AERONAUTICAL COMMUNICATIONS PANEL (ACP)

FOURTEENTH MEETING OF WORKING GROUP F

Malmo, Sweden 22 – 26 August 2005

FINAL REPORT

1. Introduction

1.1 The meeting was opened by Mr. Steve Mitchell, the Rapporteur of working group F. He expressed, on behalf of the Working Group, his thanks to Mr. Larry Johnsson, the member of ACP nominated by Sweden and his organization for hosting the meeting. He pointed out explicitly that the goal of this meeting was to improve on material supporting the various elements in the ICAO position but not, at this time, considering the recent approval of the ICAO position by the Council, to develop proposals for amending the ICAO position.

1.2 Larry Johnsson welcomed the working group to Malmo and provided information for improving the stay by the participants of the working group in Sweden.

1.3 The Secretary of the meeting was Mr. Robert Witzen. He also expressed his gratitude to Mr. Larry Johnsson and his organization for hosting the meeting, in particular since the time and location would facilitate for some members to also participate in the CEPT PT3 meeting, immediately after the working group F meeting. He further expressed, on behalf of ICAO, his thanks to the Federal Aviation Administration of the United States in sponsoring the participation of Mrs. Mary Obeng from the ICAO Regional Office in Dakar in this meeting. The regional representation in the activities of working group F, together with the experience contained in the Dakar Office, was an extremely welcome addition to the activities of working group F.

1.4. The Secretary gave a summary on the events that took place in ICAO since the last meeting of WG F (February 2005 in Bangkok, Thailand). Of importance to working group F were the meetings of ITU Working Parties 8B and 8D in April, the Meeting of the ACP working group of the Whole in June 2005 and the adoption of the ICAO position by the Council on 14 June 2005. A State Letter has been sent on 12 August to all ICAO Contracting States and relevant international organizations.

1.4 The Secretary further pointed out, in relation to material submitted to the ACP working group of the Whole, that, in accordance with the Directives for panels of the Air

Navigation Commission (Doc. 7984/4), members are participating in their personal, expert capacity and [are] not acting as representatives of their nominators [re ICAO Contracting States or international organizations]. Members should therefore express their professional opinions and not [the] established policies or points of view of a State or international organization. He continued to inform the meeting that the goal of the meeting was to establish or improve the conditions of the use of the radio-frequency spectrum in a manner that would provide the best possible position for international civil aviation as required to secure the highest standards for the safety and regularity of international civil aviation. A secondary issue would be how to convince the radio regulators to support this position. The Secretary also noted that the ICAO goal is to complete at WRC-07 all aspects dealing with the need to provide additional spectrum to aviation for the purpose of air-ground and air-air communications (aeronautical mobile (R) service). Continuation of review of aeronautical spectrum at future conferences would most likely lead to more loss for spectrum available for civil aviation applications.

1.5 The meeting approved the agenda. The agenda is contained in Appendix A.

1.6 The list of working papers submitted for consideration by working group F in contained in Appendix B. The list of participants is in Appendix C.

1.7 In connection with the review of the various agenda items, papers that were submitted to the CEPT PT3 meeting (Copenhagen, Denmark, 29-31 August 2005) were also considered.

1.8 The ICAO Secretariat went quickly through WRC-07 Agenda Items of most importance to civil aviation. Some additional comments were provided by one participant:

WRC07-AI 1.1 – The ICAO Position supports the deletion of footnote **5.203** (for the meteorological satellite service in the band 136-137 MHz) at WRC-07. The applicability of this allocation passed on 1 January 2002. As noted in the ICAO Position this footnote does not include any country name and therefore needs to be addressed under Agenda Item 7.1. The Australian Radio Regulator has brought this to the attention of the ITU BR who has confirmed that this matter will be included in the Director's Report (Agenda Item 7.1).

WRC07-AI 1.4 – In the Chairman's Report of ITU-R WP 8F (June 2005) (Document 8F/548 Ch 5 (Att 5.8-5.9) Meeting Report of Spectrum Working Group) tables list various candidate bands for IMT-2000 including aeronautical bands. The various comments (or lack of them) need to be reviewed before the next meeting of WP 8F scheduled in October 2005.

WRC07-AI 1.13 – A method X to satisfy this Agenda Item has included the consideration of HF frequencies in AP 27 of the RR. Although the frequencies listed in AP27 (AM(R)S) of the RR are specifically excluded from the scope of AI 1.13, WGF participants need to be alert to any move to broaden the Agenda. (refer to ITU-R 8B/124, 9C/81Annex 2).

2. Agenda Item 2 – WRC-07 Agenda Item 1.5

2.1 The presentations and discussions under this agenda item revolved around 2 main topics: UAVs and the use of the 5 GHz band, mainly for the purpose of aeronautical telemetry and telecommand. .

2.2 UAV

2.2.1 The meeting agreed that when considering WRC-07 Agenda Item 1.5 there may be situations where any allocation made to the Aeronautical Mobile Service (AMS) for telemetry/telecommand might be used for safety of life (not to be confused with safety and regularity of flight as defined in the ITU Radio Regulation(RR) 1.33) purposes. It was noted that although this safety of life need may be used by aircraft for such things as fire detection, humanitarian relief etc it was not intended for direct control of the aircraft or safety and regularity of flight as defined in ITU RR # 1.33. Additionally, the meeting noted that this initially appears to be in contradiction with the opening statement of the ICAO position on WRC-07 Agenda Item 1.5 and that some modification of an editorial nature in the position may be needed in the future.

2.2.2 Additionally, it was noted and agreed that where there is a need for controlling of UAVs using telemetry/telecommand in ATS airspace then an Aeronautical Mobile (Route) Service (AM(R)S) allocation will be required. It was further noted that such an allocation could be sought through either WRC-07 Agenda Item 1.5 or 1.6.

2.3. 5 GHz band

2.3.1 With regard to the requirement for using the bands 5030-5091 MHz and 5091-5150 MHz by the MLS, the meeting agreed that, primarily, these bands should be available primarily for the MLS. It was agreed that any co-frequency sharing with MLS would not be acceptable (this view was also expressed by the NSP). In relation to the suggested use of the 5091-5150 MHz band for aeronautical telemetry applications, it was agreed that any allocation for the purpose of aeronautical telemetry should be made on a secondary basis. In addition, any use of the MLS extension band (5091-5150 MHz) needs to be considered together with RR 5.444 and 5.444A (noting that 5.444A only refers to sharing of this band with the fixed satellite service and could, in the future, include provisions for other allocations for UAV purposes). Finally, any new allocation for AMS should include provisions instructing the ITU-R to develop appropriate material that would secure protection of the MLS. Compatibility aspects between AM(R)S and MLS would be addressed within ICAO. The meeting also identified the bands 5010-5030 MHz as 5150-5250 MHz as possible candidates for use by any allocation for AM(R)S and/or AMS.

2.3.2 The meeting considered a proposal to evaluate the need for MLS frequency assignments. Various comments were made on this proposal. It was agreed that a simulation intending to establish MLS spectrum requirements should be primarily based upon requirements put forward by ICAO Contracting States (See note secretary below). In addition, the criteria used in a frequency assignment planning exercise should be those contained in:

a. Annex 10, Volume I [and 5 as appropriate] and include the most recent amendments as proposed for incorporation in Annex 10, Volume I;

b Appendix D (MLS Protection Criteria For 3rd and Subsequent Adjacent Channels - Interpretation of the Proposed Changes To Annex 10);

c. Appendix E (Evaluation of the spectrum requirements for MLS);

d. Appendix F (ICAO State letter; Ref.: AN 711.3.87-0513 21 January 2005; Subject: Proposal for the amendment of Annex 10, Volume I, concerning instrument landing system (ILS), distance measuring equipment (DME) and microwave landing system (MLS)) to this report refer);

e. Appendix G (Extract from EUR Frequency Management Manual); and

f. Appendix H (MLS spectrum issues validation, NSP)

2.3.3.1 Although deviation from the relevant SARPs may be acceptable for statistical purposes, coordination with the NSP and/or the feasibility of developing amendments to these SARPs need to be primarily coordinated with the NSP, followed by coordination with the ANC and ICAO contracting States as required.

2.3.3.2 The meeting agreed to create a small e-mail coordination group, consisting of the Rapporteur of WG F, the Secretaries of ACP, the Secretary of the NSP (if available), Alain Delrieu, and Mike Biggs to finally establish the condition for these simulation activities. The meeting also noted (re. Appendix F) the consequences in terms of frequency assignment planning of the recently proposed amendments to Annex 10 (see Appendix G; EXCTRACT of EUR Doc 011; EUR FREQUENCY MANAGEMENT MANUAL. *NOTE:* This appendix to the report of ACP WG F-14 contains the planning criteria used in the EUR Region for DME and MLS. The criteria for MLS need to be updated in the light of the revisions to Annex 10 as proposed in State letter AN 7.1.3.87-05.3 from 21 January 2005). (see Appendix F)

Note Secretary: *It was confirmed after the meeting that the spectrum simulation that was offered by one Administration could only be based on a generic removal of all MLS CAT I requirements. The Secretary notes that such a limitation is not acceptable, since it would not be in conformity with the requirements put forward by Administrations.*

2.3.4 The current draft CPM text is including proposals to study and use the band 5030-5091 (MLS-band and MLS-extension band) for an allocation that could satisfy the aeronautical telemetry requirements, primarily generated in Region 1, of 60 MHz (5 channels of 12 MHz each).

2.3.4.1 Of relevance is ITU Document 150 from France, which contains a method for determining the coordination distances between MLS equipped aircraft and transmitters for aeronautical telemetry. This method is challenged by ICAO since it assumes a homogeneous distribution of the interfering signal over the total bandwidth of a 12 MHz channel bandwidth. Furthermore, any atmospheric attenuation does not necessarily provide for a calculation of a separation distance greater than in the example (See Rec. ITU-R P.525) Decrease of the protection distance, as recommended in this method, on a case-by-case basis between administrations concerned is not supported by ICAO. Furthermore, the MLS receiver has a broad R/F bandwidth in the first stage of the receiver. As a result, the separation distances offered (577 km in the co-frequency case) need to be verified.

2.3.4.2 The ICAO position includes no changes to the frequency band 5030-5091 MHz (MLS). This includes no allocation, even on a secondary basis, to any service in this band. With regard to any sharing with ARNS, the principle supported by the Secretariat is that, where possible, through partitioning of the ARNS band, spectrum could be made available for AM(R)S usage (and, where possible, with AMS on a secondary basis, e.g. in the MLS extension band). No actual real time sharing between ARNS and AM(R)S is anticipated, in order to protect the ARNS under all circumstances.

2.3.4.3 The working group CNTSG of the NSP reviewed this material and provide the following comments concerning the proposed use of the MLS bands for non-safety related aeronautical telecommand and telemetry systems:

2.3.4.4 If this proposal is accepted, the MLS system, operating under an allocation for the aeronautical radionavigation service, which is a safety-of-life service (RR1.59) will rely on frequency coordination between the MLS service providers and the telecommand and telemetry services operators. The review of an example of telemetry service requiring up to 577 km of geographical separation between one telemetry channel transmitter and up to 40 MLS channels ground systems and 45 km of geographical separation between any telemetry channel transmitter and all MLS ground stations shows the complexity of the frequency coordination and the huge foreseen restrictions on the telemetry service use that will result of it as long as several MLS systems will be planned. In addition, the mobile aspect of these services is introducing a new threat on safety-of-life MLS service as the safety of the MLS landings will rely on an impossible-to-check guarantee that the mobile element will not transmit outside the allowed coverage volume.

2.3.4.5 Further technical details of the proposed telemetry service was not provided to the group and therefore not examined but the group considers that the sharing of safety-of-life service frequency band with non-ICAO standardized service will create a precedent which is not encouraged.

Note Secretary: *After closure of the meeting, as a result of coordination with Mr. Robert Kruger, Secretary of the European frequency Management Group (FMG) of the European Air Navigation Planning Group (EANPG) it was agreed that the EUR Office would undertake, through a State letter from the European Office, to request ICAO Contracting States in the EUR Region and adjacent States, to re-submit their requirements for MLS assignments. In particular their view would be sought on the need to keep MLS Category I requirements in the plan. In this regard it was indicated by ICAO that use of GNSS for Category one approach and landing in the near future is not expected. Coordination with Eurocontrol on their medium/long term plans for the need to keep MLS assignments available (including MLS Category I) as they can be stated today was also considered essential. Similarly, the views of States from other ICAO Regions may be sought with regard to their MLS requirements, in particular for the medium and long future. The Secretary would undertake the necessary coordination with ICAO Regional Offices.*

3. Agenda Item 3 – WRC-07 Agenda Item 1.6

3.1 It was noted by the meeting that it was only possible to meet the needs of AM(R)S in Europe up until at least 2016 by a full role out of 8.33 kHz channel spacing. Additionally, while the current rate of implementation of 8.33 kHz appears to be low, it can be shown that this is fully in line with airspace sectors that have initially been targeted.

3.2 The meeting noted that although options for a new AM(R)S system is currently being developed and considered within ACP WG-C, details of the final system may not be available for WRC-07. Additionally, given that full implementation of 8.33 kHz only provides sufficient capacity until approximately 2016, the meeting agreed that additional allocation(s) must be made at WRC-07 in order to introduce any new AM(R)S system within an appropriate timeframe, even if the details of such new systems were still being developed.

3.3 Information was provided on studies being undertaken on a possible future AM(R)S system in the frequency band 960 – 977 MHz and on board interference scenarios resulting from such a system. It was suggested by the meeting that the frequency range should be extended since there are potentially more opportunities for an allocation in the frequency band 960 – 1215 MHz rather than currently is being proposed. The meeting also suggested that the interference scenarios should be made available to the NSP as well as the ACP WG-C for comment. (see Appendices I and J)

3.4 An update was provided on a model that is being developed for a ground based airport wireless in the frequency band 5091 – 5150 MHz. It was stated that it was intended to bring a final solution, which will be completed in conjunction with RTCA, into ICAO for standardization. On the basis of this information (Appendix K) further spectrum requirements are being developed in the context of the agenda item 1.6 of WRC-07 and will be available by middle 2006.

3.5 The meeting considered material on the possibility of re-farming of VOR in order to accommodate legacy AM(R)S systems. Although theoretically from a spectrum perspective the results suggest that re-farming may be possible, a number of issues were unclear from the work undertaken regarding associated DME re-farming and additional some practical issues were also raised on VOR technical capabilities and institutional implementation. Further clarification of these issues, relating to the protection of DME channels paired with the new VOR assignments in the simulation activity, the protection of already assigned DME channels which are associated with MLS, sub-banding of VOR system (only re-tuneable within a small frequency range of about 3-4 MHz)and institutional aspects was considered necessary. Such information could not be made available during the meeting.

3.6 A package of material was presented for information on an aviation spectrum roadmap, UAV requirements, security and frequency band suitability. The information provided in this package provided led to suggested CPM text changes. Unfortunately it was not possible to discuss the proposed text changes as the revision marks had been removed from the proposal.

4 Agenda item 4 - Regional Radio Regulatory WRC-07 preparatory meetings

4.1 Under this agenda item the meeting reviewed various working papers that were submitted to the meeting of CEPT PT3, which had arranged for a meeting from 29-30 August, specifically for WRC agenda items 1.5 and 1.6. The meeting considered that these papers, in particular with respect to the future use of the 5 GHz band, had not considered the ICAO position. The papers considered only the future use of the MLS bands in relation to the use of this band for aeronautical telemetry. No consideration was given to the use of this band by the AM(R)S and the proposals to share this band, on a co-frequency basis between aeronautical telemetry and the MLS were already rejected by ICAO (both by the NSP and the ACP working group F)

5. Agenda item 5 - ITU-R Working Parties 8B and 8D

5.1 The meeting reviewed various elements of the results of the meetings of ITU Working Party 8B (16th meeting, 11-15 April 2005, Geneva, Switzerland) and Working Party 8D (17th meeting, 13-19 April 2005, Geneva, Switzerland). Comments on the results of these meetings were developed by the secretariat and reviewed by the NSP in May 2005, together with the relevant material contained in the reports of these meetings.

5.1.1 With regard to the comments from the NSP, the meeting made the following observations:

a Review of annex 4 to Working Party 8D Chairman's Report - Preliminary draft new recommendation - Protection of the radionavigation-satellite service from ultra-wideband emissions

In the absence of comments from the NSP on the material contained in this preliminary draft new Recommendation, it was assumed that the information contained therein is correct and satisfies the aviation requirements for the protection for RNSS operating in the bands 1164-1215 MHz, [1215-1300 MHz] and 1559-1610 MHz.

b Review of annex 6 to Working Party 8D Chairman's Report - Preliminary draft new Recommendation ITU-R M.[CHAR-Rx3] - Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service operating in the band 1 164-1 215 MHz (ITU-R Questions 217/8 and 236/8)

In the absence of comments from the NSP on the material contained in this preliminary draft new Recommendation, it was assumed that the information contained therein is correct and satisfies the aviation requirements on the characteristics and protection criteria for receiving earth Stations in the radionavigation-satellite service operating in the band 1164-1215 MHz. The meeting noted that at the next meeting of working party 8D additional information, for incorporation in this Recommendation, will be provided with regard to the interference susceptibility of the RNSS receiving station for pulsed and non-pulsed (CW) interference.

c Annex 8 to Working Party 8D Chairman's Report - Preliminary draft new Recommendation ITU-R M. [1477_new] - Characteristics and protection criteria for receiving earth stations of the radionavigation-satellite service (space-to-Earth) in the band 1 559-1 610 MHz[1] (Questions ITU-R 217/8 and ITU-R 236/8)

The NSP noted with regard to this Recommendation the following:

According to PDNR/ITU-R M.[1477_NEW] "Characteristics and protection criteria for receiving earth stations of the radionavigation-satellite service (space-to-Earth) in the band 1 559-1 610 MHz", *recognizing b*), "… there are a number of receivers of GLONASS used in safety-of-life applications that process the GLONASS signals in different ways, as described in Annex 2, within the RNSS/ARNS band". Such a wording intends to cover all types of GLONASS receivers including those operating in civil aviation and in all other civil or military applications as well.

Re. 5.2.1 (i) and (ii)

In general no use of "wideband signals" in the sense of this PDNR is addressed in Annex 10, nor is there any plan to standardize those signals.

The text in *recognizing* c) of PDNR/ITU-R M. [1477_NEW] is correct. The SARPs address GLONASS CSA (Channel of Standard Accuracy) signals only, as opposed to CHA (Channel of High Accuracy) signals.

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[1] This Recommendation is intended to replace existing Recommendation ITU-R M.1477. Upon entry into force of this Recommendation, Recommendation ITU-R M.1477 should be suppressed.

It also be noted that, according to 3.7.3.2.5.2 (*Signal spectrum*) of GNSS SARPs**, "**GLONASS CSA signal power shall be contained within a ±5.75 MHz band centred on each GLONASS carrier frequency". Such a "wide band" is necessary to support operation of the GLONASS receivers fitted with correlators having narrow gates (strobes) and gates of special form. This is typical solution to meet accuracy requirements, as specified in GNSS SARPs. The term "wide-band" in *recognizing* c) refers instead to the CHA signals (not addressed in SARPs)

Re. 5.2.1 (iii)

According to GLONASS ICD (5th edition, 2002), item 3.3.1.1, beyond 2005 "…GLONASS satellites will use frequency channels K = (-7...+6).

In addition, according to PDNR/ITU-R M.[1477_NEW], Annex 2, after 2005 GLONASS receivers are also planned to operate using standard accuracy signals from SBAS-GLONASS satellites transmitting at frequencies $K = 5, ..., 9$.

Re. 5.4 (i) to (v)

It is assumed that civil aviation GLONASS receivers mentioned in 3.4 (i)–(iv) are fitted with correlators having narrow gates (strobes) and gates of special form to meet accuracy requirements, as specified in GNSS SARPs. All these receivers are also intended to operate with standard accuracy signals only.

It should not confuse extended spectrum that is necessary for operation of such correlators with wide-band signals for authorized users.

Difference in the types of GLONASS receivers mentioned in 3.4 (i)-(iv) reflects stages of implementation of GLONASS frequency plan and appropriate future augmentations.

The type of GLONASS receiver mentioned in 3.4 (v) does not relate to civil aviation applications.

Re. 5.4.1 The content of Annex 5 to PDNR ITU-R M. [1477_NEW] had been developed by GNSSP and it was considered correct.

The meeting noted that additional material on self-interference on received GNSS signal from different satellites.

The question was further raised whether the systems were intended to be used for approach or for approach and landing.

The comments from the NSP were supported by the meeting.

d. Review of Annex 9 to Working Party 8D Chairman's Report - Preliminary draft new Recommendation ITU-R M [1318_new] - Interference evaluation model for the radionavigation-satellite service systems and networks in the 1 164-1 215 MHz, [1 215-1 300 MHz [, 1 559-1 610 MHz and 5 010-5 030 MHz bands.

The NSP noted with regard to this Recommendation the following:

The (NSP) meeting did not find the language in *recommends* 2 of document 8D/TEMP/148-E acceptable because the aviation community has no control over the occurrence of interference; therefore the probability of occurrence should be assumed to be 1. The only thing that can be evaluated is the probabilistic impact of interference on aviation systems.

The meeting, noting the comments from the NSP, concurred with this view and proposed to remove recommends 2 from this Recommendation and, more explicitly, reconfirmed that taking into account the statistical nature of the probability of occurrence of interference, and changing RNSS system and/or network requirements for a given performance is not acceptable for any aeronautical system.

e Review of annex 10 to WP 8D Chairman's Report - PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R M.[1317_New] - Description of RNSS systems and networks and technical characteristics of transmitting space stations operating in RNSS systems and networks (space-to-Earth and space-to-space) in the bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz[2] (Questions ITU-R 217/8 and 236/8)

In the absence of comments from the NSP on the material contained in this preliminary draft new Recommendation, it was assumed that the information contained therein is correct and contains a correct description of RNSS systems and networks and technical characteristics of transmitting space stations operating in RNSS systems and networks in the bands 1164-1215 MHz, [1215-1300 MHz] and 1559-1610 MHz and 5010-5030 MHz.

The meeting noted that ITU-R Recommendation SM.12535 stipulates that the RNSS operating in the band 1215-1300 MHz is stipulated as not being used for safety applications. This needs to be reflected in the Recommendation.

f Annex 11 to Working Party 8D Chairman's Report - Preliminary draft new Recommendation ITU-R M. [1088_new] - Characteristics and protection criteria for receiving earth stations of the radionavigation- satellite service in the band 1 215-1 300 MHz[3] - (Questions ITU-R 217/8 and 236/8)

The NSP concluded that there are no plans known to the group to use the QZSS system for civil aviation purposes.

The meeting, noting this conclusion, further noted that the preliminary draft new Recommendation does NOT refer to the Radio Regulations where provision 5.329 stipulates that the use of the radionavigation-satellite service in the band 1215-1300 MHz shall be subject to the condition that no harmful interference is caused to or protection is claimed from the radionavigation service authorized under RR 5.331 (5.331 allocates the band 1215-1300 MHz to the radionavigation service in a number of countries where it is used for aeronautical primary

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[2] This Recommendation is intended to replace existing Recommendation ITU-R M.1317. Upon entry into force of this Recommendation, Recommendation ITU-R M.1317 should be suppressed.

[3] This Recommendation is intended to replace existing Recommendation ITU-R M.1088. Upon entry into force of this Recommendation, Recommendation ITU-R M.1088 should be suppressed.

(long range) radar systems. Reference to RR 5.331 needs to be incorporated in this Recommendation.

g Review of annex 20 to Working Party 8D Chairman's Report – Working document toward preliminary draft new Report ITU-R M. [DME]

The NSP noted that this working document towards a preliminary draft new Report is a compilation of different studies related to the impact of DME/TACAN and other systems on RNSS operating in the 1164-1215 MHz band. The NSP noted that sources of the studies are sometimes outdated and may only cover limited part of the elements required to design an appropriate link budget. In particular, the latest studies presented to NSP were not included. The main difference was that the working document towards a preliminary draft new Recommendation seems to indicate that the DME/TACAN systems could be operated with substantial margins, whereas the latest NSP studies indicated that reduced margins (less than 1 dB) would be available given the agreed assumptions. Therefore, the NSP expressed concerns that this draft report might give a wrong message about margins between operations of RNSS and DME/TACAN and other systems, and asked the secretariat to forward these concerns to the appropriate ITU body.

The Secretary was invited to coordinate with NSP if ICAO is working on a similar report, in which case this working document towards a preliminary draft new Report could be deleted.

h The meeting agreed, without additional comments, to proposals to update a draft new Recommendation on the compatibility between GBAS and FM broadcasting. This matter is under further review in ITU-R. The meeting also noted with concern, that similar material with regard to VDL Mode 4, also allowed to operate in the band 108-117.975 MHz has not yet been developed.

