RADIO SPECTRUM MANAGEMENT

Aero-FMBC Coordination Processes

Issue 2 | June 2014

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

ISSN 1175-6748 (PDF)

Contents, Disclaimer and Corrections

Contents

This document contains information, for general reference purposes only, on the current engineering processes used by Radio Spectrum Management (RSM) when completing the coordination required between Aeronautical ILS and VOR services and FMBC services, prior to the certification of new ILS and VOR aeronautical radio licences in the frequency band 108 to 117.95 MHz and FMBC spectrum licences and General User (Radio) Licences in the frequency band 88 to 108 MHz.

While RSM has exercised every care in the preparation of this document it may not include all the information necessary for engineers to certify spectrum and radio licences, and RSM accepts no liability for any loss suffered, whether arising directly or indirectly, due to the sole reliance on the accuracy or contents herein.

Disclaimer

The Ministry of Business, Innovation and Employment (the Ministry) makes no warranty, express of implied, nor assumes any liability for any loss suffered, whether arising directly, or indirectly, due to the sole reliance on the accuracy or contents of this document.

Corrections

Radio Spectrum Management would appreciate receiving suggestions for improvement to or advice relating to inaccuracies or ambiguity to this document. Such suggestions and advice should be emailed to rsmlicensing@mbie.govt.nz. Correspondence received will be acknowledged, investigated and appropriate action taken.

Amendment History

Issue	Date of effect	Description of Amendment
1	27 November 2007	First Publication.
2	9 June 2014	Amendments made throughout document.

Contents

1. Introduction

This document provides guidance on the coordination processes to be used in association with the Spectrum Licence Certification Rules contained in Public Information Brochure 39 (PIB39) when planning and certifying new radio services requiring aeronautical navigation and FMBC coordination.

This Aero-FMBC Coordination Processes document uses descriptions based on RSM tools and spreadsheets, PIB39 requirements and includes clarification of ITU Recommendation SM1009 processes.

The operation of high powered FMBC stations adjacent to the aeronautical navigation aids services in the 108 to 117.95 MHz band requires engineers planning FMBC or aeronautical navigational services to complete analysis to ensure there is no harmful interference into aeronautical navigational services. High level FMBC signal levels into aeronautical navigational receivers can cause significant operational issues for aircraft and aerodromes and if coincident with other problems can result in Safety of Life incidents.

Aero-FMBC interference can be in the form of:

- Unwanted FMBC emissions generated remotely from an aircraft causing in-band interference for aeronautical navigational receivers - **Type A1 interference**;
- Spurious (non intelligible) FMBC emissions from transmitters close to 108 MHz causing in-band signals in aeronautical navigational receivers - **Type A2 interference**;
- Intermodulation (IM) products generated within aeronautical receivers due to high levels of FMBC signals - **Type B1 interference**; and,
- Desensing of aeronautical receiver front ends due to high levels of FMBC signals - **Type B2 interference**.

2. Aeronautical Navigation Services

The aeronautical navigation services operating in the 108 to 117.95 MHz band include the Variable Omni Range (VOR) and Instrument Landing System (ILS) services. The VOR navigation services operate in the 108 to 114 MHz band and provide directional bearing information to aircraft travelling between aerodromes and also to aircraft approaching landing decision points at regional airfields.

The ILS services provide aircraft landing radio navigation beacons comprising horizontal and vertical guidance components. The horizontal guidance beacon operates in the band 108 to 112 MHz and is referred to as the Localiser. The vertical guidance component beacon operates in the band 328.6 to 335.4 MHz and is called the Glidepath. Coordination is required for the ILS localiser frequencies because of the close proximity of the high power FMBC frequency band. Glidepath services operate in the range 281 to 400 MHz and have no licensed adjacent channel services. Coordination is therefore required only with other new Glidepath services and is not a subject of this document.

Associated with VOR and ILS services at aerodromes are Distance Measuring Equipment (DME) services that are used to provide a pilot with continuous DME transmitter to aeroplane distance information. These services can operate as part of ILS Glidepath service or part of a VOR service (at aerodromes not ILS equipped) or as separate navigation radio services operating at UHF frequencies. Aerodrome landing charts (see Appendix B) identify minimum heights permitted for aeroplanes during the landing approach based on DME to aeroplane distances. Special coordination is not required for DME services.

