proposed recommendation for adoption of common reference assumptions for signal characteristics. The debate was lengthy, but a possible recommendation was completed that the group agreed to consider along with others during the final session of the meeting.

30. The session on Service Transparency and Performance Monitoring began with Mr. Turner quickly reviewing this area of the WG-A work plan, and suggesting that progress is being made by the ICG in the pursuit of better open service provision. First, the Providers Forum was established, followed by agreement on principles of compatibility, interoperability, and transparency. Since ICG-4 (2009), the secretariat has successfully published a report describing their systems of all providers. The development of a template for performance standards or interface control documents, followed by consideration of service assurances and commitments, appear to be logical next steps.

31. In support of this progress, Mr. Karl Kovach of the U.S. delegation returned to a presentation made earlier in the week during the Providers Forum focused on templates for GNSS service performance commitments. He skipped through most of the charts and focused on a proposed way forward for future service providers, recommending the use of the GPS standard positioning service (SPS) performance standard (PS) as a starting point for developing draft "postulated performance standards" for each system.

32. After receiving no specific comments on the presentation, Mr. Kovach volunteered to draft Postulated Performance Standards for each system, and Mr. Turner suggested that each provider identify a point of contact for receiving the draft standards. Several working group members from system provider delegations supported this next step, but a consensus could not be reached to prepare a recommendation for the ICG consideration.

33. The next day, 21 October 2010, Working Group A met for one final session during ICG-5, to consider and approve the recommendations drafted by the Co-chairs based on the deliberations of previous sessions. Consensus was reached on six recommendations that were ultimately endorsed

by the full committee as attached. The working group also agreed to target June 2011 as the time period for their next meeting. In addition, the Co-chairs agreed to explore intercessional approaches to providing members ample opportunities to review and deliberate all planned working group activities and potential recommendations for consideration at ICG-6, in September 2011.

Working Group A
Recommendation #1 for Committee Decision

Date of Submission: October 21, 2010

Issue Title: Spectrum Protection – Interference Detection and Mitigation

Background/Brief Description of the Issue:

Proposals were made to focus on the following topics related to interference detection and mitigation:

- Preventing the availability of unlawful interference devices (jammers) in the open market
- Identification of national and international regulations on spectrum protection, their possible inconsistency and necessary improvement
- Detecting and neutralizing interference sources at the national level and the identification of possible international cooperation

The potential for a future workshop was also discussed

Discussion/Analyses:

Consensus on each topic mentioned above was not achieved. However, WG-A did reach consensus on the recommendation shown below

Recommendation of Committee Action:

- Interested members of WG-A should focus on proposals to address interference detection and mitigation and draft a study plan for consideration by the ICG
- ICG participants are asked to provide points of contact for this activity to the WG-A co-chairs as soon as possible, recognising the multidisciplinary nature of the task

Working Group A
Recommendation #2 for Committee Decision

Date of Submission: October 21, 2010

Issue Title: User Community Views on Interoperability

Background/Brief Description of the Issue:

The WG-A co-chairs presented a summary report of user community views on interoperability, with the following findings:

ICG Principle of Interoperability and its definition seems valid - No substantial changes to definition required

- Benefits of interoperability include better availability, accuracy, and ability to support Receiver Autonomous Integrity Monitoring (RAIM)
- Priorities include common carrier frequencies, common time scale & reference systems, common modulation, and collocation of reference stations
- Service-related assurances viewed as important by almost all respondents
- It is difficult to draw more detailed conclusions -many respondents did not appear to understand the underlying issues
- Interviews probably were need

Discussion/Analyses:

Each provider should now indicate if the questionnaire results could now affect their:
Existing or new signal designs; System documentation; Interface and Performance Standards; System commitments; Constellation health, sustainment policy, notifications to users; treatment of unhealthy satellites, etc.

If not, the effort should be ended. If so, the interested Providers should re-shape the survey and its process for maximum benefit. To enable this, the questionnaire responses will be made available to Providers.

Recommendation of Committee Action:

- Interested members of WG-A will develop a new approach to continued collection of user and industry views on interoperability
- Potential specific topics to include in new questionnaire:
  - Value of a common third open service signal
  - Importance of DOP improvement with the addition of 2nd, 3rd, 4th, Nth global constellation
- Plan for conducting interviews in association with the questionnaires
- Consider organizing a large user/industry summit to be attended by key technical experts

Working Group A
Recommendation #3 for Committee Decision

Date of Submission: October 21, 2010

Issue Title: Time and Geodesy Aspects of Interoperability

Background/Brief Description of the Issue:

System time and geodetic reference system aspects of GNSS interoperability were identified as priority needs by respondents to the WG-A questionnaires

Discussion/Analyses:

WG-A conducted a joint session with WG-D where representatives of WG-D made presentations focused on GNSS reference system and timing issues.