6 Agenda item 6 VDL frequency assignment planning

6.1 Under this agenda item the meeting considered the frequency assignment planning criteria for VDL Mode 2. These frequency assignment planning criteria were reviewed at WG B-17 in October 2004. The ACP Working group of the G Whole approved these criteria. The meeting agreed that this material should now be incorporated in the ICAO Handbook on aviation spectrum requirements and referred to in Annex 10 to refer to this Handbook. ICAO Regions should be invited to include this material in their frequency planning process. It was agreed that the secretary would take the appropriate actions. In this regard the meeting stressed the need for an early publication of the relevant amendments to Doc. 9718.

7 Agenda item 7

7.1 The meeting also considered proposals, already agreed at the ACP working group of the whole meeting in June 2005 to update the material in Annex 10 Volume III on the maximum power levels that could be tolerated from on-board out-of-band emissions from aircraft Earth stations operating in the aeronautical mobile service. It was agreed that, rather than specifying in the new generic AMS(R)S SARPS the maximum power levels that can be tolerated in order to protect GNSS systems from harmful interference, it would be more appropriate to refer to the protection requirements for GNSS as contained in Annex 10, Volume I. Coordination with the NSP on this issue would be required.

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AGENDA

1. Introduction
2. WRC-07 Agenda Item 1.5
3. WRC-07 Agenda Item 1.6
4. Regional Radio Regulatory WRC-07 preparatory meetings
5. ITU-R Working Parties 8B and 8D
6. VDL frequency assignment planning
7. AOB

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LIST OF WORKING PAPERS

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WP04	Secretariat	NSP review of the outcome of ITU WP8B (Geneva, 11-15 April 2005) and WP8D (Geneva, 13-19 April 2005) meetings	2,3,5
WP05	Y. Nakatani	Frequency assignment planning criteria for VDL Modes 2, 3 and 4	6
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WP10	Didier Petit and Hugues de Bailliencourt	Considerations and propositions to answer to the future telecommunication needs	2, 3
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WP12	Alain Delrieu	Interference susceptibilities of Systems Operating in the 960-1215 MHz Band - Application to the Compatibility Analysis of the Future Communication System	3
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WP16	John Mettrop	Aeronautical telemetry requirement	
WP17	John Mettrop	Handling of Unmanned Aerial Vehicle (UAV) Spectrum Requirement	
WP18	John Mettrop	Implementation of 8.33 kHz Channel Spacing in the Aeronautical Mobile Service Allocation between 118 & 137 MHz	
WP19	John Mettrop	Rationale for Aviation seeking Additional Aeronautical Mobile Spectrum Allocation(s)	

Number	Source	Title	Agenda Item
WP20	Steve Mitchell	FM compatibility with GBAS	
WP21	Alain Delrieu	Use of 5 GHz band for AM(R)S zand aeronautical telemetry	
WP22	Luc Deneufchatel	Feasibility of VOR/DME replanning in Europe to free the sub-band 116 –118 MHz	
WP23	John Mettrop	MLS protection criteria For 3rd and subsequent adjacent channels; interpretation of the proposed changes to Annex 10	

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MLS Protection Criteria For 3rd and Subsequent Adjacent Channels

Interpretation of the Proposed Changes To Annex 10

1.0 INTRODUCTION

A problem has been found with the specification of a transmitted MLS signal. The correction of this error has resulted in the need to change the planning criteria in order to maintain the intended protection levels for an MLS receiver. This paper looks at the practical implications of these changes with respect to a simplified 2 dimensional planning model, noting that adding a third dimension would have an effect on the results.

2.0 ASSUMPTIONS

- That the desired transmitter is operating at the minimum power that ensures the required signal in space criteria within the required service volume will be met.
- That the undesired signal is radiated at such a level that it only just meets the required 3rd Adjacent channel criteria
- That free space path loss applies
- The back azimuth protection will not have varied and hence is not considered in this paper

3.0 PROPOSED REQUIREMENT

The following summarises the proposed minimum required signal in space criteria and the associated protection criteria:-

3.1 Minimum Desired Power Density

Function	DPSK Signal (dBW/m^2)	Angle Signals (dBW/m^2)			Clearance Signals (dBW/m^2)
		1º	2º	3º	
Approach azimuth guidance	-89.5	-85.7	-79.7	-76.2	-88.0
High rate approach azimuth guidance	-89.5	-88.0	-84.5	-81.0	-88.0
Back azimuth guidance	-89.5	-88.0	-84.5	-79.2	-88.0
Approach elevation guidance	-89.5	-88.0	-82.7	N/A	N/A

3.2 Signal to Noise Ratio Protection Criteria

Table Y

Function	Angle Signals (dBW/m^2)		
	1º	2º	3º
Approach azimuth guidance	-69.8	-63.8	-60.2
High rate approach azimuth guidance	-74.6	-68.5	-65.0
Back azimuth guidance	N/A	N/A	N/A
Approach elevation guidance	-71.0	-65.0	N/A

Where the desired signal power density is greater than the levels given in Table Y then the signal to noise ratio protection criteria to be applied are:-

Function	DPSK Signal	Angle Signals			Clearance Signals
		1º	2º	3º	
Approach azimuth guidance	5 dB	24.7 dB	30.7 dB	34.3 dB	5 dB
High rate approach azimuth guidance	5 dB	19.9 dB	26 dB	29.5 dB	5 dB
Back azimuth guidance	5 dB	5.2 dB	11.2 dB	14.8 dB	5 dB
Approach elevation guidance	5 dB	23.5 dB	29.5 dB	N/A	5 dB

Where the signal power density is less than that given in Table Y then the signal to noise ratio protection criteria to be applied are:-

Function	DPSK Signal	Angle Signals			Clearance Signals
		1º	2º	3º	
Approach azimuth guidance	5 dB	8.2 dB	14.3 dB	17.8 dB	5 dB
High rate approach azimuth guidance	5 dB	3.5 dB	9.5 dB	13 dB	5 dB
Back azimuth guidance	5 dB	5.2 dB	11.2 dB	14.8 dB	5 dB

Approach elevation guidance	5 dB	3.5 dB	9.5 dB	N/A	5 dB

3.3 Undesired Emission on the 3rd and Subsequent Adjacent Channels

- Mean power density above a height of 600 m < -94.5 dBW/m^2
- Mean power density at a distance greater than 4.8 km <-94.5 dBW/m^2

4.0 INTERPRETATION

The following interpretation is conducted on the basis of the 3 degree value for the approach azimuth guidance and using ITU-R Recommendation P.525-2.

4.1 Minimum Desired Signal Power

ITU-R Recommendation P.525-2 provides the following two formulae:-

$$E = P_t - 20\log(d) + 74.8 \qquad (1)$$
$$S = E - 145.8 \qquad (2)$$

Where:-
E = Electrical field strength (dB(µv/m))
P_t = Isotropically transmitted power (dB(W))
d = Radio path length (km)
S = Power Flux-density (dBW/m^2))

From these two formulae we can derive the following formulae:-

$$P_t = S + 20\log(d) + 71\,\text{dBW} \qquad (3)$$

Assuming that the isotropically radiated power is set at a level such that the minimum desired signal level (-76.2 dBW/m^2) is just met at maximum range (41.7 km). Substituting these values into equation (1) gives the following result:-

Minimum desired isotropically radiated power = 27.2dBW

4.2 Range at Which the Power Density In Table Y is Reached

Re-arranging equation (3) to make the radio path length the subject of the formula:-

$$d = 10^{(P_t - S - 71)/20}\ \text{km} \qquad (4)$$

Knowing the minimum desired isotropically radiated power (27.2 dBW) the the range at which the power density quoted in table Y (-60.2 dBW/m^2)is reached can be calculated which gives the following result:-

Range = 6.6 km

4.3 Maximum Undesired Signal Power

The maximum undesired signal power can also be calculated using equation (3)

$$P_t = S + 20\log(d) + 71\,\text{dBW} \qquad (3)$$

Assuming that the signal from the undesired transmitter is such that it only just meets the mean power density requirements (-94.5 dBW/m^2) at the minimum range (4.8 km) then:-

Maximum undesired radiated power = -9.9 dBW

4.4 Exclusion Zone Around the Centre Line

Knowing the minimum desired and the maximum undesired isotropically radiated powers as well as the required protection criteria then the separation distance of the undesired signal source from the desired service volume can be calculated using equation (4)

$$d = 10^{(P_{tu} - S_u - 71)/20}\,\text{km} \qquad (4)$$

Where:	P_{tu}	=	undesired isotropically radiated power	=	9.9 dBW
	S_u	=	undesired power flux density		
		=	desired power flux density – required SNR	dBW/m^2	
	d	=	minimum separation distance		km

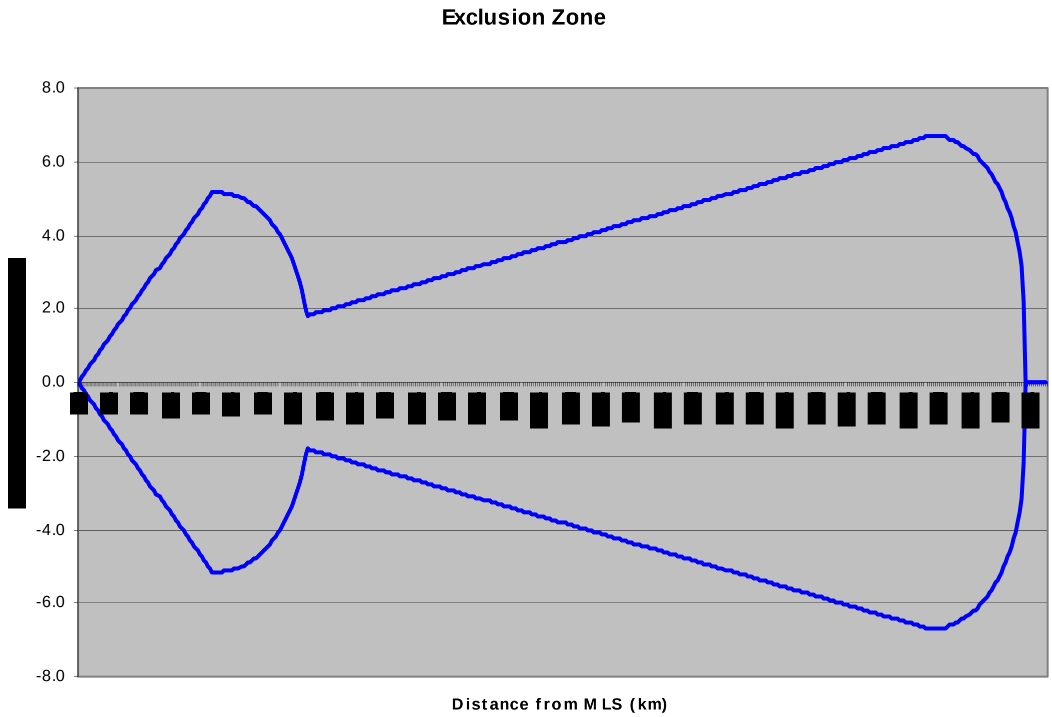
Given that the service volume for an MLS station for a straight approach will be ±3º then the exclusion zone around the centre line of an MLS approach path can be calculated by adding the relevant 3º offset to the value of d calculated above.

If we could assume that the power flux density of the desired signal conformed to free-space path loss within the desired service volume then the desired power flux density could be calculated using a re-arranged version of equation (3) as follows:-

$$S_d = P_{td} - 20\log d - 71 \qquad (3)$$

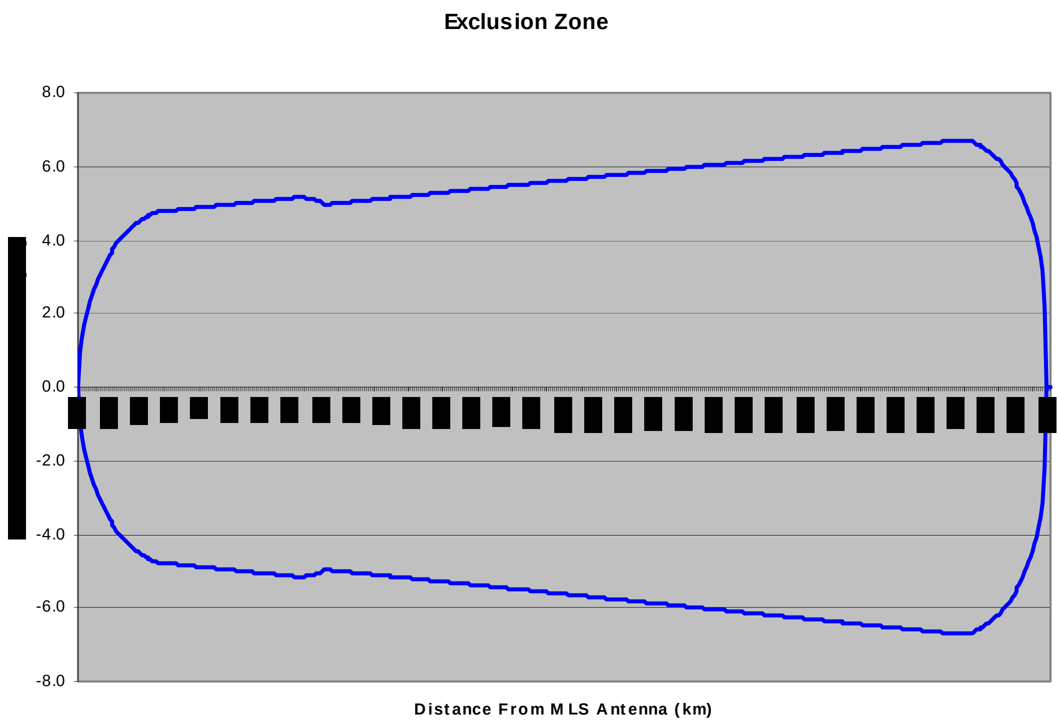
Where:	P_{td}	=	desired isotropically radiated power =	27.2 dBW	
	S_d	=	desired power flux density		dBW/m^2
	d	=	separation distance	km	

Applying these formula and allowing for a 3 degree offset from the centre line the following exclusion zone can be calculated:-



Note:- The exclusion zone given above does not take into account the vertical undesired signal requirements. Were this to be taken into account then the lateral extent of the exclusion zone would depend on the difference in altitude of the two MLS installations as well as the minimum angle of the glide slope. For two MLS which are at the same height and assuming a minimum glide slope angle of 2 degrees then the maximum lateral distance the exclusion zone would have to extend is 17km.

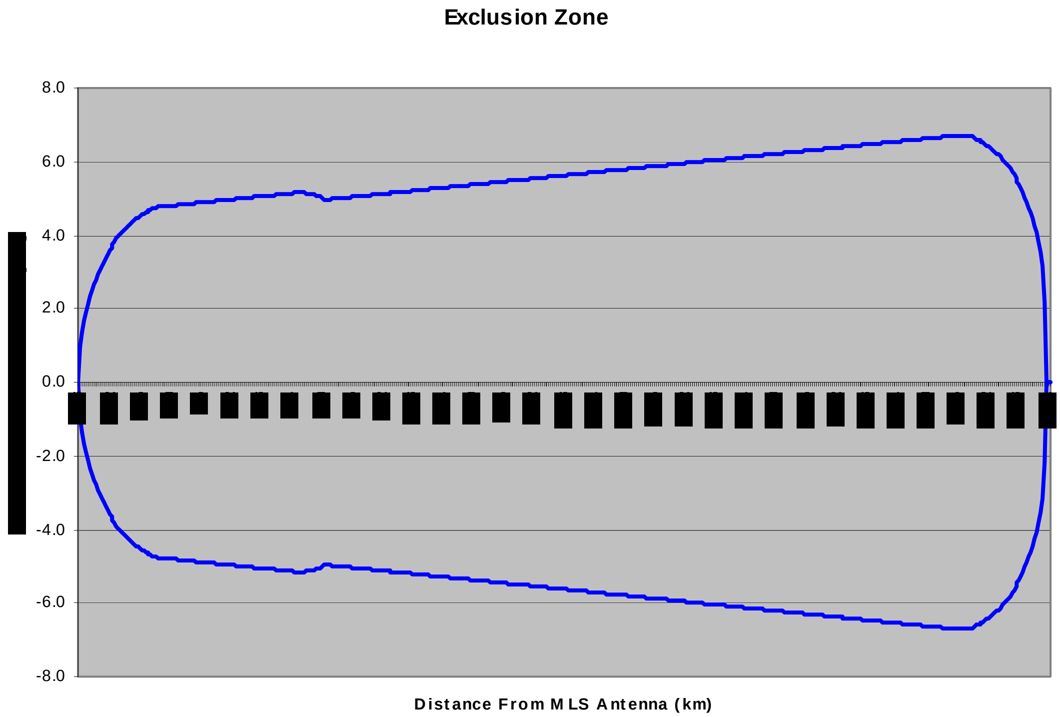
However given the proximity to the ground multipath and other propagation anomalies will cause unpredictable variations in the desired power flux density (this has been confirmed by flight test data). Since these anomalies cannot be predicted, the separation distance calculation should be based on the assumption that the desired power flux density is at a minimum which simplifies the equation and gives the following exclusion zone:-



Since there is no definition of any improvement in the transmission mask beyond the 3rd adjacent channel, then this diagram becomes an exclusion zone within which no other MLS can be placed. It should be noted that a working paper, presented in a working group of the whole meeting of the Navigation Systems Panel, suggested that it might be possible to allow for an additional role of 2dB per channel in the transmitter radiated power mask. If it were possible to take this into account then an incremental reduction in the exclusion zone for successive adjacent channels could be implemented.

5.0 CONCLUSION

That the exclusion zone given below should, for adjacent channels beyond the 2nd, be incorporated into the planning rules within the European region for MLS until such time as any improvements in the transmitter mask can be taken into account.


Exclusion Zone
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
[redacted]
[redacted]
Distance From MLS Antenna (km)

Evaluation of the spectrum requirements for MLS

Note Secretary: the text below is not identical to the text agreed at WG F-14. It is a more detailed description of a more useful spectrum requirement evaluation.

1 Introduction

1.1 A need to establish more precisely the requirements for spectrum for the MLS has been identified, in particular with regard to need of identify part of the MLS extension band (5091-5150 MHz) needed for MLS.

1.2 A simulation exercise is being undertaken in ICAO, under the coordination of the working group F of the Aeronautical Communications Panel with support from the French Administration. The purpose of this exercise is, through the development of frequency assignment plans, to establish the spectrum needs for the MLS, in particular in Europe where the first MLS frequency assignment plan was developed in 1988. Such a plan could only be developed through reducing the maximum altitude of the MLS Designated Operational Coverage (DOC) to 10.000 ft, which was a deviation from the operational requirements for MLS as specified in ICAO Annex 10 to the Convention on International Civil Aviation.

1.3 ICAO has re-established the need for MLS assignment in Europe in [2001]. However, a frequency assignment plan, based upon the renewed requirements, was never developed. Also, an amendment to the MLS system characteristic, in particular increasing the adjacent channel protection requirements for the MLS (or resulting separation distances) is currently being considered by ICAO Contracting States and ICAO (the Air Navigation Commission and Council).

1.4 This paper presents the various conditions that could be used in the simulation exercise. Although the simulation initially needs to be based upon the requirements as contained in Annex 10 (including the new adjacent channel protection requirements), various other conditions could be used in the simulation activities. However, deviations from the requirements as specified in Annex 10 could be considered for the purpose of evaluating the MLS spectrum needs. Such deviations need to be further considered by ICAO with respect to their acceptability, from an operational point of view and, likely at a later stage, be considered for incorporation in Annex 10 and/or in the ICAO European Region. .

1.5 In order to provide elements that could be used in an evaluation of necessary MLS spectrum requirements, the material below should be used for this purpose. This material, as developed by CAP working group F, requires further coordination, within ICAO, with the Navigation Systems Panel (NSP) and the European Office of ICAO (All Weather Operations Group (AWOG) and the Frequency Management Group (FMS). (The AWOG and the FMS work under the control of the European Air Navigation Planning Group (EANPG).

2. Basic assumptions to be used in a frequency assignment planning simulation

2.1 All frequency assignment planning simulations should be based upon satisfying the requirements fro MLS assignments, as brought forward by ICAO Contracting States in the

EUR Region in [2001]. Once these requirements are satisfied, the remaining capacity in the relevant band(s) should be investigated. A reasonable assumption would be that if there is enough capacity to double the total number of frequency assignments, including those required for the, with the MLS associated DME, enough capacity is available until 2025.

2.1.1 The data base to be used will be the EUR COM3 table of the EUR ANP from which all MLS assignments in the EUR Region have been removed. All remaining DME assignments, either of a single DME or a DME associated with ILS or VOR need to be protected.

2.2 The following basic parameters were considered acceptable by WG F.

2.2.2 Operational coverage of the MLS.

2.2.2.1 Initially, in a frequency assignment planning simulation, MLS requirements should be satisfied with a maximum altitude of 20.000 ft., in conformity with the requirements contained in Annex 10; the results of the simulation should be presented to ICAO. (In the development full of such a plan, the use of DME W/Z channels may be considered).

2.2.2.2 Additional further frequency assignment planning simulations may be considered where the maximum height of the DOC is reduced to 10.000 ft and 6.000 ft.
In these cases, further coordination with the NSP is with the view to identify the acceptability of deviating from the operational requirements in Annex 10. Amendments to the relevant SARPs are to be initiated in case such deviations from the current SARPs be considered acceptable.

2.2.4. Use of the MLS service volume on the basis of the actual requirements in Annex 10 (front and back azimuth sectors) is acceptable.
Note: MLS assignments are currently considered in Europe as having a circular designated operational coverage (DOC).

2.3 MLS usable channels.

2.3.1 Initially, a simulation needs to be considered where all established requirements are accommodated using only MLS frequencies, paired with DME X/Y channels (a total of hundred assignable frequencies or channels). Should it not be possible to accommodate these requirements, use should be made of MLS frequencies paired with DME W/Z channels (bringing the total of assignable MLS frequencies or channels up to 200).

2.3.2 Should it not be possible to assign all requirements on these 200 channels, or should the capacity for further growth of MLS assignments not offer the required capacity (see paragraph 2.1 above), consideration should be given to the use of the MLS extension band (5091-5150 MHz). In this regards it should be noted that a channel pairing plan with additional DME W/X/Y/Z has been developed by ICAO in the late eighties but was never incorporated in Annex 10.

2.4. Frequency assignment planning criteria

2.4.1 The frequency planning criteria for MLS and associated DME are those contained in the 2003 European Frequency Manual (see Appendix A). These planning criteria should be amended to include the adjacent channel considerations as contained in ICAO State letter AN 7/3.87-05/3 from 21 January 2005.

3. Further simulations

3.1 For statistical purposes and further review within ICAO, an MLS/DME frequency assignment plan can be established in which only the current ILS assignments in the EUR COM/3 Table and identified for CAT II/III operations have been replaced with MLS CAT II/III requirements. This would give an estimate of the total MLS spectrum requirements as and when full GNSS CAT I operations for approach, final approach and landing are technically feasible. However, for the development of a final plan under these conditions for the EUR Region, States should have the opportunity to either accept such a plan and remove the MLS Cat. I requirements or reject it, in which case MLS assignments would be required. For this case, an estimation of the long terms needs is made using a simple growing rate based upon the fact that CATII/III requirements will be extended to smaller airport by 2020/2025. The growth rate is proposed to be 20%, 50% or 80% or 100% of the current CAT II/III ILS assignments

3.2 A final complementary scenario could be run to identify any potential reduction of spectrum required for MLS and associated DME by assuming a soft MLS/DME pairing (no constraint given by the MLS on the DME frequency allocation). This scenario is used to identify the dimensioning element in frequency planning between MLS and DME. However, application of this scenario is subject to further consideration by the NSP, the ANS and ICAO Contracting States.

4. Based upon further study of the results of a complete set of simulation results, including the used frequency assignment planning criteria as well as the used software in these simulations, initially a reasonable assessment of the spectrum required in the future for MLS may be established. This activity may require involvement on the NSP. It could result in quantifying the amount of spectrum from the current MLS bands (5030-5091 MHz and 5091-5150 MHz) that can be released for other usage. The material above can be used to develop detailed plans for the simulation activities.

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Report ACP WG F-14 Appendix qqqq

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21 January 2005

Subject: Proposal for the amendment of Annex 10, Volume I, concerning instrument landing system (ILS), distance measuring equipment (DME) and microwave landing system (MLS)

Action required: Comments to reach Montreal by 14 May 2005

Sir/Madam,

1. I have the honour to inform you that the Air Navigation Commission, at the seventh meeting of its 167th Session held on 23 November 2004, considered proposals developed by the Navigation Systems Panel (NSP) to amend Standards and Recommended Practices (SARPs) relating to radio navigation aids Annex 10 — *Aeronautical Telecommunications*, Volume I — *Radio Navigation Aids*. The purpose of the amendments are to align a number of existing provisions for instrument landing system (ILS) and distance measuring equipment (DME) with established operational practice, and to address some issues identified at early stages of microwave landing system (MLS) implementation. The amendments also suggest the removal of obsolete provisions for DME/W which does not support efficient use of the DME spectrum.