Aeroplane navigation is controlled under Visual Flight Rules (VFR) and Instrument Fight Rules (IFR) issued by Civil Aviation Authority (CAA). Aeroplanes landing in poor visibility use VOR and ILS services in accordance with the IFR. The CAA website at http://aip.net.nz/ provides details of the ILS and VOR services in the Aerodrome Charts section and the rules associated with their use in the En-route (ENR) section.

The international standards and recommended practices for aeronautical navigation services are published in Annex 10 to the Convention of International Civil Aviation, Aeronautical Telecommunications Volume 1, by the International Civil Aviation Organisation (ICAO).

The sensitivity of ILS/VOR receivers to interference depends upon the type of aeronautical receiver used. CAA does not mandate the type of receiver to be used but has agreed that coordination should be based on the two common standards, the Montreal receiver and the ICAO 1998 receiver. This document is based on the most conservative performance aspects of both, i.e., those associated with the Montreal receiver.

3. General Coordination Analysis Methodology

The coordination issues for medium and high power FMBC stations close to the ILS/VOR services band can be eased by the appropriate selection of FMBC, ILS and VOR frequency assignments, that is:

- By separating FMBC and ILS/VOR frequencies to the extent possible by moving ILS/VOR assignments to the upper part of the 108 to 112 MHz band.
- By ensuring all VOR assignments are above 112 MHz.
- By ensuring that FMBC, ILS and VOR intermodulation (IM) products in ILS/VOR receivers do not coincide with wanted ILS or VOR frequencies. For example, if FMBC assignments near ILS installations are made on even 100kHz allocations (e.g., 98.2, 99.4, 106.2 MHz) their IM products would fall at even 100kHz frequencies. To minimise interference to ILS services, the ILS allocations could be made on odd 100kHz spaced frequencies (e.g., 110.1, 110.3 MHz). IM can occur in the presence of high level signals and is discussed in Appendix F.

The coordination analysis required to be completed before the licensing of new FMBC and aeronautical ILS/VOR services is based on SM1009, Annex 2, the General Assessment Method (GAM). The majority of the content of SM1009 relates to B1 type interference and its evaluation. SM1009 only briefly discusses A1, A2 and B2 interference types but offers no detailed guidance on their evaluation.

Annex 1 of SM1009 describes the significant elements of aero/FMBC interference coordination. These include:

- the types of interference commonly occurring
- characteristics of ILS localiser and VOR services
- characteristics of the high power FMBC and low power FM services
- typical aircraft receiver installations
- criteria and formulae for the assessment of potential interference.

Practical use of SM1009 indicates that consideration of those elements also requires knowledge of:

- How ILS and VOR services are set up and used at each aerodrome.
- How to select appropriate test points at which to conduct coordination Assessment.
- Establishing clearance distances required between those test points and FMBC and LPFM transmitters.
- Interpreting and adjusting assessment results.

Aero–FMBC coordination therefore uses information from the Register of Radio frequencies, FMBC operators, CAA and the ILS/VOR operators, Airways Corporation Limited and the New Zealand Defence Force.

4. Types of Interference and their Assessment

4.1. Type A1 Interference Assessment

Type A1 interference includes unwanted emissions generated inside FMBC transmitters and may include components generated during the transmitter modulation process and IM created due to non-linearities in FMBC amplifiers, filters, feeders and antennas. Such spurious emissions can be more common at sites with multiple FMBC or other high power transmitters. Such interference can be difficult to quantify but is becoming less frequent as design, construction and maintenance practices improve.

The analysis of A1 interference is generally unnecessary because:

- FMBC licences have unwanted emission limits (UELs) restricted to low values in accordance with PIB39 requirements.
- FMBC licence engineering includes analysis of the potential for FMBC emissions to overload or de-sense receivers in adjacent landmobile and aeronautical COM bands which can lead to additional restrictions on spurious emissions. The calculations for determining the additional restrictions are included in PIB39.
- SM1009 notes that Type A1 interference need not be considered for frequency differences of greater than 200 kHz, i.e., frequencies below 107.8 kHz;
- There is a 1.6 MHz guard band between the ILS/VOR and high powered FMBC services.
- There is a 200 kHz guard band between the ILS/VOR and low powered FMBC services.