Recommendation of Committee Action:

- Continue to investigate system time and geodetic reference frame aspects of interoperability within the WG-D task forces on time and geodesy
    - First task is the completion of time and geodetic reference frame templates by all system providers
    - Other specific methods to potentially improve interoperability could be addressed afterwards
        - Inclusion of multi-constellation, multi-frequency tracking in the IGS network
        - Monitor and disseminate offsets between each system time

Working Group A
Recommendation #4 for Committee Decision

Date of Submission: October 21, 2010

Issue Title: Participation in the Multi-GNSS Demonstration Campaign

Background/Brief Description of the Issue:

A Multi-GNSS Demonstration Campaign is being sponsored by the Government of Japan with support or endorsements from many organizations, including the ICG The purpose is to test and experiment with multi-system receivers and demonstrate the benefits of interoperability between systems. Based on a presentation by Mr. Satoshi Kogure of JAXA, WG-A discussed the need to encourage participation in this campaign by companies and other interested parties.

Discussion/Analyses:

In the discussion it was generally agreed that this could be of benefit, but that it should not be a formal ICG requirement that each provider is expected to participate.

Recommendation of Committee Action:

Interested ICG participants are encouraged to interact with receiver manufacturers and encourage participation in the Asia-Oceania Multi-GNSS Demonstration Campaign as:

- An opportunity to test and experiment with multi-system receivers and demonstrate the benefits of interoperability
- Also an opportunity to develop potential new GNSS applications enabled by multiple systems
- Industry, users, and system providers should all benefit

Working Group A
Recommendation #5 for Committee Decision

Date of Submission: October 21, 2010

Issue Title: Multilateral Discussions on GNSS Compatibility

Background/Brief Description of the Issue:

In June 2010, a Providers-only workshop on compatibility was conducted and a sub-group was formed to investigate organizational models relevant to multilateral coordination of GNSS compatibility. The workshop participants also confirmed the acceptability of the current ICG Principle of Compatibility and its definition without change

Discussion/Analyses:

The findings of the sub-group were presented to WG-A on 19 October 2010. After the presentation it was proposed that some of the terminology be changed, such as the use of the word "discussions" rather than "coordination". After the discussion the WG-A agreed to the following recommendation:

Recommendation of Committee Action:

Continue the Work of the Sub-group on Organizational Models and Procedures for Multilateral ***Discussions*** on GNSS Compatibility

- Define the needs and the scope of multilateral discussions on GNSS compatibility
- Recommend continued study of appropriate organizational models
    - Assess applicability to GNSS
    - Select the most relevant models and the appropriate role of the ICG

Working Group A
Recommendation #6 for Committee Decision

Date of Submission: October 21, 2010

Issue Title: Adoption of common signal characteristics reference assumptions

Background/Brief Description of the Issue:

The GNSS community is interested in knowing the characteristics of signals from each provider. In order to make this information most useful, a set of common reference assumption would be desirable. In response to this the US delegation made a presentation suggesting ways to achieve common assumptions, regarding link budgets and maximum received power, as a step toward additional common conventions and assumptions.

Discussion/Analyses:

Because of the detailed information presented, it was decided to continue this discussion in future meetings, as per the following recommendation:

Specific maximum received power conventions discussed included:

- Transmit power equal to or greater than that needed to meet minimum received power commitments
- Conventional loss due to free space propagation
- 0 dB atmospheric loss
- 0 dBic lossless reference receive antenna
- Transmit antenna gain versus angle off nadir, as a mean value over azimuth cuts and satellites*
- Mean orbital radius for circular orbits and perigee for elliptical orbits*

On these last two points, specifically, the need for further study before reaching an agreement was emphasized

Recommendation of Committee Action:

Prepare for discussions on adoption of common reference assumptions with the following priority actions:

- Common conventions for specified maximum received power*, as a step toward additional common conventions and assumptions
- Convention for link budgets to any point on the earth's surface, when used to define maximum received power
- Definition of transmit antenna gain model

**The maximum received power is the largest of the received powers over all points on the earth's surface.*