2. In regard to the latter proposal, it should be noted that, at the time of developing the proposal, the NSP was not aware of any DME/W in operation. Furthermore, Annex 10 has already recommended that there should be no new installations of DME/W after 1 January 1987. Hence the practical impact of the deletion is expected to be negligible. Nevertheless, should any DME/W installation currently be in operational use in your State, your specific comments on the potential impact of the deletion, taking into account the benefits associated with the improved spectrum efficiency, are appreciated.

3. The proposed amendments to Annex 10, Volume I, are presented in Attachments A to C to this letter. Additional background information concerning the rationale and content of the proposals is provided in Attachment D.

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EXTRACT of EUR Doc 011

EUR FREQUENCY MANAGEMENT MANUAL

This appendix to the report of ACP WG F-14 contains the planning criteria used in the EUR Region for DME and MLS. The criteria for MLS need to be updated in the light of the revisions to Annex 10 as proposed in State letter AN 7.1.3.87-05.3 from 21 January 2005

1 DME

1.1 General

1.1.1 The band 960 - 1215 MHz is allocated to aeronautical radio navigation and used mainly by the DME system. Within this band, two segments, around 1030 MHz and 1090 MHz, are reserved for SSR. Furthermore, some military systems make use of this band, e.g. TACAN (essentially a DME with additional pulses for bearing information) and data/voice systems employing frequency hopping techniques.

1.1.2 References to documents:

- Annex 10, Volume I, paragraph 3.5.3.3
  (channelling);
- Annex 10, Volume V, paragraph 4.3
  (channel groups, pairing);
- Annex 10, Attachment C to Volume I, paragraphs 7.1.7 - 7.1.10
  (signal ratios, pulse coding, adjacent channels);

1.1.3 DME is in many cases co-located and frequency paired (Annex 10, Volume I, chapter 3, Table A) with another facility (VOR, ILS, MLS) and normally has the same protected range. The protection also takes into account the pulse coding and output power. Both the first and second adjacent channels are considered.

1.1.4 Co-ordination should follow the rules for the co-located equipment; for a stand-alone DME co-ordination should at least include States within a radius of 400 - 500 NM.

1.1.5 Information on the planning of identifications can be found in section 7 below.

1.2 Frequency assignment planning criteria

Notes: For frequency planning purposes,

1) *there is no difference between DME/N and DME/P.*
2) *TACAN facilities are treated in the same way as DME stations.*
3) *no criteria are defined for DME/W because it is not used in EUR Region.*

1.2.1 Protection requirements

1.2.1.1 The necessary desired to undesired (D/U) signal ratios are needed to protect the desired transponder reply signals at the airborne receiver from the various co-frequency/adjacent-frequency, same pulse code/different pulse code, undesired transponder reply signal combinations that may exist.

1.2.1.2 In making an assignment, each facility must be treated as the desired source with the other acting as the undesired source. If both satisfy their unique D/U requirements, then the assignment can be made.

1.2.1.3 The channelling arrangement for DME, when considering X and Y channels only, is such that in the ground-to-air direction (transponder reply frequency) no use is made of multiplexing techniques on the same frequency, thus avoiding the situation where different pulse codings on the same or adjacent frequencies have to be studied when making frequency assignments.

However, when assignments on DME W or Z channels have to be made, these assignments have to be checked against interference from DME X or Y channels and vice-versa.

1.2.1.4 Co-frequency[4] protection ratios (D/U)

The co-frequency protection ratios (D/U) are:

Same pulse code: 8 dB
Different pulse code: 8 dB (column A of Table C-4, Attachment C to Annex 10, Volume I).

Geographical separation distances are based upon the required D/U ratio, taking into consideration the EIRP of both the desired and the undesired DME and the appropriate propagation characteristics. **In case these EIRP values are not provided**, the following assumptions should be made:

Landing DME: EIRP is 29 dBW
En-route DME: EIRP is 37 dBW
TACAN: EIRP is 40 dBW.

1.2.1.5 Adjacent frequency protection ratios (D/U)

The first and second adjacent channel protection requirements are governed by the spurious emission criteria of the transponder. These are:

200 mW (-7 dBW) on the first adjacent frequency
2 mW (-27 dBW) on the second adjacent frequency.

The D/U ratios are as in the co-frequency case and the minimum signal level at the airborne receiver to be protected is -89 dBW/m^2 within the designated operational coverage.

Note: Since calculations for a DME/P show that all separation distances derived for the Initial Approach (IA) mode (-89 dBW/m^2 at 23 NM) are larger than for the Final Approach (FA) mode (-75 dBW/m^2 at 7 NM), it is sufficient to consider only the IA mode protection.

1.2.1.6 Designated Operational Coverage (DOC)

1.2.1.6.1 When the DME is associated with a VOR or an ILS the coverage should be at least that of the VOR or ILS to the extent practicable.

1.2.1.6.2 When the DME is associated with an MLS, the coverage should be omnidirectional up to the operational range of the MLS approach azimuth facility. The protected height of the DME should be the same as for the MLS approach azimuth sector.

1.2.1.6.3 Where the designated operational range of a given frequency is not the same throughout 360°, the angular limits of sectorization in range should be indicated in accordance with the method described in Appendix A to Part III.

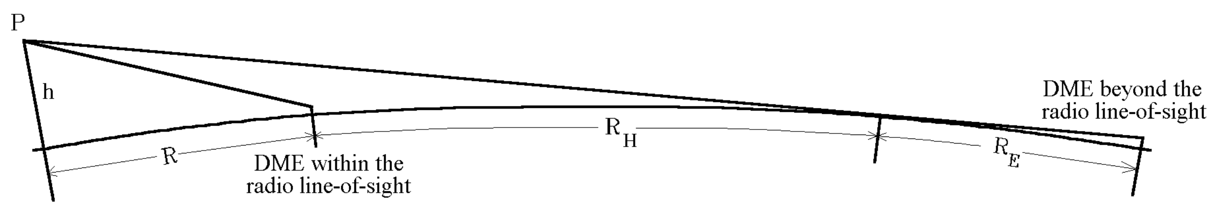
1.2.2 Propagation model

[4] Co-frequency and adjacent frequency are referred to the transponder reply frequency.

1.2.2.1 Propagation characteristics

1.2.2.1.1 The same propagation conditions along the path of the desired and the undesired signals are assumed. Within the radio line-of-sight, free space attenuation is assumed. Beyond the radio line-of-sight, propagation is approximated by an attenuation rate of 1.6 dB/NM. This is derived from the propagation 1000 MHz/50% time curve in Rec. ITU-R P.528-2 (former CCIR Rec. 528-1). For radio propagation and radio horizon calculations a smooth earth is assumed with an effective 4/3 earth radius.

1.2.2.1.2 Within and beyond the radio line-of-sight situations are depicted below:



The distance from protection point P to its radio horizon is given by:

$$R_H = 1.23 * \sqrt{h}$$

where
R_H = radio horizon distance in nautical miles (NM)
h = height of receiving point P (ft)

Taking the height of the phase centre of the DME antenna to be 30 feet, the DME will be beyond the radio line-of-sight when:

$$R_H = 1.23 * \sqrt{30}$$

where
R_E = distance of DME behind the radio horizon in NM.

1.2.2.1.3 When radio line-of-sight conditions exist between the DME and the protection point P, the following formula may be used to calculate the power density at point P as:

$$P_d = EIRP - 20 \log R - 76.3 \qquad (1a)$$

where
P_d = power density in dBW/m^2
EIRP = effective isotropically radiated power in dBW
R = distance to DME in NM

1.2.2.1.4 For distances between DME and receiving point P greater than the radio horizon, the following formula may be used instead:

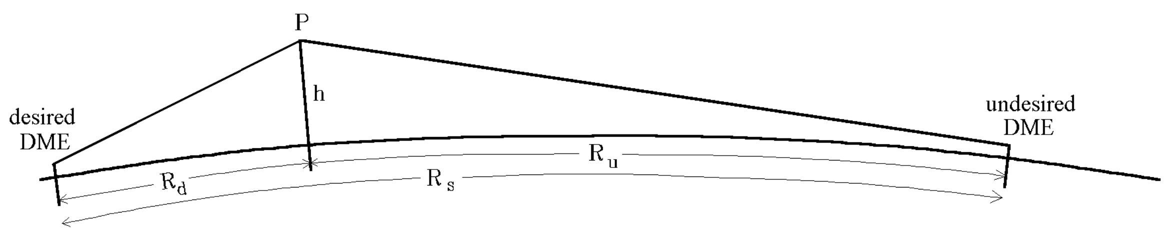
$$P_d = EIRP - 20 \log R_H - 1.6*R_E - 76.3 \qquad (1b)$$

1.2.3 Calculation of separation distances

The difference in power densities of the desired and undesired DME facility at the protection point P directly gives the protection ratio in dB. In calculating separation distances, the conditions of paragraph 5.2.1 above shall be met. The table at the end of chapter 5 contains the co-frequency, different pulse code, and adjacent frequency, same and different pulse code, DME channels to consider when an assignment on a particular DME channel is proposed.

1.2.3.1 Co-frequency; desired and undesired DME facility having the same pulse code.

1.2.3.1.1 Undesired DME facility within the radio line-of-sight



Application of formula (1a) to the desired and undesired DME as appropriate, results in:

$$D/U = K + 20 \log (R_u/R_d) \quad (2a)$$

where

D/U = protection ratio in dB (minimum 8 dB)

K = EIRP of the desired minus the EIRP of the undesired facility in dBW

R_u = distance between the edge of the DOC of the desired facility and the undesired facility in NM

R_d = operational range of desired facility in NM

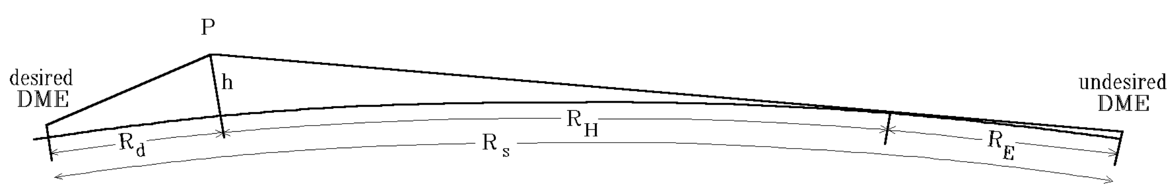
This can be expressed as the required separation distance R_s:

$$R_s = R_d (1 + 10^{[(D/U - K) / 20]}) \quad (3a)$$

where

R_s = required separation distance between the desired and undesired facilities in NM

1.2.3.1.2 Undesired DME facility beyond the radio line-of-sight



Application of formula (1a) to the desired DME and of (1b) to the undesired DME leads to:

$$D/U = K + 20 \log (R_H/R_d) + 1.6 R_E \qquad (2b)$$

This can be expressed as the required separation distance R_s:

$$R_s = R_d + R_H + [D/U - K - 20 \log (R_H/R_d)] / 1.6 \qquad (3b)$$

In the figure of DME separation curves below, the minimum station-to-station distance R_s minus the range R_d of the desired facility is plotted in accordance with formulas (3a) and (3b) as a function of T, where

$$T = D/U - K + 20 \log R_d \text{ (NM)}$$

In this way, a single set of curves is sufficient to cover all possible situations of distances within as well as beyond the radio horizon. The use of these curves can be clarified by the following examples:

a) DME(1) coverage: 23 NM, 10 000 ft; EIRP = 29 dBW
DME(2) coverage: 23 NM, 10 000 ft; EIRP = 29 dBW

For a D/U ratio of 8 dB, no EIRP difference: K=0 and thus T = 8 - 0 + 20 log 23 = 35.

Using the figure of DME separation curves below, one reads R_s - R_d = 57 NM and therefore R_s = 80 NM is the required minimum separation between the stations.

b) DME(1) coverage: 25 NM, 10 000 ft; EIRP = 29 dBW
DME(2) coverage: 120 NM, 40 000 ft; EIRP = 40 dBW

D/U = 8 dB.

i) separation distance to protect DME(1):

T = 8 - (29-40) + 20 log 25 = 47

The figure of DME separation curves below indicates for T = 47 and FL 100 that R_s - R_d = 125 and thus the minimum required separation between the stations is 150 NM.

ii) separation distance to protect DME(2):

T = 8 - (40-29) + 20 log 120 = 38.6

The figure of DME separation curves below indicates for T = 38.6 that R_s - R_d = 85 NM and thus the minimum required separation between the stations is 205 NM.

To assure protection to both facilities, the minimum separation distance between these facilities should be at least 205 NM.

1.2.3.2 Co-frequency; desired and undesired DME facility having different pulse codes

Since the required protection is provided at the airborne DME receiver, different pulse coding protection is only required when a DME X channel is interfered with a DME W channel (or DME Y versus DME Z) or vice versa (see also paragraph 5.2.1.3). The separation distances can be calculated along the same principles as indicated in paragraph 5.2.3.1. The protection ratio is 8 dB (see paragraph. 5.2.1.4). The figure of DME separation curves below can also be used to determine the required separation distance.

1.2.3.3 Adjacent channel separation distances

1.2.3.3.1 First adjacent frequency

The first adjacent frequency protection requirement is governed by the spurious emission criteria of the transponder (cf. Annex 10, Volume I, paragraph 3.5.4.1.3e). On its first adjacent frequency the maximum radiated level of spurious emission is 200 mW (-7 dBW).

Protection criteria are:

a) minimum power density at the airborne antenna to be protected: - 89 dBW/m2 (DME/N or DME/P in IA mode)

b) D/U ratio 8 dB for the same pulse code and for different pulse coding.

When the undesired signal has the same pulse code as the desired signal, the maximum level of the undesired signal is therefore -97 dBW/m2.

Formula (1a) gives:

$- 97 = - 7 - 20 \log R - 76.3$; $R = 4.8$ NM.

This implies that the station-to-station distance between two DMEs operating on their first adjacent channel (with the same or different pulse code) shall be at least the operational range of the beacon having the larger DOC + 5 NM.

1.2.3.3.2 Second adjacent frequency

The second adjacent frequency separation distances are almost insignificant. However it is recommended that second adjacent frequency assignments on the same aerodrome should be avoided. For practical planning purposes, a minimum required separation distance between the facilities of 10 NM may be used.

1.2.3.4 Separation requirement for DME frequencies which are separated by 63 MHz

Annex 10, Attachment C to Volume I, paragraph 7.1.9 indicates that "assignment of an Y or Z channel whose reply frequency is 63 MHz from the reply frequency of another channel (either W, X, Y, Z) or vice versa requires a separation distance of at least 28 km (15 NM) between facilities" (Annex 10, Attachment C to Volume I, paragraph 3.4.9 gives a less conservative minimum separation distance of 10 NM).

This requirement is to prevent desensitization that may occur to the transponder that is receiving on the same frequency the other transponder is transmitting, irrespective of the pulse code.

For example:

	downlink	uplink		downlink	uplink
18X(W)	1042	979	81X(W)	<u>1105</u>	1168
18Y(Z)	1042	<u>1105</u>	81Y(Z)	<u>1105</u>	1042

Channel 18Y(Z), transmitting on 1105 MHz may cause interference to the transponder receiver operating on channels 81X(W) or 81Y(Z). Similarly, channel 81Y(Z) may interfere with channels 18X(W) and 18Y(Z).

1.2.3.5 Sectorization

The material of paragraph 3.3.5 (VOR) on sectorization is also applicable for DME. However, the calculation of the separations distance must be adapted as indicated below:

The correct assessment of compatibility for facility A requires the following calculations:

Co-channel:

Minimum separation distance between "Critical Point" and transmitter B:

$R_s = R_d*10^{[(D/U– K)/20]}$ if undesired facility within radio line-of-sight; or

$R_s = R_H+[D/U-K-20 \log (R_H/R_d)]/1.6$ if undesired facility beyond radio line-of-sight;

(this is derived from a subtraction of Rd from $R_s = R_d$ (1 + 10[(D/U– K)/20]) and from $R_d+R_H+[D/U-K-20 \log (R_H/R_d)]/1.6.$);

where
R_d = operational range of facility A at the " Critical Point".

Co-frequency:

Minimum separation distance between " Critical Point" and transmitter B:

$R_s = R_d$*10[(D/U– K)/20] if undesired facility within radio line-of-sight; or

$R_s = R_H+[D/U-K-20 \log (R_H/R_d)]/1.6$ if undesired facility beyond radio line-of-sight;

(this is derived from a subtraction of Rd from $R_s = R_d$ (1 + 10[(D/U– K)/20]) and from
$R_d+R_H+[D/U-K-20 \log (R_H/R_d)]/1.6.$).

First adjacent channel:

Minimum separation distance between " Critical Point" and transmitter B:

Range of facility A plus 5 NM.

Second adjacent channel:

Minimum separation distance between transmitter A and transmitter B:

10 NM.

63 MHz separated facilities:

Minimum separation distance between transmitter A and transmitter B:

15 NM.

Compatibility of facility A (undesired facility) with B (desired facility) must also be considered.

If the " Critical Point" lies on the direct line between the two facilities A and B, then the "normal" calculation method may be applied (i.e. point "P" is " Critical Point").

1.2.4 Summary Table of example minimum separation distances used in DME planning

Facility 1	**Facility 2**	**Minimum required separation distance (NM)**		
Desired	**Undesired**	**Co-frequency**	**1st adjacent frequency**	**2nd adjacent frequency**
Cylindrical DOC and EIRP				
DME (MLS) 23 NM/10000 ft 29 dBW 1)	1)	81	28	10
1)	2)	81	28	10
1)	3)	154	28	10
1)	4)	156	28	10
DME (ILS) 25 NM/10000 ft 29 dBW 2)	1)	88	30	10
2)	2)	88	30	10
2)	3)	156	30	10
2)	4)	158	30	10
DME (VOR) 100 NM/50000 ft 37 dBW 3)	1)	200	105	10
3)	2)	200	105	10
3)	3)	351	105	10
3)	4)	383	105	10
TACAN 40 NM/25000 ft 40 dBW 4)	1)	68	45	10
4)	2)	68	45	10
4)	3)	111	45	10
4)	4)	140	45	10

Image - 63 MHz:

separation 28 km (15 NM) Reference Annex 10, Volume I, Attachment C, paragraph 7.1.9.

Notes:
1) Typical for a DME associated with a MLS
2) Typical for a DME associated with an ILS
3) Typical for a DME associated with a VOR
4) Typical for a TACAN

The required separation distance for two facilities A and B is the greater of the separation distances between A and B or B and A (e.g. the required co-frequency separation distance between A being a DME associated with an ILS and B a DME associated with a VOR is the greater of 156 and 200 NM, i.e. 200 NM).

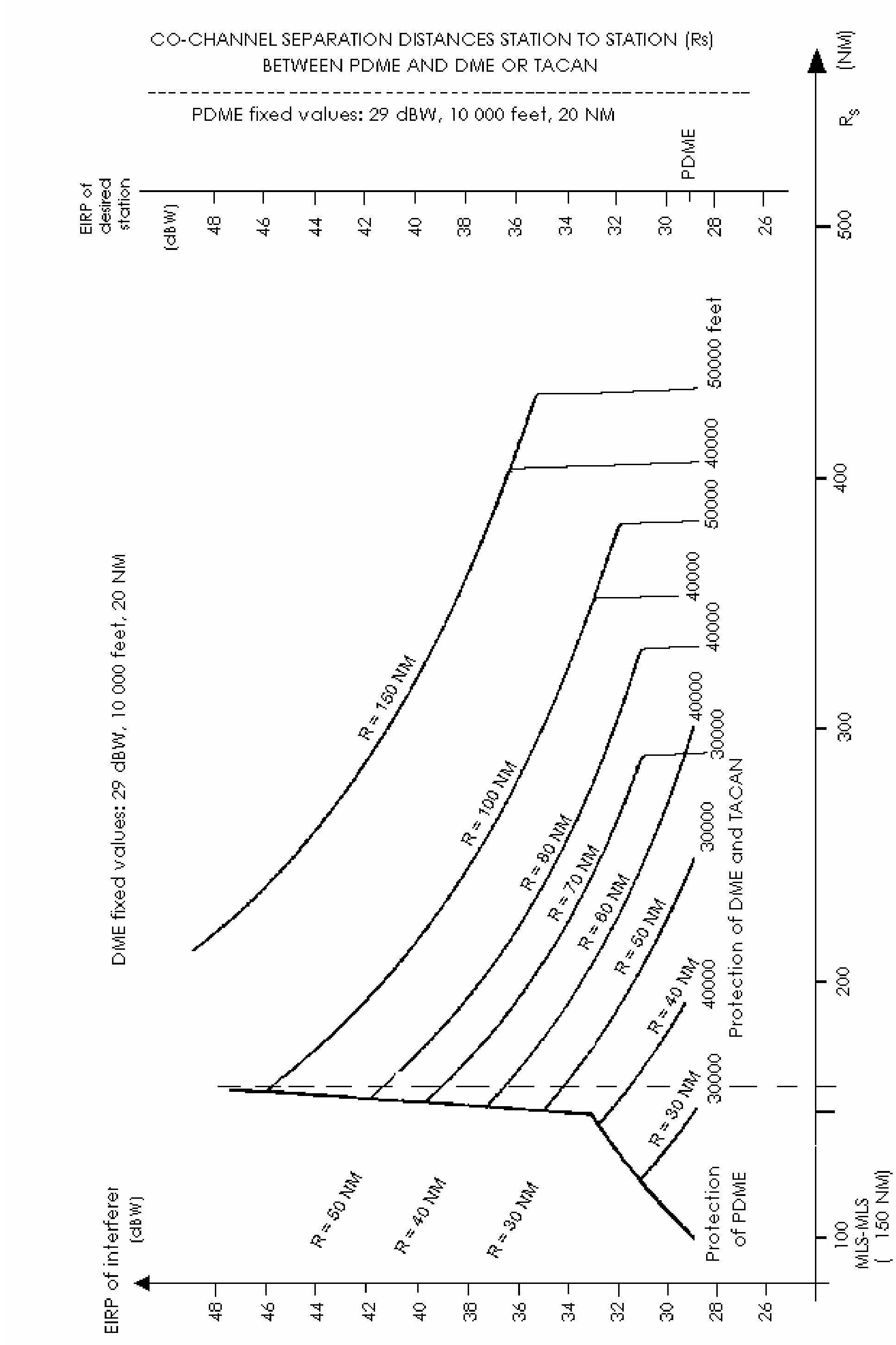


Figure of DME separation curves

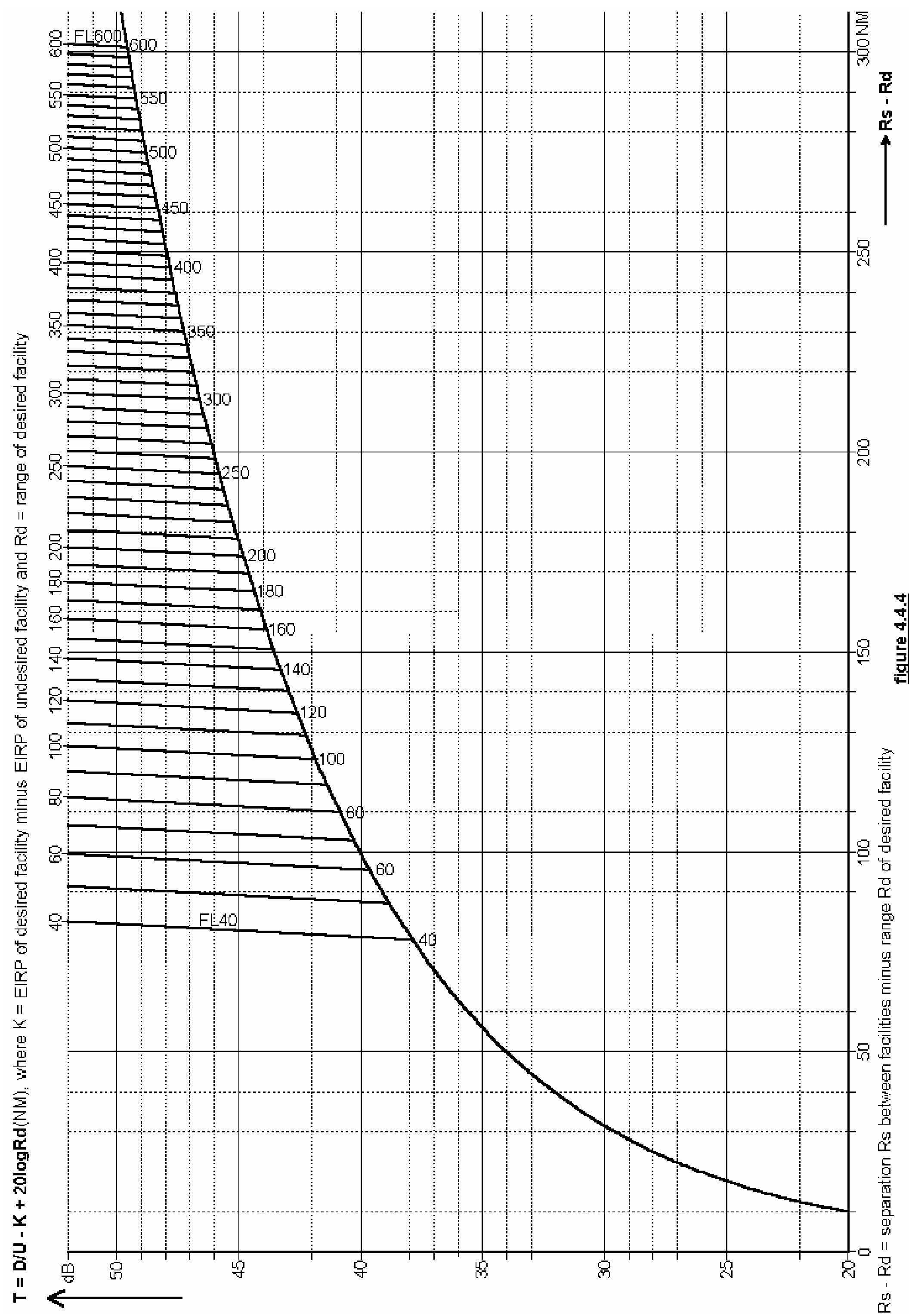

T = D/U - K + 20logRd(NM), where K = EIRP of desired facility minus EIRP of undesired facility and Rd = range of desired facility
dB
50
45
40
35
30
25
20
0
50
100
150
200
250
300NM
Rs - Rd
Rs - Rd = separation Rs between facilities minus range Rd of desired facility
FL40
FL600
40
60
80
100
120
140
160
180
200
250
300
350
400
450
500
550
600