4.2. Type A2 Interference Assessment

Type A2 interference includes non-intelligible emissions in the aeronautical band which arise only from FMBC transmitters close to 108 MHz and will only interfere with ILS/VOR services close to 108 MHz. For the reasons discussed in respect of the Type A1 interference, analysis of Type A2 interference is generally unnecessary.

4.3. Type B1 Interference Assessment

This type of interference is the primary subject of this document and occurs when aeronautical receivers produce IM as a result of high signal levels received from multiple FMBC transmitters. This type of interference is the most frequent cause of potential interference issues.

SM1009 provides sets of formulae for determining potential interference issues in Annex 1, sections 4.2.3 (Montreal receiver) and 4.3.3 (ICAO 1998 receiver). Section 4.2.3 (Montreal receiver) provides the most conservative result.

4.4. Type B2 Interference Assessment

This type of interference is also the subject of this document and is the desensing of an aeronautical receiver that results from the reception of one or more high signal levels received from FMBC transmitters. Analysis of Type B2 interference is prescribed in SM1009. That analysis includes determination of the level of each received signal and the power sum of all received signals to ensure they do not exceed a calculated threshold.

SM1009 Annex 1, clauses 4.2.4 and 4.3.4 identify empirical formulae for determining the maximum levels of permitted receiver input signal levels. The formula in 4.2.4 is more conservative and is as part of the SM1009 General Assessment Method. More detailed analysis can be undertaken using actual field strength measurements if required.

As a general guide to the sensitivities of ILS/VOR receiver interference margins graphs have been determined using SM1009 methods. These graphs are included in Appendix G.

Interpretation of these graphs can show that, for example:

- From Graph G1, a 106 MHz FMBC transmitter, with an eirp of 47dBW, needs to be more than 120km from an aircraft Montreal receiver to avoid contributing to B1 IM products in that receiver.
- From Graph G2, the same FMBC transmitter needs to be more than 28km from a Montreal ILS/VOR receiver to avoid triggering B1 IM in that Receiver.
- From Graph G3, the same FMBC station needs to be only 0.6 km from an aircraft receiver to avoid causing B2 interference in that receiver. Note that this indicates that the Desensing interference (B2) potential is likely to be much less of a coordination issue than B1 IM interference.

With regard to B1 IM interference, harmful interference will occur only if part of the IM product frequency band is in the wanted ILS frequency band.

5. Characteristics of VOR and ILS Services

5.1. VOR Services

VOR transmitters are installed at major city aerodromes, regional aerodromes and at sites remote from aerodromes. Those at Whenuapai, Auckland, Ohakea, Wellington, Christchurch and Dunedin are used for guiding aircraft to aerodrome landing approach positions. Once at these points, aeroplanes can use ILS services, if required, for final landing approaches during busy operational periods and/or through cloud to low altitudes.

VOR transmitters at Hamilton, Rotorua, Gisborne, New Plymouth, Napier, Nelson, Woodbourne, Queenstown and Invercargill regional aerodromes are used for guiding aircraft to aerodrome landing approach positions and then, if required, for final landing approaches during busy operational periods and/or through cloud to low altitudes. Such VOR services are less accurate that ILS services and require pilots to identify visual approach aids earlier in the flight landing routines than required for ILS services.

Aerodrome landing charts at http://aip.net.nz provide landing approach information for all ILS and VOR equipped aerodromes.

Guidance on aeroplane route heights is available at http://aip.net.nz and in AIP Area Charts and Enroute Charts.

Aerodrome charts providing landing information often include frequencies of COM (aeronautical voice simplex communications in the band 118 to 137 MHz) and Non-Directional Beacon (NDB) navigational aids operating below 2 MHz. The NDB services are sometimes identified in those charts with VHF frequencies that may appear to be a VOR frequency. However, ICAO mandate frequency-pairing for LF, VHF and UHF radio navigation services that is used in aeroplanes to set-up three receivers using only the VHF (VOR) frequency. As a consequence, it is necessary to use the Register of Radio Frequencies licence search facilities to confirm that a frequency reference in an aerodrome landing chart is related to a VOR or NDB service, i.e., if there is no licence at the VOR frequency then the aerodrome is using a low frequency NDB service.