figure 4.4.4

Table

DME-channel	*Reply FREQ (MHz)*	*Co-FREQ different pulse code*	*1st adjacent FREQ same pulse code*		*1st adjacent FREQ different pulse code*		*2nd adjacent FREQ same pulse code*		*2nd adjacent FREQ different pulse code*	
17X	978	-	16X	18X	-	18W	15X	19X	-	-
17Y	1104	17Z	16Y	18Y	-	18Z	15Y	19Y	-	19Z
17Z	1104	17Y	-	18Z	16Y	18Y	-	19Z	15Y	19Y
18X	979	18W	17X	19X	-	-	16X	20X	-	20W
18W	979	18X	-	-	17X	19X	-	20W	16X	20X
18Y	1105	18Z	17Y	19Y	17Z	19Z	16Y	20Y	-	20Z
18Z	1105	18Y	17Z	19Z	17Y	19Y	-	20Z	16Y	20Y
19X	980	-	18X	20X	18W	20W	17X	21X	-	-
19Y	1106	19Z	18Y	20Y	18Z	20Z	17Y	21Y	17Z	21Z
19Z	1106	19Y	18Z	20Z	18Y	20Y	17Z	21Z	17Y	21Y
20X	981	20W	19X	21X	-	-	18X	22X	18W	22W
20W	981	20X	-	-	19X	21X	18W	22W	18X	22X
20Y	1107	20Z	19Y	21Y	19Z	21Z	18Y	22Y	18Z	22Z
20Z	1107	20Y	19Z	21Z	19Y	21Y	18Z	22Z	18Y	22Y
21X	982	-	20X	22X	20W	22W	19X	23X	-	-
21Y	1108	21Z	20Y	22Y	20Z	22Z	19Y	23Y	19Z	23Z
21Z	1108	21Y	20Z	22Z	20Y	22Y	19Z	23Z	19Y	23Y
22X	983	22W	21X	23X	-	-	20X	24X	20W	24W
22W	983	22X	-	-	21X	23X	20W	24W	20X	24X
22Y	1109	22Z	21Y	23Y	21Z	23Z	20Y	24Y	20Z	24Z
22Z	1109	22Y	21Z	23Z	21Y	23Y	20Z	24Z	20Y	24Y
23X	984	-	22X	24X	22W	24W	21X	25X	-	-
23Y	1110	23Z	22Y	24Y	22Z	24Z	21Y	25Y	21Z	25Z
23Z	1110	23Y	22Z	24Z	22Y	24Y	21Z	25Z	21Y	25Y
24X	985	24W	23X	25X	-	-	22X	26X	22W	26W
24W	985	24X	-	-	23X	25X	22W	26W	22X	26X
24Y	1111	24Z	23Y	25Y	23Z	25Z	22Y	26Y	22Z	26Z
24Z	1111	24Y	23Z	25Z	23Y	25Y	22Z	26Z	22Y	26Y
25X	986	-	24X	26X	24W	26W	23X	27X	-	-
25Y	1112	25Z	24Y	26Y	24Z	26Z	23Y	27Y	23Z	27Z
25Z	1112	25Y	24Z	26Z	24Y	26Y	23Z	27Z	23Y	27Y
26X	987	26W	25X	27X	-	-	24X	28W	24W	28W
26W	987	26X	-	-	25X	27X	24W	28X	24X	28X
26Y	1113	26Z	25Y	27Y	25Z	27Z	24Y	28Y	24Z	28Z
26Z	1113	26Y	25Z	27Z	25Y	27Y	24Z	28Z	24Y	28Y
27X	988	-	26X	28X	26W	28W	25X	29X	-	-
27Y	1114	27Z	26Y	28Y	26Z	28Z	25Y	29Y	25Z	29Z
27Z	1114	27Y	26Z	28Z	26Y	28Y	25Z	29Z	25Y	29Y
28X	989	28W	27X	29X	-	-	26X	30X	26W	30W
28W	989	28X	-	-	27X	29X	26W	30W	26X	30X
28Y	1115	28Z	27Y	29Y	27Z	29Z	26Y	30Y	26Z	30Z
28Z	1115	28Y	27Z	29Z	27Y	29Y	26Z	30Z	26Y	30Y
29X	990	-	28X	30X	28W	30W	27X	31X	-	-
29Y	1116	29Z	28Y	30Y	28Z	30Z	27Y	31Y	27Z	31Z
29Z	1116	29Y	28Z	30Z	28Y	30Y	27Z	31Z	27Y	31Y
30X	991	30W	29X	31X	-	-	28X	32X	28W	32W
30W	991	30X	-	-	29X	31X	28W	32W	28X	32X
30Y	1117	30Z	29Y	31Y	29Z	31Z	28Y	32Y	28Z	32Z
30Z	1117	30Y	29Z	31Z	29Y	31Y	28Z	32Z	28Y	32Y
31X	992	-	30X	32X	30W	32W	29X	33X	-	-
31Y	1118	31Z	30Y	32Y	30Z	32Z	29Y	33Y	29Z	33Z
31Z	1118	31Y	30Z	32Z	30Y	32Y	29Z	33Z	29Y	33Y
32X	993	32W	31X	33X	-	-	30X	34X	30W	34W
32W	993	32X	-	-	31X	33X	30W	34W	30X	34X
32Y	1119	32Z	31Y	33Y	31Z	33Z	30Y	34Y	30Z	34Z
32Z	1119	32Y	31Z	33Z	31Y	33Z	30Z	34Z	30Y	34Y
33X	994	-	32X	34X	32W	34W	31X	35X	-	-
33Y	1120	33Z	32Y	34Y	32Z	34Z	31Y	35Y	31Z	35Z
33Z	1120	33Y	32Z	34Z	32Y	34Y	31Z	35Z	31Y	35Y
34X	995	34W	33X	35X	-	-	32X	36X	32W	36W
34W	995	34X	-	-	33X	35X	32W	36W	32X	36X
34Y	1121	34Z	33Y	35Y	33Z	35Z	32Y	36Y	32Z	36Z

DME-channel	*Reply FREQ (MHz)*	*Co-FREQ different pulse code*	*1st adjacent FREQ same pulse code*		*1st adjacent FREQ different pulse code*		*2nd adjacent FREQ same pulse code*		*2nd adjacent FREQ different pulse code*	
34Z	1121	34Y	33Z	35Z	33Y	35Y	32Z	36Z	32Y	36Y
35X	996	-	34X	36X	34W	36W	33X	37X	-	-
35Y	1122	35Z	34Y	36Y	34Z	36Z	33Y	37Y	33Z	37Z
35Z	1122	35Y	34Z	36Z	34Y	36Y	33Z	37Z	33Y	37Y
36X	997	36W	35X	37X	-	-	34X	38X	34W	38W
36W	997	36X	-	-	35X	37X	34W	38W	34X	38X
36Y	1123	36Z	35Y	37Y	35Z	37Z	34Y	38Y	34Z	38Z
36Z	1123	36Y	35Z	37Z	35Y	37Y	34Z	38Z	34Y	38Y
37X	998	-	36X	38X	36W	38W	35X	39X	-	-
37Y	1124	37Z	36Y	38Y	36Z	38Z	35Y	39Y	35Z	39Z
37Z	1124	37Y	36Z	38Z	36Y	38Y	35Z	39Z	35Y	39Y
38X	999	38W	37X	39X	-	-	36X	40W	36W	40W
38W	999	38X	-	-	37X	39X	36W	40X	36X	40X
38Y	1125	38Z	37Y	39Y	37Z	39Z	36Y	40Y	36Z	40Z
38Z	1125	38Y	37Z	39Z	37Y	39Y	36Z	40Z	36Y	40Y
39X	1000	-	38X	40X	38W	40W	37X	41X	-	-
39Y	1126	39Z	38Y	40Y	38Z	40Z	37Y	41Y	37Z	41Z
39Z	1126	39Y	38Z	40Z	38Y	40Y	37Z	41Z	37Y	41Y
40X	1001	40W	39X	41X	-	-	38X	42X	38W	42W
40W	1001	40X	-	-	39X	41X	38W	42W	38X	42X
40Y	1127	40Z	39Y	41Y	39Z	41Z	38Y	42Y	38Z	42Z
40Z	1127	40Y	39Z	41Z	39Y	41Y	38Z	42Z	38Y	42Y
41X	1002	-	40X	42X	40W	42W	39X	43X	-	-
41Y	1128	41Z	40Y	42Y	40Z	42Z	39Y	43Y	39Z	43Z
41Z	1128	41Y	40Z	42Z	40Y	42Y	39Z	43Z	39Y	43Y
42X	1003	42W	41X	43X	-	-	40X	44X	40W	44W
42W	1003	42X	-	-	41X	43X	40W	44W	40X	44X
42Y	1129	42Z	41Y	43Y	41Z	43Z	40Y	44Y	40Z	44Z
42Z	1129	42Y	41Z	43Z	41Y	43Y	40Z	44Z	40Y	44Y
43X	1004	-	42X	44X	42W	44W	41X	45X	-	-
43Y	1130	43Z	42Y	44Y	42Z	44Z	41Y	45Y	41Z	45Z
43Z	1130	43Y	42Z	44Z	42Y	44Y	41Z	45Z	41Y	45Y
44X	1005	44W	43X	45X	-	-	42X	46X	42W	46W
44W	1005	44X	-	-	43X	45X	42W	46W	42X	46X
44Y	1131	44Z	43Y	45Y	43Y	45Y	42Y	46Y	42Z	46Z
44Z	1131	44Y	43Z	45Z	43Z	45Z	42Z	46Z	42Y	46Y
45X	1006	-	44X	46X	44W	46W	43X	47X	-	-
45Y	1132	45Z	44Y	46Y	44Z	46Z	43Y	47Y	43Z	47Z
45Z	1132	45Y	44Z	46Z	44Y	46Y	43Z	47Z	43Y	47Y
46X	1007	46W	45X	47X	-	-	44X	48X	44W	48W
46W	1007	46X	-	-	45X	47X	44W	48W	44X	48X
46Y	1133	46Z	45Y	47Y	45Z	47Z	44Y	48Y	44Z	48Z
46Z	1133	46Y	45Z	47Z	45Y	47Y	44Z	48Z	44Y	48Y
47X	1008	-	46X	48X	46W	48W	45X	49X	-	-
47Y	1134	47Z	46Y	48Y	46Z	48Z	45Y	49Y	45Z	49Z
47Z	1134	47Y	46Z	48Z	46Y	48Y	45Z	49Z	45Y	49Y
48X	1009	48W	47X	49X	-	-	46X	50X	46W	50W
48W	1009	48X	-	-	47X	49X	46W	50W	46X	50X
48Y	1135	48Z	47Y	49Y	47Z	49Z	46Y	50Y	46Z	50Z
48Z	1135	48Y	47Z	49Z	47Y	49Y	46Z	50Z	46Y	50Y
49X	1010	-	48X	50X	48W	50W	47X	51X	-	-
49Y	1136	49Z	48Y	50Y	48Z	50Z	47Y	51Y	47Z	51Z
49Z	1136	49Y	48Z	50Z	48Y	50Y	47Z	51Z	47Y	51Y
50X	1011	50W	49X	51X	-	-	48X	52X	48W	52W
50W	1011	50X	-	-	49X	51X	48W	52W	48X	52X
50Y	1137	50Z	49Y	51Y	49Z	51Z	48Y	52Y	48Z	52Z
50Z	1137	50Y	49Z	51Z	49Y	51Y	48Z	52Z	48Y	52Y
51X	1012	-	50X	52X	50W	52W	49X	53X	-	-
51Y	1138	51Z	50Y	52Y	50Z	52Z	49Y	53Y	49Z	53Z
51Z	1138	51Y	50Z	52Z	50Y	52Y	49Z	53Z	49Y	53Y
52X	1013	52W	51X	53X	-	-	50X	54X	50W	54W
52W	1013	52X	-	-	51X	53X	50W	54W	50X	54X
52Y	1139	52Z	51Y	53Y	51Z	53Z	50Y	54Y	50Z	54Z
52Z	1139	52Y	51Z	53Z	51Y	53Y	50Z	54Z	50Y	54Y

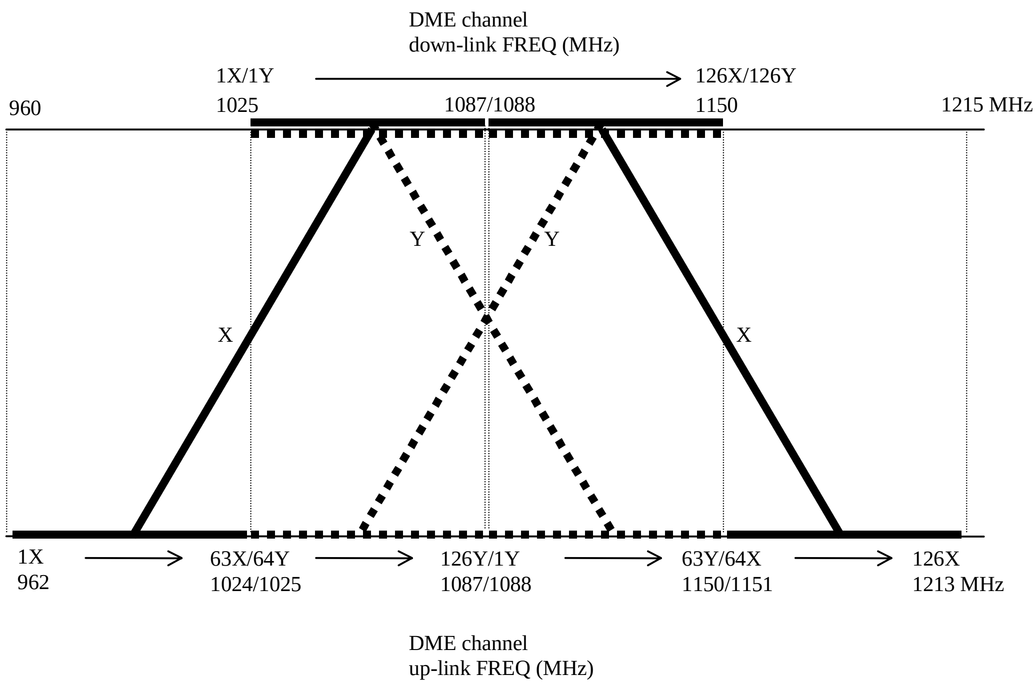
DME-channel	*Reply FREQ (MHz)*	*Co-FREQ different pulse code*	*1st adjacent FREQ same pulse code*		*1st adjacent FREQ different pulse code*		*2nd adjacent FREQ same pulse code*		*2nd adjacent FREQ different pulse code*	
53X	1014	-	52X	54X	52W	54W	51X	55X	-	-
53Y	1140	53Z	52Y	54Y	52Z	54Z	51Y	55Y	51Z	55Z
53Z	1140	53Y	52Z	54Z	52Y	54Y	51Z	55Z	51Y	55Y
54X	1015	54W	53X	55X	-	-	52X	56X	52W	56W
54W	1015	54X	-	-	53X	55X	52W	56W	52X	56X
54Y	1141	54Z	53Y	55Y	53Z	55Z	52Y	56Y	52Z	56Z
54Z	1141	54Y	53Z	55Z	53Y	55Y	52Z	56Z	52Y	56Y
55X	1016	-	54X	56X	54W	56W	53X	57X	-	-
55Y	1142	55Z	54Y	56Y	54Z	56Z	53Y	57Y	53Z	57Z
55Z	1142	55Y	54Z	56Z	54Y	56Y	53Z	57Z	53Y	57Y
56X	1017	56W	55X	57X	-	-	54X	58X	54W	58W
56W	1017	56X	-	-	55X	57X	54W	58W	54X	58X
56Y	1143	56Z	55Y	57Y	55Y	57Y	54Y	58Y	54Z	58Z
56Z	1143	56Y	55Z	57Z	55Z	57Z	54Z	58Z	54Y	58Y
57X	1018	-	56X	58X	56W	-	55X	59X	-	-
57Y	1144	-	56Y	58Y	56Z	-	55Y	59Y	55Z	-
58X	1019	-	57X	59X	-	-	56X	60X	56W	-
58Y	1145	-	57Y	59Y	-	-	56Y	60Y	56Z	-
59X	1020	-	58X	60X	-	-	57X	61X	-	-
59Y	1146	-	58Y	60Y	-	-	57Y	61Y	-	-
60X	1021	-	59X	61X	-	-	58X	62X	-	-
60Y	1147	-	59Y	61Y	-	-	58Y	62Y	-	-
61X	1022	-	60X	62X	-	-	59X	63X	-	-
61Y	1148	-	60Y	62Y	-	-	59Y	63Y	-	-
62X	1023	-	61X	63X	-	-	60X	-	-	64Y
62Y	1149	-	61Y	63Y	-	-	60Y	-	-	64X
63X	1024	-	62X	-	-	64Y	61X	-	-	65Y
63Y	1150	-	62Y	-	-	64X	61Y	-	-	65X
64X	1151	-	-	65X	63Y	-	-	66X	62Y	-
64Y	1025	-	-	65Y	63X	-	-	66Y	62X	-
65X	1152	-	64X	66X	-	-	-	67X	63Y	-
65Y	1026	-	64Y	66Y	-	-	-	67Y	63X	-
66X	1153	-	65X	67X	-	-	64X	68X	-	-
66Y	1027	-	65Y	67Y	-	-	64Y	68Y	-	-
67X	1154	-	66X	68X	-	-	65X	69X	-	-
67Y	1028	-	66Y	68Y	-	-	65Y	69Y	-	-
68X	1155	-	67X	69X	-	-	66X	70X	-	-
68Y	1029	-	67Y	69Y	-	-	66Y	70Y	-	-
69X	1156	-	68X	70X	-	-	67X	71X	-	-
69Y	1030	-	68Y	70Y	-	-	67Y	71Y	-	-
70X	1157	-	69X	71X	-	-	68X	72X	-	-
70Y	1031	-	69Y	71Y	-	-	68Y	72Y	-	-
71X	1158	-	70X	72X	-	-	69X	73X	-	-
71Y	1032	-	70Y	72Y	-	-	69Y	73Y	-	-
72X	1159	-	71X	73X	-	-	70X	74X	-	-
72Y	1033	-	71Y	73Y	-	-	70Y	74Y	-	-
73X	1160	-	72X	74X	-	-	71X	75X	-	-
73Y	1034	-	72Y	74Y	-	-	71Y	75Y	-	-
74X	1161	-	73X	75X	-	-	72X	76X	-	-
74Y	1035	-	73Y	75Y	-	-	72Y	76Y	-	-
75X	1162	-	74X	76X	-	-	73X	77X	-	-
75Y	1036	-	74Y	76Y	-	-	73Y	77Y	-	-
76X	1163	-	75X	77X	-	-	74X	78X	-	-
76Y	1037	-	75Y	77Y	-	-	74Y	78Y	-	-
77X	1164	-	76X	78X	-	-	75X	79X	-	-
77Y	1038	-	76Y	78Y	-	-	75Y	79Y	-	-
78X	1165	-	77X	79X	-	-	76X	80X	-	-
78Y	1039	-	77Y	79Y	-	-	76Y	80Y	-	80Z
79X	1166	-	78X	80X	-	-	77X	81X	-	-
79Y	1040	-	78Y	80Y	-	80Z	77Y	81Y	-	81Z
80X	1167	-	79X	81X	-	-	78X	82X	-	-
80Y	1041	80Z	79Y	81Y	-	81Z	78Y	82Y	-	82Z
80Z	1041	80Y	-	81Z	79Y	81Y	-	82Z	78Y	82Y

DME-channel	*Reply FREQ (MHz)*	*Co-FREQ different pulse code*	*1st adjacent FREQ same pulse code*		*1st adjacent FREQ different pulse code*		*2nd adjacent FREQ same pulse code*		*2nd adjacent FREQ different pulse code*	
81X	1168	-	80X	82X	-	-	79X	83X	-	-
81Y	1042	81Z	80Y	82Y	80Z	82Z	79Y	83Y	-	83Z
81Z	1042	81Y	80Z	82Z	80Y	82Y	-	83Z	79Y	83Y
82X	1169	-	81X	83X	-	-	80X	84X	-	-
82Y	1043	82Z	81Y	83Y	81Z	83Z	80Y	84Y	80Z	84Z
82Z	1043	82Y	81Z	83Z	81Y	83Y	80Z	84Z	80Y	84Y
83X	1170	-	82X	84X	-	-	81X	85X	-	-
83Y	1044	83Z	82Y	84Y	82Z	84Z	81Y	85Y	81Z	85Z
83Z	1044	83Y	82Z	84Z	82Y	84Y	81Z	85Z	81Y	85Y
84X	1171	-	83X	85X	-	-	82X	86X	-	-
84Y	1045	84Z	83Y	85Y	83Z	85Z	82Y	86Y	82Z	86Z
84Z	1045	84Y	83Z	85Z	83Y	85Y	82Z	86Z	82Y	86Y
85X	1172	-	84X	86X	-	-	83X	87X	-	-
85Y	1046	85Z	84Y	86Y	84Z	86Z	83Y	87Y	83Z	87Z
85Z	1046	85Y	84Z	86Z	84Y	86Y	83Z	87Z	83Y	87Y
86X	1173	-	85X	87X	-	-	84X	88X	-	-
86Y	1047	86Z	85Y	87Y	85Z	87Z	84Y	88Y	84Z	88Z
86Z	1047	86Y	85Z	87Z	85Y	87Y	84Z	88Z	84Y	88Y
87X	1174	-	86X	88X	-	-	85X	89X	-	-
87Y	1048	87Z	86Y	88Y	86Z	88Z	85Y	89Y	85Z	89Z
87Z	1048	87Y	86Z	88Z	86Y	88Y	85Z	89Z	85Y	89Y
88X	1175	-	87X	89X	-	-	86X	90X	-	-
88Y	1049	88Z	87Y	89Y	87Z	89Z	86Y	90Y	86Z	90Z
88Z	1049	88Y	87Z	89Z	87Y	89Y	86Z	90Z	86Y	90Y
89X	1176	-	88X	90X	-	-	87X	91X	-	-
89Y	1050	89Z	88Y	90Y	88Z	90Z	87Y	91Y	87Z	91Z
89Z	1050	89Y	88Z	90Z	88Y	90Y	87Z	91Z	87Y	91Y
90X	1177	-	89X	91X	-	-	88X	92X	-	-
90Y	1051	90Z	89Y	91Y	89Z	91Z	88Y	92Y	88Z	92Z
90Z	1051	90Y	89Z	91Z	89Y	91Y	88Z	92Z	88Y	92Y
91X	1178	-	90X	92X	-	-	89X	93X	-	-
91Y	1052	91Z	90Y	92Y	90Z	92Z	89Y	93Y	89Z	93Z
91Z	1052	91Y	90Z	92Z	90Y	92Y	89Z	93Z	89Y	93Y
92X	1179	-	91X	93X	-	-	90X	94X	-	-
92Y	1053	92Z	91Y	93Y	91Z	93Z	90Y	94Y	90Z	94Z
92Z	1053	92Y	91Z	93Z	91Y	93Y	90Z	94Z	90Y	94Y
93X	1180	-	92X	94X	-	-	91X	95X	-	-
93Y	1054	93Z	92Y	94Y	92Z	94Z	91Y	95Y	91Z	95Z
93Z	1054	93Y	92Z	94Z	92Y	94Y	91Z	95Z	91Y	95Y
94X	1181	-	93X	95X	-	-	92X	96X	-	-
94Y	1055	94Z	93Y	95Y	93Z	95Z	92Y	96Y	92Z	96Z
94Z	1055	94Y	93Z	95Z	93Y	95Y	92Z	96Z	92Y	96Y
95X	1182	-	94X	96X	-	-	93X	97X	-	-
95Y	1056	95Z	94Y	96Y	94Z	96Z	93Y	97Y	93Z	97Z
95Z	1056	95Y	94Z	96Z	94Y	96Y	93Z	97Z	93Y	97Y
96X	1183	-	95X	97X	-	-	94X	98X	-	-
96Y	1057	96Z	95Y	97Y	95Z	97Z	94Y	98Y	94Z	98Z
96Z	1057	96Y	95Z	97Z	95Y	97Y	94Z	98Z	94Y	98Y
97X	1184	-	96X	98X	-	-	95X	99X	-	-
97Y	1058	97Z	96Y	98Y	96Z	98Z	95Y	99Y	95Z	99Z
97Z	1058	97Y	96Z	98Z	96Y	98Y	95Z	99Z	95Y	99Y
98X	1185	-	97X	99X	-	-	96X	100X	-	-
98Y	1059	98Z	97Y	99Y	97Z	99Z	96Y	100Y	96Z	100Z
98Z	1059	98Y	97Z	99Z	97Y	99Y	96Z	100Z	96Y	100Y
99X	1186	-	98X	100X	-	-	97X	101X	-	-
99Y	1060	99Z	98Y	100Y	98Z	100Z	97Y	101Y	97Z	101Z
99Z	1060	99Y	98Z	100Z	98Y	100Y	97Z	101Z	97Y	101Y
100X	1187	-	99X	101X	-	-	98X	102X	-	-
100Y	1061	100Z	99Y	101Y	99Z	101Z	98Y	102Y	98Z	102Z
100Z	1061	100Y	99Z	101Z	99Y	101Y	98Z	102Z	98Y	102Y
101X	1188	-	100X	102X	-	-	99X	103X	-	-
101Y	1062	101Z	100Y	102Y	100Z	102Z	99Y	103Y	99Z	103Z
101Z	1062	101Y	100Z	102Z	100Y	102Y	99Z	103Z	99Y	103Y
102X	1189	-	101X	103X	-	-	100X	104X	-	-

DME-channel	*Reply FREQ (MHz)*	*Co-FREQ different pulse code*	*1st adjacent FREQ same pulse code*		*1st adjacent FREQ different pulse code*		*2nd adjacent FREQ same pulse code*		*2nd adjacent FREQ different pulse code*	
102Y	1063	102Z	101Y	103Y	101Z	103Z	100Y	104Y	100Z	104Z
102Z	1063	102Y	101Z	103Z	101Y	103Y	100Z	104Z	100Y	104Y
103X	1190	-	102X	104X	-	-	101X	105X	-	-
103Y	1064	103Z	102Y	104Y	102Z	104Z	101Y	105Y	101Z	105Z
103Z	1064	103Y	102Z	104Z	102Y	104Y	101Z	105Z	101Y	105Y
104X	1191	-	103X	105X	-	-	102X	106X	-	-
104Y	1065	104Z	103Y	105Y	103Z	105Z	102Y	106Y	102Z	106Z
104Z	1065	104Y	103Z	105Z	103Y	105Y	102Z	106Z	102Y	106Y
105X	1192	-	104X	106X	-	-	103X	107X	-	-
105Y	1066	105Z	104Y	106Y	104Z	106Z	103Y	107Y	103Z	107Z
105Z	1066	105Y	104Z	106Z	104Y	106Y	103Z	107Z	103Y	107Y
106X	1193	-	105X	107X	-	-	104X	108X	-	-
106Y	1067	106Z	105Y	107Y	105Z	107Z	104Y	108Y	104Z	108Z
106Z	1067	106Y	105Z	107Z	105Y	107Y	104Z	108Z	104Y	108Y
107X	1194	-	106X	108X	-	-	105X	109X	-	-
107Y	1068	107Z	106Y	108Y	106Z	108Z	105Y	109Y	105Z	109Z
107Z	1068	107Y	106Z	108Z	106Y	108Y	105Z	109Z	105Y	109Y
108X	1195	-	107X	109X	-	-	106X	110X	-	-
108Y	1069	108Z	107Y	109Y	107Z	109Z	106Y	110Y	106Z	110Z
108Z	1069	108Y	107Z	109Z	107Y	109Y	106Z	110Z	106Y	110Y
109X	1196	-	108X	110X	-	-	107X	111X	-	-
109Y	1070	109Z	108Y	110Y	108Z	110Z	107Y	111Y	107Z	111Z
109Z	1070	109Y	108Z	110Z	108Y	110Y	107Z	111Z	107Y	111Y
110X	1197	-	109X	111X	-	-	108X	112X	-	-
110Y	1071	110Z	109Y	111Y	109Z	111Z	108Y	112Y	108Z	112Z
110Z	1071	110Y	109Z	111Z	109Y	111Y	108Z	112Z	108Y	112Y
111X	1198	-	110X	112X	-	-	109X	113X	-	-
111Y	1072	111Z	110Y	112Y	110Z	112Z	109Y	113Y	109Z	113Z
111Z	1072	111Y	110Z	112Z	110Y	112Y	109Z	113Z	109Y	113Y
112X	1199	-	111X	113X	-	-	110X	114X	-	-
112Y	1073	112Z	111Y	113Y	111Z	113Z	110Y	114Y	110Z	114Z
112Z	1073	112Y	111Z	113Z	111Y	113Y	110Z	114Z	110Y	114Y
113X	1200	-	112X	114X	-	-	111X	115X	-	-
113Y	1074	113Z	112Y	114Y	112Z	114Z	111Y	115Y	111Z	115Z
113Z	1074	113Y	112Z	114Z	112Y	114Y	111Z	115Z	111Y	115Y
114X	1201	-	113X	115X	-	-	112X	116X	-	-
114Y	1075	114Z	113Y	115Y	113Z	115Z	112Y	116Y	112Z	116Z
114Z	1075	114Y	113Z	115Z	113Y	115Y	112Z	116Z	112Y	116Y
115X	1202	-	114X	116X	-	-	113X	117X	-	-
115Y	1076	115Z	114Y	116Y	114Z	116Z	113Y	117Y	113Z	117Z
115Z	1076	115Y	114Z	116Z	114Y	116Y	113Z	117Z	113Y	117Y
116X	1203	-	115X	117X	-	-	114X	118X	-	-
116Y	1077	116Z	115Y	117Y	115Z	117Z	114Y	118Y	114Z	118Z
116Z	1077	116Y	115Z	117Z	115Y	117Y	114Z	118Z	114Y	118Y
115X	1204	-	116X	118X	-	-	115X	119X	-	-
115Y	1078	115Z	116Y	118Y	116Z	118Z	115Y	119Y	115Z	119Z
115Z	1078	115Y	116Z	118Z	116Y	118Y	115Z	119Z	115Y	119Y
118X	1205	-	117X	119X	-	-	116X	120X	-	-
118Y	1079	118Z	117Y	119Y	117Z	119Z	116Y	120Y	116Z	-
118Z	1079	118Y	117Z	119Z	117Y	119Y	116Z	-	116Y	120Y
119X	1206	-	118X	120X	-	-	117X	121X	-	-
119Y	1080	119Z	118Y	120Y	118Z	-	117Y	121Y	115Z	-
119Z	1080	119Y	118Z	~~120Z~~	118Y	120Y	117Z	-	115Y	121Y
120X	1207	-	119X	121X	-	-	118X	122X	-	-
120Y	1081	-	119Y	121Y	119Z	-	118Y	122Y	118Z	-
121X	1208	-	120X	122X	-	-	119X	123X	-	-
121Y	1082	-	120Y	122Y	-	-	119Y	123Y	119Z	-
122X	1209	-	121X	123X	-	-	120X	124X	-	-
122Y	1083	-	121Y	123Y	-	-	120Y	124Y	-	-
123X	1210	-	122X	124X	-	-	121X	125X	-	-
123Y	1084	-	122Y	124Y	-	-	121Y	125Y	-	-
124X	1211	-	123X	125X	-	-	122X	126X	-	-
124Y	1085	-	123Y	125Y	-	-	122Y	126Y	-	-
125X	1212	-	124X	126X	-	-	123X	-	-	-

DME-channel	*Reply FREQ (MHz)*	*Co-FREQ different pulse code*	*1st adjacent FREQ same pulse code*		*1st adjacent FREQ different pulse code*		*2nd adjacent FREQ same pulse code*		*2nd adjacent FREQ different pulse code*	
125Y	1086	-	124Y	126Y	-	-	123Y	1Y	-	-
126X	1213	-	125X	-	-	-	124X	-	-	-
126Y	1087	-	125Y	1Y	-	-	124Y	2Y	-	-

Note: *The DME channelling and frequency pairing (see figure below) results in "anomalous" adjacent channel combinations around 63X/64X and 63Y/64Y (e.g. 63X and 64Y). The term "up-link FREQ" is used instead of "reply FREQ".*



2 MLS

2.1 General

2.1.1 The 200 MLS channels that are presently planned, occupy the frequency segment 5031 – 5091 MHz within the band 5000 – 5250 MHz, that is allocated to aeronautical radio navigation.

2.1.2 References to documents:

- Annex 10, Volume I, paragraph 3.11.4.1
  (channelling);
- Annex 10, Attachment G to Volume I, paragraph 9
  (geographical separation, adjacent frequency requirements);
- European Region Air Navigation Plan (Doc 7754), Volume I, Basic ANP, Part IV, paragraph 49
  (use of associated DME channels, 10000 ft protection height, frequency tripling with ILS/DME).

2.1.3 The range is standardised to 20 NM and the protection altitude to 20000 feet (within Europe reduced). For practical reasons the frequency planning is based on a circle with 23 NM radius. An unwanted signal must not be stronger than the level of receiver noise due to the risk of locking onto the wrong station. Both the first and second adjacent channels are considered.

2.1.3.1 Within Europe MLS is normally protected only to 10000 feet altitude (20000 feet in other regions and special cases in Europe) and a deviation is listed as remark in Table COM 3. The Table COM 3 includes all planned stations for the implementation of MLS in Europe.

2.1.3.2 All MLS installations include a frequency-paired DME. For civil use only X- and Y-channels are generally accepted while W- and Z-channels may be accepted by military users.

2.1.4 Co-ordination should be made with States within a radius of 400 NM due to the fact that the same DME channel can be used by the other State for en-route purposes.

2.1.5 Information on the planning of identifications can be found in section 7 below.

2.2 Frequency assignment planning criteria

2.2.1 Protection Requirements

2.2.1.1 Co-channel Protection Requirements

2.2.1.1.1 The DPSK preamble signal protection is the most demanding protection. The requirement is that power density of any undesired DPSK preamble signal shall not exceed the assumed noise-threshold of the receiver (-114.5 dBW/m²) throughout the designated operational coverage of the desired MLS facility.

2.2.1.1.2 Since the minimum power density of the DPSK preamble signal at the edge of the designated operational coverage is -89.5 dBW/m² in the approach azimuth direction and -81.5 dBW/m² in the back azimuth direction, the effective Desired/Undesired (D/U) ratios are 25 dB and 33 dB respectively.

2.2.1.1.3 These protection requirements for the DPSK preamble signal also adequately protect the scanning-beam signal and the out-of-coverage signal.

Note: The EIRP in both the approach azimuth and back azimuth direction is the same.

2.2.1.2 Adjacent Channel Protection Requirements

2.2.1.2.1 The receiver adjacent channel rejection for the first and second adjacent channels is 33 dB (Annex 10, Volume I, Attachment G to Part I, paragraph 7.2.2). Using the criteria in 4.3.1.1.1 above permits the power density on the 1^{st} and 2^{nd} adjacent channels to be increased to -114.5 + 33 = -81.5 dBW/m² throughout the coverage of the desired MLS.

2.2.1.2.2 For third and higher adjacent channels the rejection is assumed to be infinite. These channels therefore do not require consideration in frequency planning.

Note: Protection of adjacent channel MLS signals does not automatically include protection of the associated DME; separate investigation of the protection of the DME element is required.

Note secretary ACP: These parameters are under consideration and more restrictive criteria may need to be applied. This matter is under consideration in the NSP as well as the European Frequency Management Group.

2.2.1.3 Designated Operational Coverage

2.2.1.3.1 For frequency planning purposes the designated operational coverage is:

a) up to a range of 20 NM (37 km) from runway threshold
b) up to a height of 10000 ft (3000 m)
c) omnidirectional in azimuth

2.2.2 Propagation Model

2.2.2.1 Propagation Characteristics

2.2.2.1.1 The same propagation conditions along the path of the desired and undesired signals are assumed. For distance up to the radio horizon, free space attenuation is assumed. Beyond the radio horizon, an attenuation rate of 2.7 dB/NM is used. This value is derived from the 5000 MHz/50% time propagation curve in Rec. ITU-R P.528-2 (former CCIR Rec. 528-1).

2.2.2.1.2 The minimum field strength required at the edge of coverage of the MLS is given in Annex 10 in terms of power density (dBW/m²). The EIRP of the MLS transmitter can be calculated by the free space formula:

$$P_d = \frac{EIRP}{4\pi d^2} \qquad (1)$$

where
P_d = power density in W/m^2
EIRP = effective isotropically radiated power (W)
d = distance (metres).

Formula (1) expressed in logarithmic terms gives

$$P_d = EIRP - 20 \log d - 76.3 \qquad (2)$$

Formula (1) and (2) may only be used when line-of-sight conditions exist or to calculate the path attenuation up to the radio horizon.

2.2.2.1.3 When calculating the minimum separation distances a smooth earth is assumed; the radio horizon is calculated assuming a 4/3 earth radius.

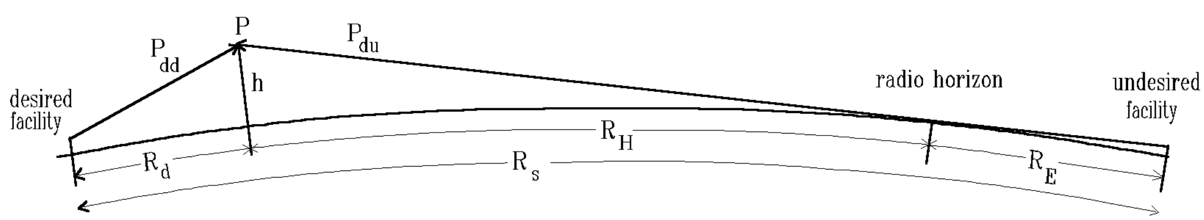
2.2.2.1.4 The geographical separation between the undesired station and the edge of coverage of the desired station is to be calculated by projecting the power density at the edge of coverage of the undesired station to a point such that the distance produces the necessary attenuation.

2.2.2.1.5 The phase centre of the transmitting antenna is assumed to be 7 feet above ground level.

2.2.2.1.6 Runway length of 3 NM is assumed.

2.2.3 Calculation of Separation Distance

2.2.3.1 Co-channel Separation Distances



P_{dd}	= power density from desired facility at point P
P_{du}	= power density from undesired facility at point P
R_H	= distance from point P to radio horizon
R_E	= distance from radio horizon to undesired facility
h	= designated operational height.

The power density of the undesired MLS facility at point P is:

$$P_{du} = -114.5 = EIRP - 20 \log R_H - 2.7\, R_E - 76.3 \qquad (3)$$

where R_H is the distance from P to the radio horizon (free space propagation) and R_E is the distance from the radio horizon to the undesired MLS facility.

The power density of the desired MLS facility at its coverage is:

$$P_{dd} = -89.5 = EIRP - 20 \log 23 - 76.3 \qquad (4)$$

Since the desired and undesired facilities are assumed to have equal EIRP, one can eliminate EIRP from (3) and (4) to obtain:

$$EIRP = -114.5 + 20 \log R_H + 2.7\, R_E + 76.3 = -89.5 + 20 \log 23 + 76.3$$

or

$$2.7\ R_E = 52.24 - 20 \log R_H. \qquad (5)$$

Calculation of the distance from point P to the radio horizon, assuming a smooth earth with 4/3 radius gives:

$$D = K\ (\sqrt{h} + \sqrt{7}\ ) \qquad (6)$$

where
D = distance R_H in NM
K = 1.23
h = height of protection point P in feet
7 = height of the antenna above ground level (7 ft)

HEIGHT (ft)	DISTANCE R_H (NM)
5 000	90.23
10 000	126.25
15 000	153.89
20 000	177.20

Distance to the radio horizon for different heights of the protection point P

These distances substituted in (5) allow the calculation of the required excess distance beyond the radio horizon R_E and one so obtains for the total minimum separation distance between the desired and undesired facility:

Protection Height	Separation Distance
5000 ft	23 + 90.23 + 4.86 = 118 NM
10000 ft	23 + 126.25 + 3.78 = 153 NM
15000 ft	23 + 153.89 + 3.15 = 180 NM
20000 ft	23 + 177.20 + 2.7 = 203 NM

Separation distances between the desired and the undesired MLS facility for different heights of the coverage area.
(assuming equal EIRP of the desired and undesired facilities)

Since in the situation above the required protection of the desired MLS facility is dependent on the large attenuation losses obtained on that portion of the radio path that is beyond the radio horizon, these separation distances must be considered as the absolute minimum.

In cases where the EIRPs of the two MLS facilities are not equal, the calculated separation distances must be increased with 0.4 NM for each dB where these EIRPs are different.

2.2.3.2 Adjacent Channel Separation Distances (1st and 2nd adjacent channels)

Annex 10 requires the receiver adjacent channel rejection to be 33 dB for the first and second adjacent channels. This permits the maximum level of the undesired DPSK preamble signal to increase to -114.5 + 33 = -81.5 dBW/m². In this case, the separation distance between the undesired MLS facility and point P is smaller than the distance to the radio horizon and one has:

$$P_{du} = -81.5 \text{ dBW/m}^2 = EIRP - 20 \log R_A - 76.3 \qquad (7)$$

where
R_A = distance from point P to undesired adjacent channel MLS station.

Assuming again equal EIRP for the desired and the undesired facility, one obtains by eliminating EIRP from (7) and (4):

$$EIRP = -81.5 + 20 \log R_A + 76.3 = -89.5 + 20 \log 23 + 76.3$$

or

$$R_A = 9.15 \text{ NM}. \qquad (8)$$

The minimum distance between the two MLS facilities is thus:

$$23 + 9.15 = 32 \text{ NM}$$

Third and higher adjacent channels need not to be considered.

When there is a difference in EIRP between the two facilities concerned, the separation distance must be increased in accordance with the following table:

Difference in EIRP	Increase of the separation distance
1 dB	2 NM
2 dB	3 NM
3 dB	4 NM
4 dB	6 NM
5 dB	7 NM
6 dB	10 NM
7 dB	12 NM
8 dB	14 NM
9 dB	17 NM
10 dB	20 NM

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NSP WGW - WP/50

NSP WG of the Whole meeting

St Petersburg, Russia, 25th May to 4th June 2004

Agenda Item 4d: MLS

MLS Spectrum issues validation

Presented by Tim Murphy

(Prepared by Pierre Gayraud, THALES Avionics
and Stéphane Devaux, THALES Communications)

WP 48 proposes to amend the SARPS requirements concerning a frequency protection issue: protection of the airborne MLS receivers against the potential interferences due to surrounding MLS ground stations transmitting on adjacent channels.
The amendment consists in amending:

- The MLS radio frequency spectrum performances paragraph
- The receiver adjacent channel spurious response paragraph
- The Geographical Frequency Separation criteria Attachment G paragraph

The present Working Paper addresses the second change concerning the receiver adjacent channel spurious response paragraph.
It provides analysis demonstrating that the requirements are consistent with the other receiver requirements as well as test results showing that a given receiver complies with the proposed requirements.

Introduction

WP 12 presented during the CN&TS SG meeting in Toulouse and the WP 48 presented during the St. Petersburg meeting propose to change the SARPS requirements concerning a frequency protection issue: the protection of the MLS receivers against the potential interferences due to surrounding MLS ground stations transmitting on adjacent channels.

The changes impact:

- The MLS radio frequency spectrum performances paragraph
- The receiver adjacent channel spurious response paragraph
- The Geographical Frequency Separation criteria Attachment G paragraph

The present WP addresses the second point: Receiver adjacent channel spurious response.

WP 48 proposes to replace the current requirement:

3.11.6.1.4 Adjacent channel spurious response. The receiver performance specified in 3.11.6 above shall be met when a desired signal is being tracked in the presence of an adjacent channel signal that is 25 dB stronger.

by the following requirement:

3.11.6.1.4 Adjacent channel spurious response.
"The receiver performance specified in 3.11.6 above shall be met when the ratio between the desired tracked signals and the noise produced by the adjacent channel signals in a 150 kHz bandwidth centred around the desired frequency is equal or greater than the SNR values:

a. as specified in the table X1 when the power density received from the desired ground station is equal or higher than the values as specified in the table Y, or

b. as specified in the table X2 when the power density received from the desired ground station is between the minimum density power values as specified in the paragraph 3.11.4.10.1 and the values as specified in the table Y"

	Angular function Beam width *(Note 2)*		
Function	1°	2°	3°
Approach Azimuth guidance	- 69.8 dBW/m²	- 63.8 dBW/m²	- 60.2 dBW/m²
High Rate Approach Azimuth guidance	- 74.6 dBW/m²	- 68.5 dBW/m²	- 65 dBW/m²
Approach Elevation Guidance	-71 dBW/m²	- 65 dBW/m²	N/A
Back Azimuth	N/A *(Note 4)*	N/A *(Note 4)*	N/A *(Note 4)*

Table Y

		SNR (Note1)		
		Beam width ***(Note 2)***		
Function	Data	1°	2°	3°
Approach Azimuth guidance	5 dB	24.7 dB	30.7 dB	34.3 dB
High Rate Approach Azimuth guidance	5 dB	19.9 dB	26 dB	29.5 dB
Approach Elevation Guidance	5 dB	23.5 dB	29.5 dB	N/A
Back Azimuth b *(Note 4)*	5 dB	5.2 dB	11.2 dB	14.8 dB

Table X1

		SNR (Note 1)		
		Beam width *(Note 2)*		
Function	Data	1°	2°	3°
Approach Azimuth guidance	5 dB	8.2 dB	14.3 dB	17.8 dB
High Rate Approach Azimuth guidance	5 dB	3.5 dB	9.5 dB	13 dB

Approach Elevation Guidance	5 dB	3.5 dB	9.5 dB	N/A
Back Azimuth *(Note 4)*	5 dB	5.2 dB	11.2 dB	14.8 dB

Table X2

Note 1: When the radiated desired signal power density is high enough to cause the airborne receiver noise contribution to be insignificant, the airborne CMN contribution for Elevation and Approach Azimuth guidance (not for Back Azimuth) is required as stated by paragraph 3.11.6.1.1. to be reduced compared to the CMN contribution when the radiated desired signal power density are at the minimum specified in 3.11.4.10.1. and the minimum SNR are therefore higher.

Note 2 : The relationship is linear between adjacent points designated by the beam widths.

Note 3 : These SNR values have to be protected by the service provider through application of frequency separation criteria as explained in Appendix G § 9.3.

Note 4 : As there is no change in Back Azimuth guidance accuracy when the airborne receiver noise may be considered as insignificant, the same SNR are to be applied for Back Azimuth.

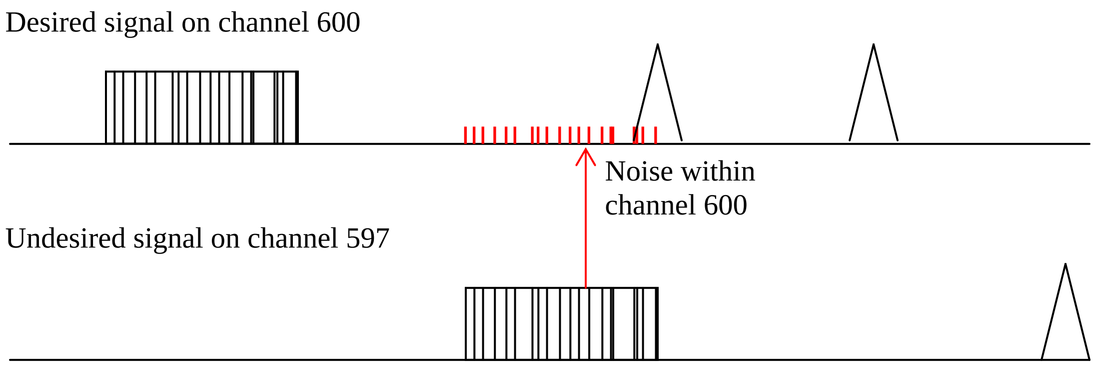
Validation

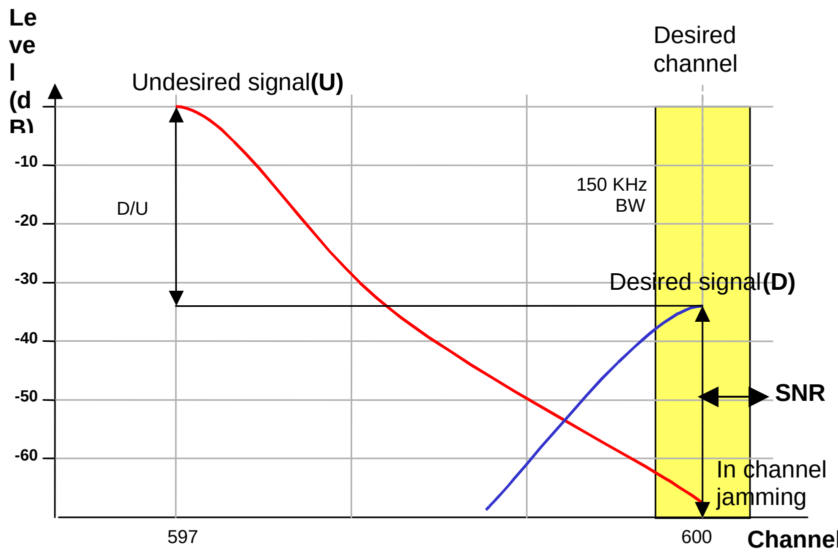
Consistency of the proposed requirements with the other current receiver requirements

Airborne MLS equipments receive two kinds of signals from MLS ground stations:

- Data signals that are DPSK modulated i.e. their spectrum spreads outside the allocated channel,
- Angle signals that are narrow band i.e. their spectrum don't spread outside the allocated channel,

As a consequence, only the Data signals from an undesired station transmitting on an adjacent channel can transmit noise into the desired channel and potentially creates interferences in the receiver.





The noise can affect:

- The reception of the desired Data signals

  The impact can be a loss of DPSK detection.

  The MLS Guidance Materials (Attachment G, 2.6.1.1 and Table G-2) state that the minimum signal-to-noise ratio (SNR) needed for an at least 72 per cent detection probability of the DPSK transmission is 5 dB. It means that the desired Data signals have to be 5 dB stronger than the noise. This value has been used to establish the minimum level of DPSK in the SARPS (3.11.4.10): –89,5 dBW/m² which is 5 dB above the receiver noise (Attachment G, 2.6.2.1 and Table G-2).

  The minimum SNR in tables X1 and X2 are set to this same 5 dB value.

- The reception of the desired Angle signals.

  The impact can be errors on beam measurements that is to say a CMN or PFE increase. Indeed, the nature of the noise (coloured and random) does not cause a bias in the angle decoding. So, this noise has low impact on the PFE and its impact is firstly CMN.

  As explained in WP/48 the proposed values are based on the formula in Attachment G, 2.6.1.2. It is the same formula that was used to determine the minimum angle signals (SARPS 3.11.4.10) with respect to the receiver noise (i.e. the minimum SNR with respect to the receiver noise).

Conclusion: the proposed change requires the receiver to meet its performance for desired signals that are above the undesired signal in the same channel from a quantity identical to the SNR value used for the determination of the minimum levels above the receiver noise.

Impact on the receiver

Tests have demonstrated that:

- The requirement concerning the decoding of data is not the critical one: it is easily achieved when the angle requirement is achieved.
- Concerning angles, for the same SNR the impact on the CMN due to noise coming from undesired residual of MLS signals is less than the impact of the receiver noise. For instance, if the desired signal is set to –40 dBm, in presence of an undesired of –60 dBm, the CMN performance is better than when the desired is set to –100 dBm, assuming a thermal noise of –120 dBm.

The reason is that the receiver noise is a permanent noise whereas the noise due to undesired residual of MLS signals is intermittent (see the first figure in section 2.1) and does not affect all the angle signals.

Consequently, this new requirement does not impact the current design of the receiver.

Note: as mentioned in WP/48 the current requirement expressed in terms of D/U can require very low SNR and a receiver meeting the current requirement would necessarily meet the proposed one.

Tests

This section provides the results of the validation tests conducted on a THALES TLS 755-14 receiver.

Calibration of the noise

The level of spurious transmitted by the MLS Set 2 (see figure below) has been first calibrated. The purpose was to measure the actual spectrum attenuation on the adjacent channels.

The signal generator being set on a given channel (N), the spectrum analyser central frequency is offset step by step until the measured level is closed to the analyser resolution. Each step corresponds to a channel width, i.e. 300 kHz.

The resolution of the analyser was set to 150 KHz (or 100 kHz with a subsequent shape correction).

The purpose being to measure the level of the DPSK, the level of the beams were set to the level of DPSK.

The measurements were performed with the spectrum analyser set to a SPAN 2 MHz and in MAX HOLD mode and without synchronisation.

Identical results are obtained with the spectrum analyser in SPAN 0, MAX HOLD and with a synchronisation on data words 1 or 2.

At the issue of this calibration, the relationship between the spectrum attenuation and the channel separation was tabulated (dash curve on the figures below). Note that this calibration was made for the different channels tested, in high and low level.

A specific amplifier was required to measure the signal generator level for low level. The accuracy of these measurements is estimated within the range 1-2 dB.

Installation

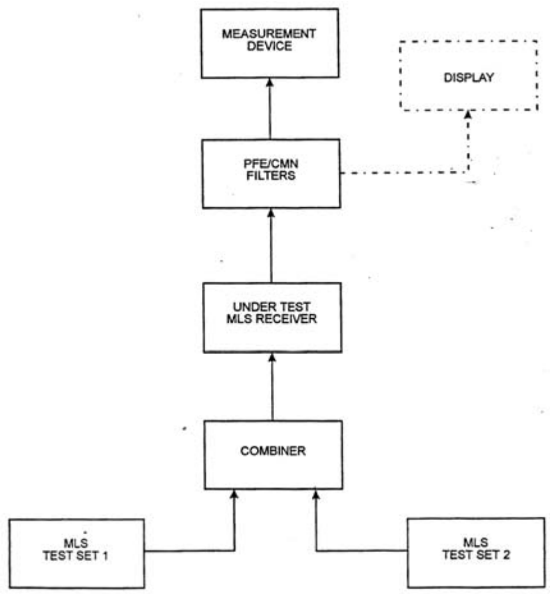


Figure 5-1: Multiple Input Signal Test Configuration

The above figure (extracted from MOPS ED-36A and similar to figure 2-5 in DO-177) shows the test installation:

- MLS Test set 1 is used as the desired set: level S, channel C1
- MLS Test set 2 is used as the undesired, set on channel C2, with all functions present including data words, auxiliary data words and back azimuth. The beam levels are set to the same level as the DPSK.

On channel C1, the level of the spurious is given by:
N = absolute level of MLS test 2 on selected channel (C2) – spectrum attenuation (C1-C2).
The spectrum attenuation function is the tabulation established previously.

Measurement validating the adequacy of SNR requirements

Method

Two series of measurements are made, according to Table Y:

- for high level desired signals (correspond to CMN 0,01° and 0,015°)
- for low level desired signals (-100 dBm) that correspond to CMN 0,1° and 0,08°.

For the first series, the undesired is set to –20 dBm on channel C2. The desired is set successively to channel C1 = C2 +1, 2, 3, …8. Its level is set in order to meet the validity criteria (SSM = NO), the PFE criteria and the CMN criteria.

The SNR is given by the difference S – N for channel C1. This value of SNR shall be less than the SNR provided in table of section 1.

For the second series of tests, the desired is fixed to –100 dBm. The undesired is set to channel C2 and its level is set in order to meet the previous criteria.

The SNR measurement method is the same as for the first series.

Results

The results are provided below for High level signals and then for Low level signals (for Azimuth and Elevation).
For the purpose of this demonstration the levels are expressed with respect to the level of the undesired signal ("attenuation").

Legend:

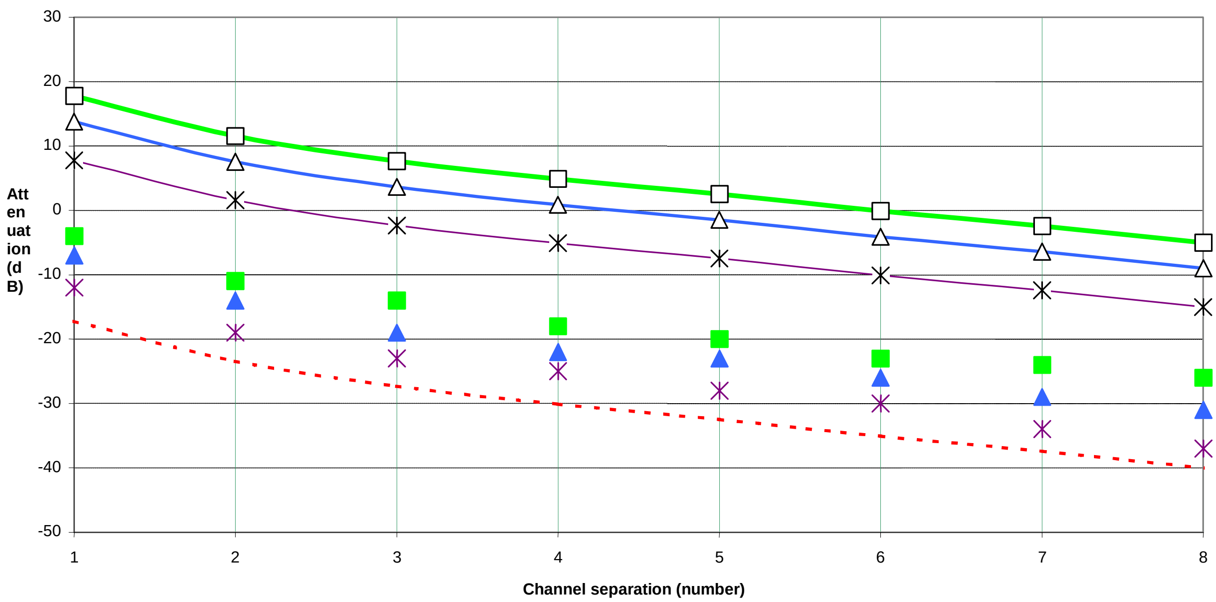
Undesired signal (150 kHz RBW Max hold)

Minimum desired signal level:

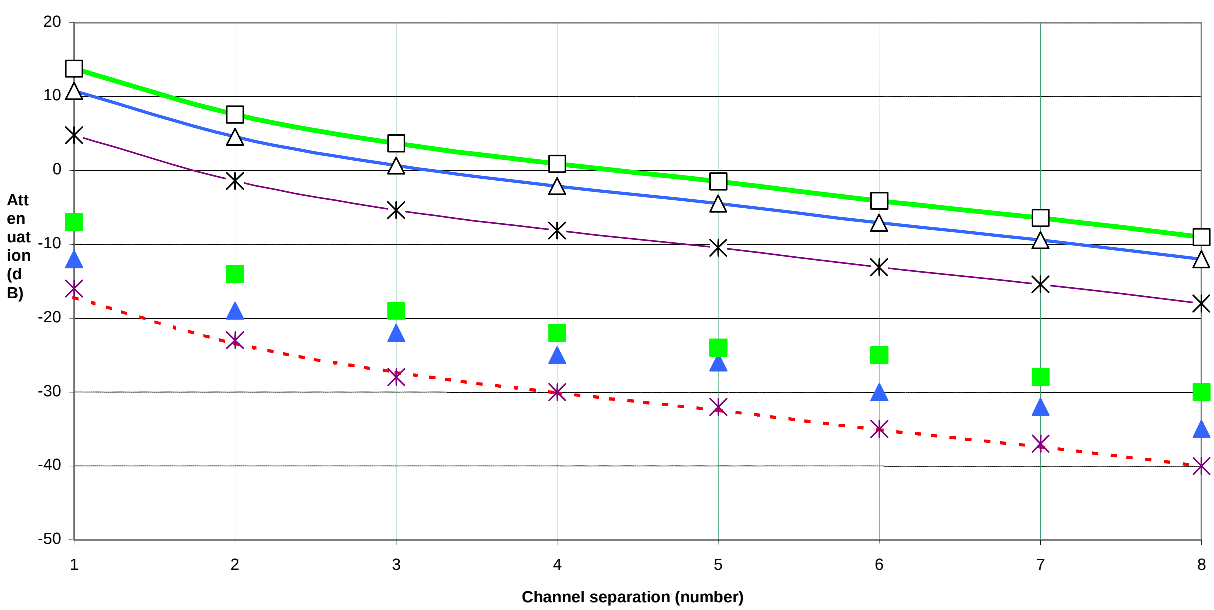
Channel separation (number)

Proposed requirement	Measured	
		BW 3°
		BW 2°
	X	BW 1°

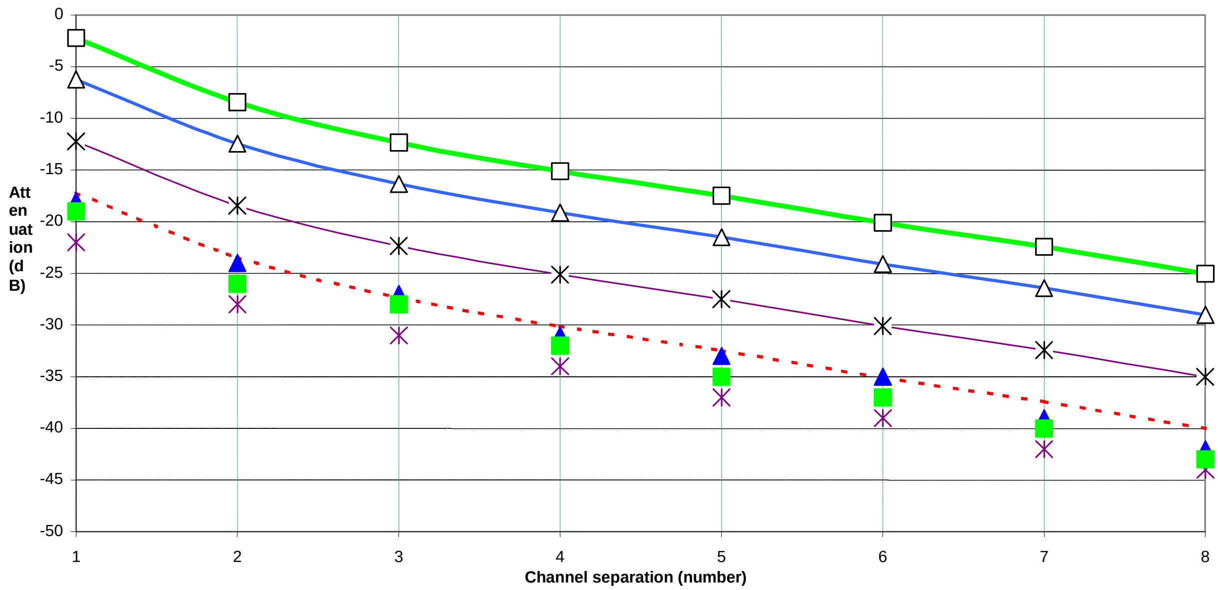
Elevation - High level signals (CMN 0,01°) - Comparison: measurements / proposed SNR (150 kHZ RBW)



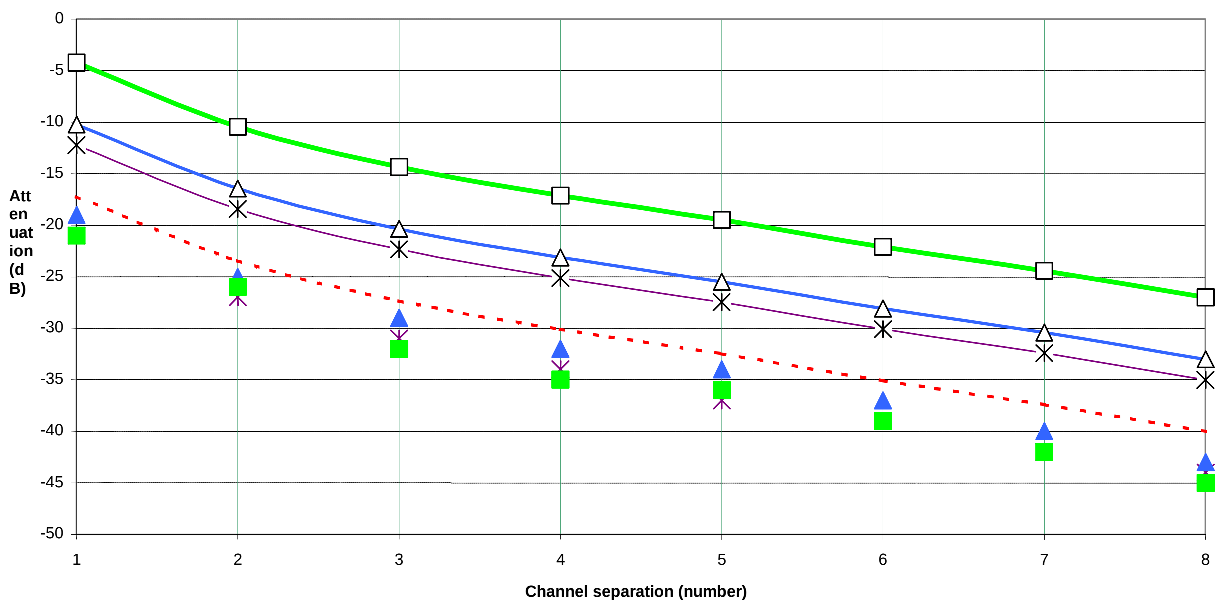
Azimuth - High level signals (CMN 0,015°) - Comparison: measurements / proposed SNR (150 kHZ RBW)



Elevation - Low level signals (CMN 0,08°) - Comparison: measurements / proposed SNR (150 kHZ RBW)



Azimuth - Low level signals (CMN 0,1°) - Comparison: measurements / proposed SNR (150 kHZ RBW)



Conclusion

The above results demonstrate that:
1 – The SNR concept is appropriate to characterize the impact on the airborne receivers of undesired signal due to MLS transmission on adjacent channels;
2 - The proposed SNR requirements are met with margins (20 dB in high level and 10 dB in low level).

Verification of the feasibility of Tables X1 and X2 requirements

The tables below provide, the range of minimum SNR measured:

- Within the range of "High level signals";
- Within the range of "Low level signals".

The proposed SNR requirements are mentioned.

SNR			
Function	Beam width 1°	 2°	 3°
High Rate Approach Azimuth guidance	0,7 to 1,3 dB Proposed: < 19.9 dB	4,4 to 6.5 dB < 26 dB	8,1 to 10,2 dB < 29.5 dB
Approach Elevation Guidance	3 to 5,2 dB Proposed < 23.5 dB	8,1 to 10,2 dB <29.5 dB	12,1 to 14 dB N/A

Table X1

SNR			
Function	Beam width 1°	 2°	 3°
High Rate Approach Azimuth guidance	-4,6 to -3,5 dB Proposed: < 3,5 dB	-3 to -1,5 dB < 9,5 dB	-5 to -2,5 dB < 13 dB
Approach Elevation Guidance	-4,8 to -3,7 dB Proposed < 3,5 dB	-2 to 0,35 dB <9,5 dB	-3 to -0,7 dB N/A

Table X2

These results demonstrate that there are margins from 7 to 20 dB.

Notes:

- It has been explained in section 2.2 that the SNR requirements concerning the data are no critical.
- The Approach Azimuth (low rate) and the Back azimuth requirements are not critical.

Conclusions and recommendations

Conclusions:

- The proposed receiver requirement is homogeneous with the other current receiver requirements and should not require new performances to the airborne MLS equipment,
- It has been demonstrated that an existing airborne MLS receiver meet the propose requirements with margins,
- If Signal in Space meets the proposed SNR requirements the airborne receivers are protected.

Recommendations:

The subgroup is invited

- To note the results provided;
- To close the validation of the proposed paragraph amendment;
- To adopt this amendment.

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ACP-WGF14/WP-14
15/08/05

International Civil Aviation Organization

WORKING PAPER

AERONAUTICAL COMMUNICATIONS PANEL (ACP)

FOURTEENTH MEETING OF WORKING GROUP F

Malmo, Sweden 22 – 26 August 2005

Agenda Item 3: WRC Agenda Item 1.6

ITU WRC-07 - AGENDA ITEM 1.6, RESOLUTION 414 - ALLOCATIONS TO THE AERONAUTICAL MOBILE (R) SERVICE

(Presented by Secretariat)

SUMMARY

Studies on detailed spectrum requirements and compatibility issues for future aeronautical communications system are underway, and ICAO has developed a plan for assessing compatibility with other systems/services of any new AM(R)S systems that might use those new allocations. However these studies may not be completed before WRC-07. As a result, and in recognition of the conditions which drove the development of WRC-07 Agenda Item 1.6, Resolution 414 the completion of sharing studies should not be a prerequisite for making new AM(R)S allocations.

ACTION

ACP WG-F is invited to note and comment the draft ICAO input to the ITU-R WP 8B meeting, September 2005

1. INTRODUCTION

In some regions of the world the frequency band 117.975 – 137 MHz used for air-to-air and air-ground communications is heavily congested. Assignable frequency channels for line-of-sight communications to support safety and regularity of flight have become increasingly limited, and are in some cases non-existent, even after the introduction of more spectrum efficient technologies (8.33 kHz channel spacing in Europe).

In addition, new applications are foreseen to be globally implemented and to accommodate expected air traffic growth and to support various new air traffic management and air navigation functions. These new applications provide, through the exchange of data messages communication, navigation or surveillance functions or a combination of these. Based on the current definitions in the ITU Radio Regulations, this may require operating under an allocation to the aeronautical mobile (route) service (AM(R)S). Since these new applications cannot be satisfied in the VHF band (117.975-137 MHz), additional allocations are to be made in other frequency bands.

Also, new RF spectrum requirements to satisfy security provisions are emerging.

The combination of spectrum congestion in the band 117.975 – 137 MHz, growing air traffic and the associated need to increase communication capacity as well as evolving new aeronautical applications drives a need for new AM(R)S allocations. This was recognized at the ITU World Radiocommunication Conference 2003 (WRC-03) which agreed to introduce an agenda item for WRC-07 relating to the need to consider additional allocations for the AM(R)S in parts of the bands between 108 MHz and 6 GHz. (Refer to ITU-R Resolution 114 (Rev. WRC-03), Resolution 413 (WRC-03) and Resolution 414 (WRC-03).

Spectrum currently globally allocated to the aeronautical radionavigation service (ARNS) and having suitable propagation conditions to support air-ground communication systems to satisfy current and emerging AM(R)S requirements is currently being considered in International Civil Aviation Organization (ICAO). (See also Resolution 414, *further resolves to invite the ITU-R, paragraph 1).* Studies completed to date identify the bands 960 – 1 024 MHz and 5 091 – 5 150 MHz as being suitable for allocations to the AM(R)S. Other ARNS bands may be added as studies progress. The bands used for ILS and MLS (108-112 MHz, 328.6-335.4 MHz and 5030-5091 MHz) are excluded from these studies since these bands are required to accommodate the essential capabilities for precision approach and landing systems. (Refer to ICAO Position for ITU-R WRC-07 Agenda Item 1.6 at Appendix A).

2. DISCUSSION

ICAO is currently studying terrestrial and satellite-based technologies for future air-ground communication systems, on the basis of their potential for ICAO standardization for aeronautical communications use. The goal of the study is to identify potential future communication technologies to meet global requirements for safety and regularity of flight communications i.e. those supporting Air Traffic Services (ATS) and Aeronautical Operational Communications (AOC). Progress of the work, including work products and recommended positions are being presented at an ICAO expert panel as a means of achieving international coordination and assuring that the study accounts for global requirements and interoperability. Additional consultations with users and stakeholders in the community are also being carried out through separate forums.

The following study objectives continue to be in line with the recommendations out of the ICAO Eleventh Air Navigation Conference including,

- to provide communications capacity to support Air Traffic Management through 2030;
- to allow a realistic transition for service providers and airspace users;
- to support ATS communications, AOC communications for safety and regularity of flight and air-to-air communications (voice, data and surveillance);
- to address spectrum depletion in different regions of the world; and
- to investigate the use of multi-mode avionics for implementation.

In order to identify technologies that may be applicable to aeronautical communications, a survey of widely used and successful commercial and military technologies has been conducted to identify technologies that offer potential value to air-to-air and air-ground and communications.

The need for increased air-ground and air-to-air communications and consequential for additional radio spectrum, primarily using data links, has been established and appropriate regulatory provisions, including the need for additional allocations to the AM(R)S are required to meet the requirements.

The current draft CPM text includes: "*Based on available studies, two distinct categories of AM(R)S spectrum are required. The first – for surface applications – is distinguished by a high data throughput, however only moderate transmission distances and it is expected that a single resource can be shared at multiple geographic locations. The second category, like the current VHF AM(R)S, will require line-of-sight propagation, moderate bandwidth, and a number of distinct channels to allow for sector-to-sector assignments.*"

With regard to the two categories of AM(R)S spectrum, the first category (surface applications and possibly also short-range air-ground and air-to-air communications) current studies show that the frequency band 5091-5150 MHz may be suitable. For the second category (line-of-sight communications up to a distance of 200 NM) the 1000 MHz range could be suitable.

3. COMPATIBILITY BETWEEN THE AM(R)S AND CURRENT USERS

In order to address compatibility issues with incumbent band users, ICAO proposes that the development of regulatory provisions supporting additional allocations to the AM(R)S service, to be agreed at WRC-07, shall stipulate the conditions under which such AM(R)S spectrum can be made available, and should be followed by the development of technical criteria enabling the introduction of new communication systems.

The regulatory provisions envisaged by ICAO to protect the current and planned usage of aeronautical radionavigation systems from harmful interference include:

a) use of the AM(R)S allocations shall be limited to systems operating in accordance with international (ICAO) standards;
b) compatibility issues with regard to aeronautical radionavigation systems operating in accordance with international (ICAO) standards will be addressed in

ICAO to ensure the new AM(R)S will not cause harmful interference to nor claim protection from or otherwise impose constraints on the operation and future development of co-band aeronautical radionavigation systems, operating in accordance with international (ICAO) standards. This effort will be part of the development of relevant Standards and Recommended Practices (SARPs) for the new communication systems; and

c) compatibility issues with regard to non-aeronautical systems to which the bands are allocated will be addressed in ITU (most likely ITU-R, resulting in the adoption of ITU-R Recommendations).

The methodology outlined above would allow for making allocations to the aeronautical mobile (R) service in certain frequency bands currently allocated to the aeronautical radionavigation service without requiring the ITU to develop additional specifications for technical characteristics of the affected aeronautical systems and compatibility criteria at the timing of WRC-07. Compatibility issues, including available spectrum, would be addressed in the future in ICAO and form part of the ICAO standardization process for any new systems. Flexibility in the future use of the shared bands would be technically and economically beneficial to international civil aviation, in particular when introducing technical systems that will form part of the future CNS/ATM system. At the same time, existing usage, even in congested frequency bands, is protected through the regulatory provisions accompanying the new allocations to AM(R)S in the Radio Regulations. When tasks to develop SARPs for new communication systems are established by the Air Navigation Commission, protection of and compatibility with existing aeronautical systems will be included in these tasks.

Standardization activities for the Universal Access Transceiver (UAT) currently under way within ICAO can be seen as an example how compatibility issues between existing and future ICAO standardized radio systems, operating under different frequency allocations, can be achieved within the ICAO framework. The UAT waveform and receiver front-end has been specifically tailored to tolerate a high-density pulsed environment stemming from systems operating under the ARNS allocation. The impact of the UAT transmitted signal on navigation and surveillance systems operating in the same band has been studied and coordinated with the appropriate ICAO expert panels.

This approach is reflected in the ICAO WRC-07 Position for Agenda Item 1.6: "Use of the AM(R)S allocations shall be limited to systems which operate in accordance with recognized international aeronautical (ICAO) standards. Compatibility issues with regard to aeronautical radionavigation systems, operating in accordance with recognized international aeronautical (ICAO) standards will be addressed in ICAO and will be part of the development of relevant Standards and Recommended Practices (SARPs) for the communication systems."

In the case where the frequency bands proposed for use by the AM(R)S are shared with other (non-aeronautical) services (e.g., the 5091-5150 MHz band which is also used by the Fixed Satellite Service (FSS), compatibility studies will have to be completed within the ITU-R when the technical characteristics of the new AM(R)S systems are being developed. This approach is also reflected in the ICAO WRC-07 Position: "*Compatibility issues with regard to other services to which the bands are allocated will be addressed in the ITU-R as appropriate.*"

4. RECOMMENDATION

In summary, studies on detailed spectrum requirements and compatibility issues for future aeronautical communications system are underway but may not be completed before WRC-07, and ICAO has developed a plan for assessing compatibility with other systems/services of any new AM(R)S systems that might use those new allocations. As a result, and in recognition of the conditions which drove the development of WRC-07 Agenda Item 1.6, new AM(R)S allocations should be made under conditions that protect current users.

Appendix A

WRC-07 Agenda Item 1.6

Agenda Item Title:

To consider allocations for the aeronautical mobile (R) service in parts of the bands between 108 MHz to 6 GHz, in accordance with Resolution 414 (WRC-03) and to study current satellite frequency allocations that will support the modernization of civil aviation telecommunication systems, taking into account Resolution 415 (WRC-03)

Discussion:

Resolution 414 – Consideration of the frequency range between 108 MHz and 6 GHz for new aeronautical applications

In some regions, in particular in portions of Region 1 (Europe) and Region 2 (North America), the aeronautical VHF communications band 117.975 - 137 MHz is heavily congested. Assignable VHF spectrum for line-of-sight communications to support safety and regularity of flight has become increasingly limited, and in some cases non-existent, even after introduction of more spectrum efficient techniques.

In addition, new applications are foreseen to be globally implemented and mainly making use of data communication systems. These are needed to accommodate expected air traffic growth and to support various new ATM, as well as aviation security requirements. In particular, aviation has identified the need for introducing aeronautical safety systems including those that would:

a) overcome limitations of conventional systems and allow ATM to further develop on a global scale;

b) allow for the introduction of unmanned aerial vehicles (UAVs) in air traffic services airspace;

c) provide increased information exchange between aircraft and ground systems as well as between aircraft (e.g. ATC centers, aircraft operating agencies, etc); and

d) reduce runway incursions through the use of high integrity, wireless local area networks combined with connected grids of distributed sensors.

For aviation, these new applications support air navigation functions (i.e. either communication, navigation or surveillance or a combination of these) through the transmission or exchange of data. However, within the terms of the ITU definitions, they require to operate under an allocation to the AM(R)S, thus requiring additional allocations to be made in the relevant bands between 108 MHz to 6 GHz.

The combination of VHF band spectrum congestion, growing air traffic and evolving aeronautical applications drive an urgent need for new AM(R)S allocations. The quantity of spectrum required is under study in ICAO.

Furthermore, an increased use of short-range communication links on or around airports is expected to be required to support the transfer of safety critical information generated by systems such as air traffic control radar, wind-shear radar, remote control systems, automated weather information systems, runway lighting etc. between nodes of high integrity airport surface wireless local area networks.

Spectrum currently globally allocated to the aeronautical radionavigation service (ARNS) and having suitable propagation conditions to support air ground communication systems is being considered in ICAO studies to satisfy current and emerging AM(R)S requirements. These studies focus on an additional allocation to the AM(R)S service in portions of the frequency bands 960 – 1 215 MHz, and 5 091 – 5 150 MHz. The introduction of an allocation to the AM(R)S in any of these bands needs to be limited to ICAO standardized systems (‘...operating in accordance with international aeronautical standards’), preferably through an appropriate footnote. Compatibility with ICAO standardized systems will be addressed in ICAO. Compatibility with in-band and adjacent band non-aeronautical systems will be addressed in ITU, as required, when the technical characteristics of these communication systems are being established. Special attention is required for appropriate provisions in the Radio Regulations to allow for the proposed use of the universal access transceiver (UAT) system which operates on the frequency 978 MHz.

Recently, ICAO SARPs for MLS were amended, including the need for larger separation distances between MLS facilities than assumed. Therefore, the whole of the band 5 030 – 5 091 MHz is required to satisfy requirements for MLS. The impact this may have on the need for using the MLS band 5 091 – 5 150 MHz is under consideration in ICAO.

Allocations to AM(R)S are considered to be not feasible in the bands 108 - 112 MHz and 328.6 - 335.4 MHz since it is expected that these bands for the foreseeable future (more than twenty years) would be required to accommodate the Instrument Landing System (ILS) (Localizer and Glide Path), including ILS Category I, Category II and Category III operations and other systems covered under No. **5.197A** (mobile to support navigation and surveillance).

Studies completed to date identify the bands 960 – 1 024 MHz and 5 091 – 5 150 MHz as being suitable for allocations to the AM(R)S. Other ARNS bands may be added as studies progress.

Frequency bands allocated to the aeronautical radionavigation service or radionavigation service between 1 215 – 4 400 MHz and 5 350 – 5 470 MHz are considered to be not available for an allocation to the aeronautical mobile (R) service due to the extensive use of some of these bands by primary radar systems, introduction of aeronautical radionavigation systems supporting GNSS, by radio altimeters and airborne weather radar systems.

There is a significant amount of development work taking place on unmanned aerial vehicles (UAV). Developments have already demonstrated the capability of large UAVs to operate over long distances (including transcontinental). There is a need for aviation to consider how to integrate these aircraft into air traffic services airspace, shared with civil manned aircraft safely, and it may become necessary to develop common global standards for telemetry and telecommand links between the

UAV and the UAV ground control centre. This agenda item seeks to make provision for the required safety related air-ground telemetry/telecommand link for UAVs.

The potential introduction of UAVs into air traffic services airspace is an important development within aviation. Further, in order to allow UAVs to be fully integrated safely into air traffic services airspace it is essential that suitable safety service air ground data links are provided. The development of telemetry and telecommand links to support UAV operations, however, must not adversely affect existing and planned aeronautical systems.

Resolution 415 - Study of current satellite frequency allocations that will support the modernization of civil aviation telecommunication systems

Resolution **415 (WRC-03)** is addressing possibilities of broadening the services and applications of the use of current satellite frequency allocations to allow the expansion of International Civil Aviation Organization (ICAO) communications, navigation, surveillance and air traffic management (CNS/ATM) systems through using, for aeronautical safety purposes, systems that can also support other, non-aeronautical services.

Ground-ground communications

Satellite communications provide a real possibility to meet the demands of the ICAO CNS/ATM system, especially in areas where a terrestrial communication infrastructure is lacking. The benefits of using in particular very small aperture terminals (VSAT) include the use of the most appropriate and cost-effective technology to improve aeronautical ground-ground communications. VSAT networks have been implemented in a number of ICAO regions and the operation of these networks is well under control. Potential shortcomings, such as interoperability issues between different networks, require a technical or administrative (with administrations and/or service providers) solution. In view of their role in aeronautical safety service communications, aeronautical VSAT systems can be used on a shared basis to offer telecommunication services to non-aeronautical users, subject to appropriate priorities being afforded to aeronautical telecommunications.

VSAT networks operate under an allocation to the fixed satellite service (FSS) which in the ITU is not recognized as a safety service. In this regard, it is necessary to consider in the ITU, through the adoption of a new Recommendation at WRC-07, how to recognize the safety aspects of the aeronautical telecommunications element VSAT networks can carry. Such a Recommendation, however, should not impose additional constraints on the VSAT operators.

Air-ground communications

AMS(R)S:

Currently, special provisions in the Radio Regulations provide for priority to accommodate the spectrum requirements for the aeronautical mobile satellite (R) service (AMS(R)S) through No. **5.357A** and Resolution **222 (WRC-2000)** in the frequency bands 1 545 - 1 559 MHz and 1 646.5 - 1 660.5 MHz. The results of ITU-R studies on the feasibility of real-time pre-emptive access between different networks of mobile-satellite systems, as requested by Resolution **222 (WRC-2000)** and in No. **5.357A** seen as a method to ensure priority access and immediate availability AMS(R)S are on the agenda for the WRC-10.

AMSS:

At WRC-03, ICAO supported the extension of the allocation to the mobile-satellite (Earth-to-space) on a secondary basis in the band 14 - 14.5 GHz to permit the operation of the aeronautical mobile-satellite service as stipulated in Resolution **216 (Rev. WRC-2000)**. The ICAO support to this allocation, which was made in 2003, addressed non-safety broadband communications by aircraft operators and passengers of commercial aircraft. This allocation will not form part of the AMS(R)S since any secondary allocation is not acceptable for any aeronautical safety service. A need to provide complementary spectrum for the space-to-Earth direction has been identified at WRC-03. Under the provisions of Resolution **415 (WRC-03)**, ICAO would wish to provide support to such allocations on the basis that this service has the potential to promote the general efficiency of aircraft operations.

ICAO Position:

Resolution 414

To support global allocations to the aeronautical mobile (R) service in portions of the aeronautical radionavigation service (ARNS) frequency bands between 108 MHz to 6 GHz if shown by aviation studies that these meet global CNS/ATM requirements. Use of the AM(R)S allocations shall be limited to systems which operate in accordance with recognized international aeronautical (ICAO) standards. Compatibility issues with regard to aeronautical radionavigation systems, operating in accordance with recognized international aeronautical (ICAO) standards will be addressed in ICAO and will be part of the development of relevant Standards and Recommended Practices (SARPs) for the communication systems. Compatibility issues with regard to other services to which the bands are allocated will be addressed in the ITU-R as appropriate.

To support an appropriate provision allowing the use of frequency 978 MHz by the UAT system, subject to its standardization by ICAO, as required.

No change to the current allocation in the band 5 030 - 5 091 MHz since this band is required to satisfy the requirements of the aeronautical radionavigation service (MLS).

No change to the current allocations in the bands 108 - 112 MHz and 328.6 - 335.4 MHz.

To support the identification and allocation of suitable spectrum to support the safety service related aspects of UAV operations provided they do not adversely affect existing or planned aeronautical systems.

Resolution 415

To support appropriate regulatory measure, preferably in the format of an ITU-R Recommendation attached to the Radio Regulations which recognizes that VSAT networks operating in the fixed satellite service can also be used for aeronautical safety applications. This includes provisions for the necessary priorities for aeronautical telecommunications when aeronautical VSAT networks are also being used to provide non-aeronautical telecommunications.

Support, where applicable, the inclusion of an allocation on a secondary basis for the AMSS (space-to-Earth) to provide for the complimentary component of the secondary allocation to AMSS (Earth-to-space) in the band 14 - 14.5 GHz. This secondary allocation is not intended to be used for aeronautical safety service ICAO CNS/ATM communications.

Note. —Aviation studies currently indicate the suitability of portions of the bands 960 – 1 215 MHz as well as the whole band 5 091 – 5 150 MHz for an allocation to AM(R)S. Portions of other ARNS bands may be added as studies in ICAO progress.

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AERONAUTICAL COMMUNICATIONS PANEL (ACP)

FOURTEENTH MEETING OF WORKING GROUP F

1. INTRODUCTION

The draft ICAO WRC'07 position wrt A.I. 1.6, Res 414, reads as follows:

To support global allocations to the aeronautical mobile (R) service in portions of the aeronautical radionavigation service (ARNS) frequency bands between 108 MHz–6 GHz if shown by aviation studies these meet global CNS/ATM requirements

The present study plan is hereby proposed to precisely address the points raised in above ICAO position by aiming at:

a) verification of feasibility of band sharing between a potential AM(R)S with currently allocated ARN services and services other than those of civil aviation operating eithr in the band of interest or in adjacent bands

b) assessment of the capacity of an aeronautical Future Radio System (FRS) operating under the sought AM(R) S allocation(s) to meet identified operational communications requirements, in terms of quality of service and of air-traffic peak volume .

This study plan aims at the feasibility of reusing part of the band 960-1215 MHz for AM(R)S and to establish whether such use can meet the ATM requirements envisaged for the timeframe 2015+-2030. It focuses on the sub-band 960-977 MHz. The band 960-1215 MHz is allocated to aeronautical radionavigation service (ARNS) and is reserved for use by electronic aids to air navigation

The motivation behind this plan can be easily understood if one considers that the only available alternative spectrum candidate for FRS requirements, is that of the MLS band, 5030-5150 MHz. It is generally recognized that long range (circa 150 nautical miles) communication is achievable in practice, due to antenna gain limitations on-board aircraft, through the use of the 960-1215 MHz band, since there are no other aeronautical bands with suitable long range propagation properties.

2. Discussion

Study context and positioning wrt on-going Eurocontrol /FAA/NASA collaborative agreement

The task activities identified in this study plan complements rather than overlap with those identified under the Eurocontrol/FAA/NASA collaborative agreement (ref 1, ACP/WGC material) aiming at the conceptual design and standardization of a future radio system (FRS) or communication system (FCS) to be proposed for acceptance by ICAO It does so however with a different angle of attack. It starts with the consideration of the most pressing constraint, for AM(R)S band sharing with existing services, is that of electromagnetic compatibility (EMC) with other on-board avionics and outside the aircraft with other radio equipment either within the aviation domain or with other domains . As the result it investigates what kind of system, modulation, data format etc… can effectively be designed around such a constraint . It the assesses its potential communication capacity achievable and ultimately how well it could meet the ATM concepts and associated communications requirements identified under the above collaborative agreement .

This study plan is predicated on a bottom up approach . It starts with the realisation that the spectrum available for AM(R)S in the band 960-1215 MHz is limited if one wants it to operate in the sub-band not yet assigned globally to ICAO standard DME , i.e. 960-977 MHz. . This is the main starting point in this paper, as co-site co-channel sharing with ARNS /DME is outside its scope.
As a prerequisite for an additional AM(R)S allocation by WRC'07 the feasibility of AM(R)S band sharing with ARNS is to be established, which implies electromagnetic compatibility (EMC) verification under the most constraining circumstances, .i.e. the co-site case on board same aircraft, as well as with avionics operating on nearby aircraft on airport apron and taxiways. These aircraft are assumed to be equipped with ICAO standard DME, SSR/Mode-S/ACAS. . Compatibility verification should be accomplished with respect to DME, SSR/Mode-S/ACAS and GNSS, the latter operating in the sub-band 1160-1215 MHz , which benefits of an RNSS allocation in addition to ARNS since WRC 2003.,

The DME global ICAO-standard frequency assignments spans the whole band 978-1215 MHz sub-band. The SRR/Mode S transponder operates on 1030 MHz for on-board reception of ground station interrogations and transmit replies on 1090 MHz . The ACAS equipment equally uses the 1090 MHz frequency for both transmit and receive operations. Furthermore, since the recent ICAO/ACP working group meeting as a whole held in Montreal last June has recommended the UAT SARPS adoption, UAT is another potential "victim" for which EMC is also to be verified..

Study points

Determination of interference susceptibility threshold of current L-band avionics (DME, SSR/Mode-S/ACAS, GNSS) assuming worst case constraints as imposed by the co-site on board same aircraft case:

Comments /Rationale:
In general susceptibility thresholds are known with respect to broadband interference : see ICAO annex 10, RTACA/EUROCAE MOPS, summed up in ECC report 64 on services and systems protection against UWB protection. In some cases, i.e. DME, the CW thresholds are also known. What is unknown are those thresholds value against pulsed interference, of low duty cycle, when interference occurs in short transmission bursts with small time duration with respect to its pulse repetition period (PRP), of typically 1 or 2 %; A well known example is the DME case for which on one hand the RTCA MOPS defines the broadband threshold in the neighbourhood of -129 dBW, (or -99 dBm) and on the other hand, JTIDS/MIDS interference threshold has been assessed experimentally as -36 dBm (see national and NATO-common DOD/CAA JTIDS/MIDS frequency clearance agreement); It is quite likely that the sought susceptibility is dependant on both the interference pulse waveform and on its repetition period,

or for a given waveform, on the interference duty cycle.
It is recommended for this susceptibility assessment to assume specific interference characteristics : pulse waveform and PRP

Determination of Out of Bands (OOB and) spurious emissions rejection requirements applicable to an L-band Future communication system following applicable ITU-R recommendations and taking into account industry state of the art

Comments /Rationale:
Applicable ITU-R recommendations are well known , starting with ITU-R SM. 329-9 for spurious rejection. Interference from an AM(R)S future communication system (FCS) can be classified as out of band wrt to UAT, operating at 978 MHz, immediately adjacent to the FCS sub-band of 960 to 977 MHz, or of spurious type with respect to DME frequencies in the upper band of the 978-1215 MHz range. This lower range limit is set depending on where the out-of-band bandwidth ends and that of spurious one begins, i.e at 250 % of the FCS transmission bandwidth according to the ad-hoc ITU-R recommendation.

Practical OOB and spurious rejection achievable values should take into account the state of the art in filter design in the aeronautical context. A good indication to what is achievable is given by both the JTIDS/MIDS and the UAT transmission spurious rejection characteristics, which are in the 70 dBc (with respect to pulse carrier level) range. And following the UAT conceptual design lead, if one assumes a 30 dB isolation between the victim receiver and interfering transmitter - due to coupling between respective antennas on the same side of an aircraft body located no more than a few meter away from each other - the sought interference rejection is in the order of 100 dB

Note : a) . *With isolation between FCS and on-board victims in the order of 100 dB, and given the fact that to achieve long range communication, circa 150 NM, a minimum FCS EIRP in the range of 1 to 10 watts in case of continuous transmission mode (i.e; in the order of 30 to 40 dBm) is needed to achieve satisfactory link margin, one can conclude that no continuous transmission FCS design will achieve EMC wrt DME interference limit of -99 dBm. Hence the choice to opt for a pulsed transmission concept for the FCS design , with a low enough transmission duty cycle, to achieve protection against spurious interference for existing L band system aboard and outside the considered aircraft.*

b) Following the UAT design lead, the determination of applicable FCS emission limitations to ensure compatibility with other L-Band avionics (UAT, SSR, Mode S transponder/ACAS and GNSS) , assuming a pulsed transmission concept, should take into account the presence of an Aircraft Mutual Suppression Bus (MSB) . The L-Band systems that are connected to the MSB may drive the bus to announce to other systems that a transmission is taking place during the time the bus is activated.. The L-band systems that listen on the bus may choose to delay their own transmissions and/or desensitize its receiver to protect itself during high power transmissions which could damage or impair its receive capability. A summary of the MSB purpose, and other L-Band systems behaviour in presence of MSB activity signal is given in reference 2

Identification of minimum transmission symbol redundancy to ensure predefined performance transmission requirements in terms of data integrity and transmission delay

Comments/Rationale

The AM(R)S FCS receiver is also susceptible to interference coming from all the other on-board transmitters : DME interrogator and SSR/Mode-S transponder, seen as spurious transmission. Additionnaly UAT interference will be seen by the FCS receiver as out-of-band emissions
In order to protect against such interference impact on data integrity and consequential data transmission delay (due to transport control protocol repeat mechanism, in presence of transmission errors) transmission symbol redundancy will have to be introduced , designed to cope with the predicted interference environment. An usual integrity performance objective is 10 E-7 for data and 10 E-4 for digitized voice

The on-board interference environment is expected to be dominated by transmitted spurious signals from both the DME interrogators (two functioning simultaneously) and the SSR/Mode-S transponder as well as the ACAS transmitter, also transmitting on 1090 MHz . In all interference cases, the associated interference duty factor is quite low , of the order of a few percents. With the DME interrogator in its tracking mode, 30 pairs of pulses , each with a 3.6 µs duration are transmitted, 150 in its search mode (see ICAO Annex 10). As for the SSR transponder, one can argue its worst case loading corresponds to an aircraft flying at high altitude , being seen by up to 40 SSR/Mode S interrogators. Each interrogator is assumes to have a 4 second antenna repetition period, meaning that the transponder is interrogated on the average by 10 SSR/Mode S radars. Further assuming that half of interrogations received on 1030 MHz are from SSR mode A and C, i.e. yielding an average of 13 interrogations per aircraft SSR antenna sweep (400 Hz PRF and 3 degree antenna angular beamwidth) and the other half come from Mode S interrogators giving an average of two interrogation per antenna sweep , the worst case average transponder interrogation rate should be about 75 per second . Each received interrogations elicits transponder burst replies of either 56 or 112 µs duration (see ICAO Annex 10, Vol 4)
The AM(R)S FCS receiver is expected to see those DME interrogators and SSR transponder transmitted pulses , with EIRP typically in the range of 100 to 1000W, as spurious emissions , attenuated by about 100 dB compared to their peak power

Assumption will have to be made regarding the FCS architecture and transmission/modulation characteristics:
It is suggested to use as starting assumptions towards FCS design concepts, the radio link air interface characteristics - modulation (CPFSK), spectrum access, bandwidth occupancy – of the UAT system, currently under ICAO standardization (Significant work towards the UAT compatibility with existing ARNS systems (DME, SSR) and GNSS has already been undertaken with the active support of one State (see ACP/WGC 7, 8, and 9 meeting documents, dowloadable from the ICAO ACP site, ref 1)

Assess capacity of a future AM(R)S communication system (FCS) and its adequacy to meet expected air- traffic communication loading taking into account predicted peak instantaneous aircraft count , (PIAC) assuming ICAO/ACP/WG- C -defined operations concepts and communications requirements

Comments/rationale

- The air-traffic loading scenario is that of the densest airspace areas (West Europe, and North America North-East corridor, and/or Los-Angeles Basin on the West Coast). Predicted air-traffic statistics are available from EUROCONTROL , for Western Europe and for the time frame of 2015 +

- Several hypotheses will be examined wrt FCS deployment :
  a) limited to commercial air-transporters and upper-end bizjets segment of general aviation
  b) limited to all IFR-equipped aircraft above a certain flight level (FL 195 foor instance using the precedent of 8.33 Khz spacing scheme deployment) and to designated TMAs
  c) deployed on all aircraft

- Communication capabilities will be assessed wrt to the operational communication requirements set by Eurocontrol MACONDO (ref to Eurocontrol project web site) and the FCOCR (Final concept and operational communication requirements) studies, the latter being available from the ICAO ACP web site (ref 1)

- Those capabilities, in terms of achievable bitrates , average and peak, taking into account the minimum transmission symbol redundancy necessary to cope with the FCS interference environment, will be assessed with regard their suitability to provide for both data and digitized voice services

- An outcome of this assessment will determine whether spectrum for the voice service - with a quality required to be as good , from a subjective testing viewpoint as that of the existing VHF band analog radiotelephony – should be found within the sub-band 960-977 MHz, or in another band .
  A second outcome might be to reconsider the underlying assumption of this study plan: that of the FCS operations being confined to the sub-band 960-977 MHz leading to a decision to include the co-site co channel FCS-DME case within its scope

Define EMC testing scenarios:

…in order to verify:

a) co-site on board same aircraft compatibility with receivers of DME, SSR/Mode-S/ACAS in the band 979-1215 MHz , UAT operating on 978 MHz (see ref 2) and of GNSS in the band 1160-1215 Mhz,
b) compatibility with receivers , same bands, on nearby aircraft located on ground with less than 50 meters separation,
c) compatibility with JTIDS/MIDS equipment on military platforms separated by either 300 meters vertically or 3 nautical miles horizontally

Note : FCS compatibility with SSR/Mode S and DME ground equipment may be sufficiently verified by analysis only . Similarly the FCS compatibility with radio systems operating below 960 Mhz, such as GSM hand held terminals or base stations, may too be only addressed by analysis.

3. ACTION BY THE MEETING

The ACP WGF is invited to:

…to note this study plan and provide comments as appropriate

4. REFERENCES

1) ACP WEB site : http://www.icao.int/ANB/PANELS/ACP/

2) ACP/WGC9/WP 04 : Implementation Manual for the Universal Access Transceiver (UAT), Revision 1.5

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5 GHz Wireless Channel Characterization for the MLS Extension Band: Measurement and Modeling Update

27 July 2005

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Summary

This document is a brief description of the recent progress made in wireless channel characterization for the MLS extension band (5.091-5.15 GHz), under NASA Glenn's ACAST project. We summarize the project activities to date, provide a short discussion of the major findings and channel characteristics, then provide some example measurement and modeling results.

The aim of the channel characterization project is to develop models for the wireless channel in this band, around airport surface areas. This includes the development of time-varying tapped delay line models, and empirical path loss models. An overview of the importance of the project, methods, and work plan is provided in [1]. Interim results have been published in [2]-[5], and journal papers, and the project final report, are in preparation.

Project Activities

The primary project activities have been a detailed literature review, planning and conduct of measurements, data processing to obtain channel statistics, and development of the channel models from the measured data and statistics.

We have made mobile measurements at two large airports to date: Cleveland and Miami. We have also made mobile measurements at three small airports: Ohio University airport, Burke Lakefront (in Cleveland), and Tamiami (in Miami). For these mobile measurements, the transmitter (Tx) is set up at the air traffic control tower (ATCT), and the receiver (Rx) is moved around the airport surface areas in a van to emulate the channel seen by an aircraft or airport ground vehicle. In addition to the mobile measurements, at the large airports we have also taken point-to-point measurements, with the Tx again at the ATCT, and the Rx located at a sensor or radio location on the airport surface. The point-to-point measurements employ directional antennas, and the mobile measurements employ omni-directional antennas. We have also taken some mobile measurements with the Tx located on the airport surface, to emulate a relay type of communication link.

Measurements at an additional large airport (JFK in New York) are planned for late August, and if time and budget permit, measurements at an additional airport (likely Detroit) will also be made. The project is to conclude at the end of the calendar year 2005. Worth noting is that coordination with local airport and FAA personnel at the sites—essential for the measurement campaign success—has been efficient and effective.

At each airport, thousands of power delay profiles (PDPs) were taken, along with received signal strength information (RSSI). From these measurements, we have obtained statistics on delay spread, coherence bandwidths, path loss, and channel tap amplitude and correlation statistics, all of which will be used to develop the detailed channel models.

Characterization Results

After collecting the measurements, planning for future measurements, and analyzing the data, we have developed a simple airport classification scheme, based upon airport size:

- Small airports: general aviation airports
- Medium airports: for example, Cleveland Hopkins
- Large airports: for example, Miami International, JFK

The channel models developed will be specific to airport size, but there will of course be some commonality when appropriate, i.e., when similar physical environment characteristics obtain.

For the large and medium-sized airports, we have divided the airport surface into three distinct regions:

- Line of sight-open (LOS-O): for example, nearly all runways, and some taxiways fit this;
- Non-line of sight-specular (NLOS-S): mostly NLOS conditions, but with a dominant (specular) component at minimal delay, and some low-energy multipath components, e.g., some taxiways and near airport terminal buildings;
- NLOS: completely obstructed LOS, with significant and relatively high-energy multipath components, e.g., very near airport gates.

The small airports also have these three regions, but generally they have less area in the NLOS categories. The regions have distinct ranges of delay spreads, with LOS-O the smallest, and NLOS the largest.

Naturally, aircraft will typically inhabit all three regions after landing or prior to takeoff. This results in a statistically <u>non</u>-stationary channel, in contrast to most terrestrial models. In addition, for the large airports, the large buildings on and around the airport surface present persistent, long-delay multipath, also in contrast to most terrestrial models. Also in contrast to other models (both for terrestrial, e.g., cellular radio, and analytical airport surface channel models), scattering around the mobile is almost never isotropic, and the channel taps are frequently correlated. Finally, in some areas, at all the airports, some of the channel taps exhibit very severe fading (so-called "worse than Rayleigh" fading).

For the point to point measurements, as with the majority of the mobile measurements, we have found that link closure is easy with typical components. As expected, the point to point channels exhibit a smaller channel dispersion and much larger coherence bandwidth than the mobile settings. With the directional antennas, we have made measurements of received power and delay spread as a function of azimuth angle, and have obtained data that can be used to evaluate the potential for angular (spatial) diversity for improved security and performance in an airport surface network. These measurements are also valuable for airport surface station siting.

Example Measurements and Modeling Results

Figure 1 shows a photograph taken of the Miami International Airport. In the lower right foreground is the edge of the wall along the "catwalk" near the top of the ATCT. Large buildings both on the airport surface, and beyond the runway in the distance can be clearly seen.

Fig. 1. View of part of Miami airport surface, from ATCT.

An example PDP from the Miami measurements is shown in Figure 2. The plot is received power in dBm versus delay in microseconds. This plot is for an NLOS case, and significant multipath components within a few dB of the main (first-arriving) impulse are evident within 1 microsecond. The root mean square (RMS) delay spread σ_τ for this PDP is 1.43 microseconds. To connect this with the modeling, a tapped delay line channel model based upon this PDP would have approximately 15 taps, with the taps spaced at 20 nanosecond intervals. For all PDPs we have also employed a noise thresholding technique, such that the probability of mistaking a noise impulse for an actual multipath echo is 10^{-3} or smaller.

To illustrate the non-stationarity in the airport surface environment, Figure 3 shows a plot of σ_τ versus PDP index (time), for mobile measurements in Miami. The approximately 100 PDPs taken for this figure show σ_τ values ranging from as low as 200 nanoseconds to as large as 2 microseconds as the mobile van moved from NLOS to LOS and back to NLOS conditions.

Figure 4 shows explicitly the time variation of the PDPs, also for Miami, in NLOS conditions. The rightward axis is delay in microseconds, and the leftward axis is time in seconds. Over the course of a few seconds, channel fading can be observed for all the significant received impulses. Fades of several dB are present on the main tap, and subsequent taps incur fades of 10-20 dB.

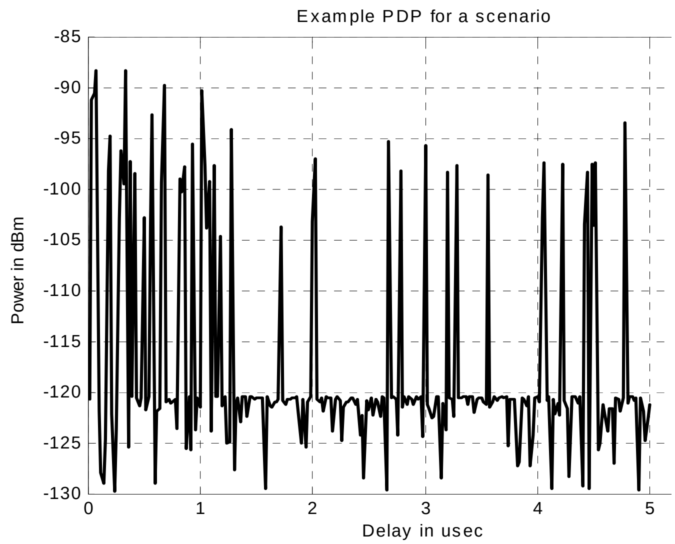

Fig. 2. Example PDP (received power vs. delay) for NLOS region in Miami.

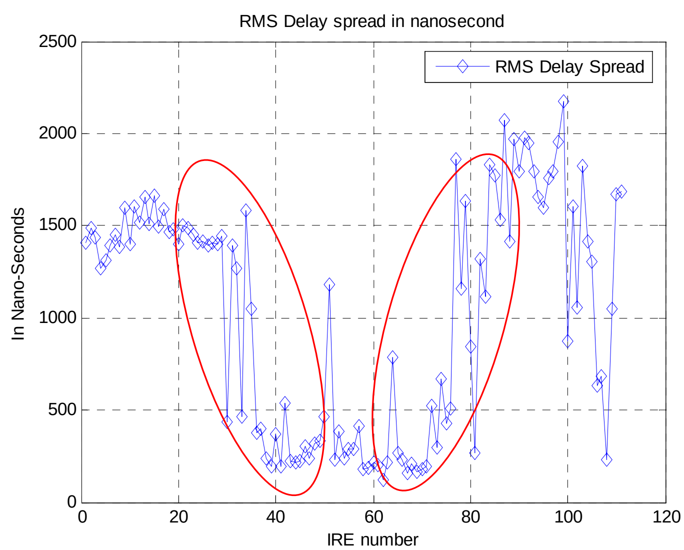

Fig. 3. Example RMS delay spread vs. time, Miami, showing transitions (circled) from NLOS to LOS to NLOS conditions.

Table 1 provides some example statistics for Miami. Similar results were collected for Cleveland, and the small airports, and will also be collected from future measurements.

In addition to time and delay domain characterization, by Fourier transforming PDPs we can obtain frequency domain information. Figure 5 shows an example frequency correlation estimate (FCE) from Cleveland. The FCE can be thought of as the spaced frequency correlation function of the channel, whose width is approximately the channel coherence bandwidth. For the example in Figure 5, which is for a NLOS case, the correlation is approximately 0.3 at 1.5 MHz away from the mid-band frequency. This means that for frequency separations greater than 3 MHz, the channel affects the frequency components in an approximately uncorrelated manner.

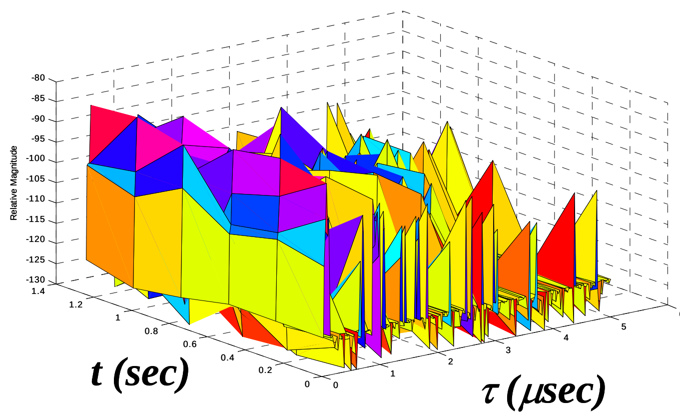

Fig. 4. Example PDPs vs. time, Miami, NLOS case.

Table 1. RMS delay spread statistics for Miami, two regions.

σ_τ Statistic	NLOS-S (nsec)	NLOS (nsec)
Max	1000	2394
Min	32.8	1001
Mean	380	1382

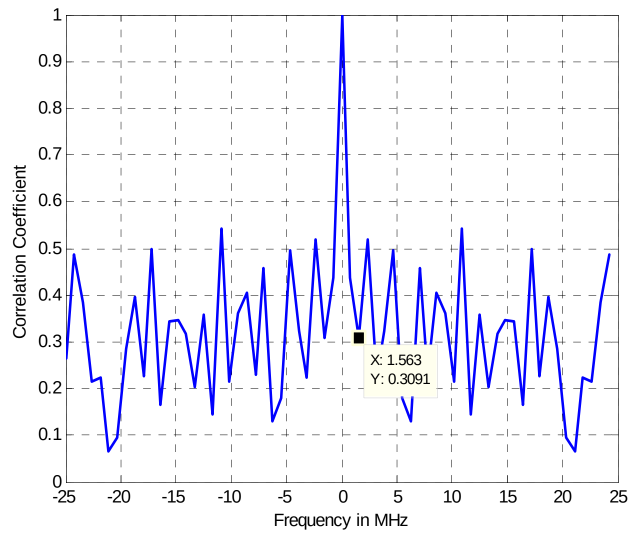

Fig. 5. Example FCE, Cleveland, NLOS case.

Some example modeling results obtained from these measurement are now described. First, Figure 6 shows the probability of occurrence of a given tap in the tapped delay line model, versus the tap index. This is an outcome of the non-stationarity of the channel—some of the multipath echoes (taps) exist, or “persist,” for only some fraction of time as the mobile receiver moves through the environment. For our 50 MHz measurement bandwidth, the tap spacing is 20 nanoseconds. This figure pertains to Miami, for both NLOS-S and NLOS regions. Closely related to this figure is Figure 7, which shows the average relative tap power or energy vs. tap index, for the same regions as in Figure 6. For both these figures, a threshold of 20 dB below the main tap was employed.

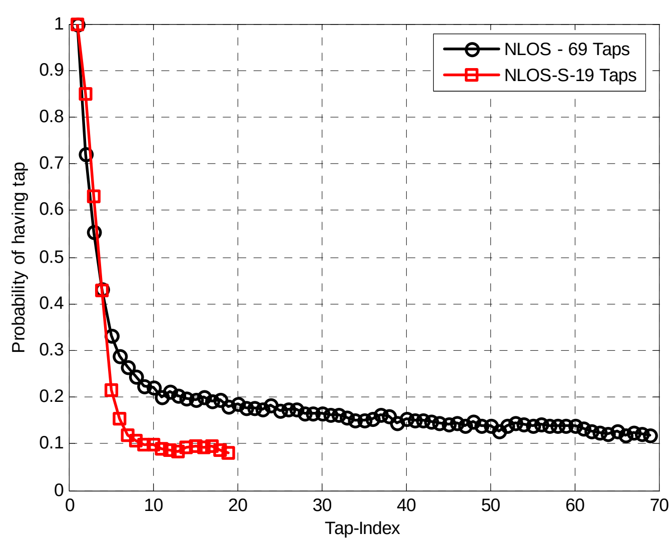

Fig. 6. Probability of tap occurrence vs. tap index, Miami, NLOS and NLOS-S cases.

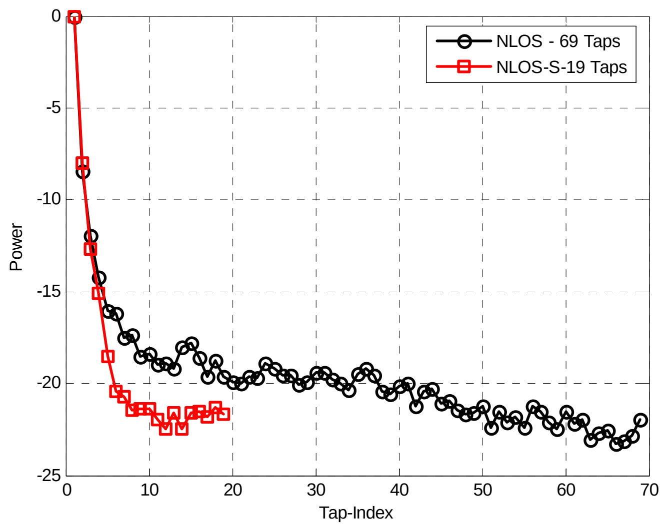

Fig. 7. Relative tap power vs. tap index, Miami, NLOS and NLOS-S cases

By collecting statistics for each tap amplitude versus time, we can estimate appropriate fading tap amplitude models. These models are random processes, often with the well-known Rician or Rayleigh statistics. Example amplitude histograms and fits for the NLOS-S case in Miami are shown in Figure 8 for the first two (of 5) channel taps. The first tap is well modeled as Rician, with a *K*-factor of nearly 6 dB, whereas the second tap is worse than Rayleigh, modeled via the Nakagami process, with parameter *m*~0.75. We have also found that the Weibull and lognormal distributions are often applicable for obtaining good fits.

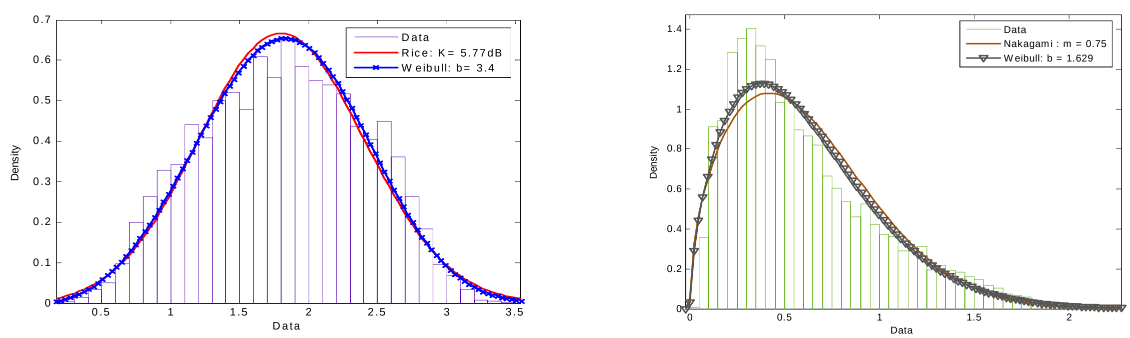

Fig. 8. Example tap amplitude statistics for Miami NLOS-S case; main (specular) tap (left) is Rician, second tap (right) is worse than Rayleigh.

For the point to point measurements, we show here only one figure, that of RMS delay spread versus azimuth angle, for Miami, at two locations. Figure 9 illustrates the range of delay spreads seen in this type of environment.

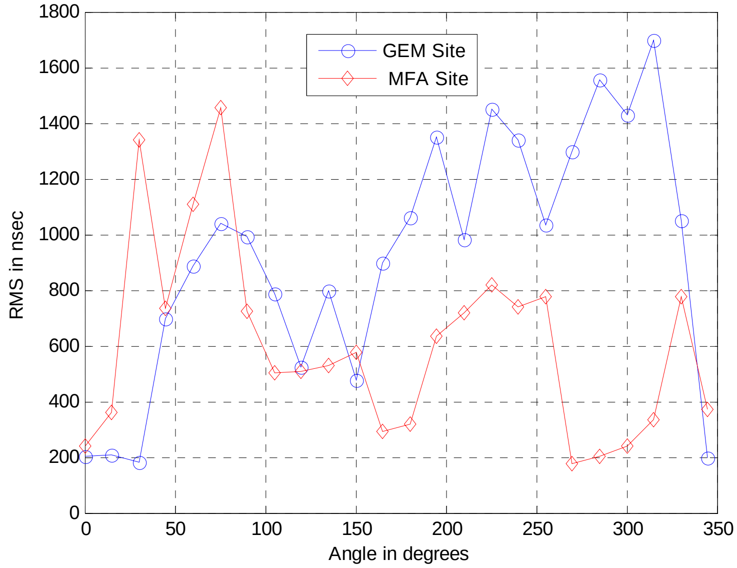

Fig. 9. RMS delay spread vs. azimuth angle for Miami, two sites.

Conclusion

The channel models to be developed will be tapped delay line, statistical models. In addition to these models will be propagation path loss models. Most commonly in both analysis and simulations, the effects of path loss and channel fading can be treated separately. The tapped delay line structures are the most typical form of dispersive, fading channel model employed [6]. An illustration of such a model is shown in Figure 10. In this figure, the k^{th} input symbol is x_k, the k^{th} output symbol is y_k. The τ's denote delays, and the h's are the randomly time-varying channel tap weights. Our measurements provide us with estimates of the number of taps (L), the delays (τ's), and the random tap weights (h's). For each airport region and type of airport, we are developing models for the average energies of the tap weights, the random process models that best describe their (amplitude and phase) time variation and persistence, and the inter-tap correlations.

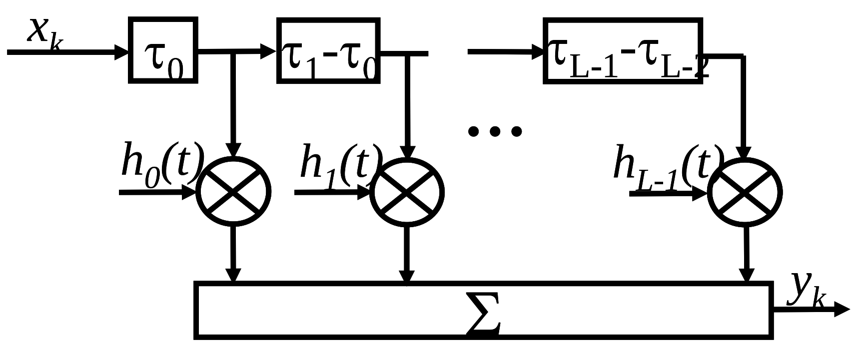

Fig. 10. Canonical tapped delay-line model of time varying channel.

These channel models can be used by any researchers or engineers who evaluate the performance of waveforms or systems on this channel. Thus, the models provide a *common* framework for comparison of different systems. Different candidate systems can be compared over models that are realistic, yielding more realistic estimates of system performance than if only analytical models were used.

Knowledge of channel statistics can be used in system design in many specific ways. Here we provide just a few examples of how the channel model can be used.

1. For multicarrier OFDM systems (such as the IEEE 802.11/16), a guard time or "cyclic prefix" is employed to specifically avoid intersymbol interference caused by multipath. The length of this guard time should be as long as (or longer than) the channel impulse response, and this length is directly quantified by the channel delay spread we measure.
2. When the channel taps are highly correlated (which we have found in many cases), the amount of attainable time diversity, or multipath diversity, is greatly reduced over that which is available with uncorrelated taps. Thus, simpler combining or equalization schemes should be used, as more complex ones offer little benefit other than an often very small gain in received signal energy. This offers design guidance for both narrowband (equalizer) and spread spectrum (RAKE) single carrier schemes.
3. For multicarrier OFDM, direct sequence (MC-DS) spread spectrum systems, or frequency-hopped (FH) spread spectrum systems, the channel coherence bandwidth

should be used in design. For FH schemes, the average hop frequency difference should be larger than the coherence bandwidth to attain frequency diversity. In the MC-DS case, depending upon complexity and performance requirements, the coherence bandwidth is used to select both the number of subcarriers and their bandwidths (~chip rates). The coherence bandwidth is also of use in OFDM systems, as it can provide guidance for how the input data bits are distributed across subcarriers, and the data rate of each subcarrier.
4. For specifying link parameters such as transmit power levels, antenna gains, and receiver amplifier quality (e.g., noise figure), the path loss models provide invaluable information.
5. For interference estimation analyses. This band is allocated on a co-primary basis to non-geostationary mobile-satellite-service Earth-to-space feeder uplinks. Therefore, proper interference characterization with respect to empirical data can be performed.

References

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