5.2. ILS Services

ILS services are installed in six aerodromes, Whenuapai, Auckland, Ohakea, Wellington, Christchurch and Dunedin. Each of these has an associated VOR service. These aerodromes, with the exception of Wellington, conform to the basic characteristics described in SM1009 Annex 1, 3.2.1, with Designated Operational Coverage areas (DOC) unlimited by local terrain. The northern aircraft landing approach to Wellington aerodrome are significantly limited by terrain with hills well within a standard ILS DOC. The Wellington aerodrome northern approach ILS DOC is therefore non-standard and is as shown in Appendix A.

The ILS services at all aerodromes except Auckland are currently CAT1 level and provide guidance for aircraft to a point of between 200 and 800 feet above ground level depending upon wind and visibility. Auckland is expected to become CAT 3 and will allow aircraft to land when ground level visibility is almost zero.

ILS localiser antenna arrays, where deployed, are installed at both ends of runways. They typically comprise a horizontal stack of 14 x 6 element yagis, vertically polarised and installed just above ground or in a trench with antennas level with the ground. The effective transmit powers of these arrays can therefore be 6 to 20 dB below the licensed transmitter power. Correction factors for wanted ILS signal levels can therefore not be based upon licensed transmitter power levels and some actual field measurements are required for the coordination processes. This also allows effective ILS power levels to be determined based on actual field strengths and for these to be used when considering the contribution ILS signal levels make to aeronautical receiver IM levels.

Analysis of aero-FMBC interference associated with ILS services requires knowledge of the flight paths of aircraft during landing approaches. These flight paths can be located at the CAA web site at http://aip.net.nz and selecting Aerodrome Charts, and on subsequent screens, by selecting aerodrome name and then appropriate ILS landing charts. Information on these charts can be used to identify positions and minimum ground clearance of aircraft during landing approaches. This information is required for the identification of test points for interference assessments.

Appendix B, Aerodrome Landing Chart, is a typical chart showing both landing approach and aeroplane route minimum heights within a ILS DOC.

Aeroplanes landing under Instrument Flight Rules (IFR) conditions at a CAT1 equipped aerodrome, or as directed by the control tower, will follow the flight path, from an outer NDB marker beacon and staying close to centre of the flight path, to the decision point marked as MAPt on the aerodrome landing charts. At the MAPt a decision is made as to whether conditions are suitable for landing.

Should a pilot lose the ILS display due to interference or other issues during a landing approach under IFR conditions (poor visibility) the pilot is required to abort the landing and follow missed approach procedures.

6. Characteristics of the High Power FMBC Services

Parameters and analysis processes for FMBC services discussed in SM1009 are relevant for use in New Zealand and the licence parameters in The Register of Radio Frequencies are generally sufficient to complete coordination analysis based on the GAM. A more detailed analysis may require direct contact with licence holders to identify more specific antenna and other information or alternatively actual field measurements.

Information on particular FMBC services is available in the Register of Radio Frequencies.

7. Characteristics of Low Power FM (LPFM) services

The General User Licence (GUL) for LPFM services gazetted in June 2003 permitted any person to operate a FMBC transmitter on frequencies 106.7, 106.8, 106.9, 107, 107.1, 107.2, 107.3, 107.4, 107.5, 107.6 and 107.7 MHz with a maximum transmitter power of 0.5 Watt e.i.r.p. (-3 dBW) and in any location, provided that use complied with the terms, restrictions and conditions contained therein. The GUL may be viewed on the RSM website.

As a consequence of the ubiquitous nature of LPFM services and because there is no register identifying which frequencies are used in particular locations, all available LPFM frequencies above 106.6 MHz need to be included at every test point required for aero-FMBC coordination analysis.

Analysis for all ILS and VOR services has been completed by RSM using minimal clearance distances between the LPFM transmitters and aircraft receivers, and the frequencies of local current and planned FMBC services. The analysis has shown that where the clearance height between aircraft and LPFM transmitters is low, emissions by LPFM transmitters can contribute to aircraft receiver IM and result in potential coordination incompatibilities. These locations include areas under aircraft landing approaches and adjacent to high power FMBC sites, particularly sites where there are multiple FMBC transmitters. As a consequence, the revised GUL for LPFM services that permits an increase in transmitter power level to 0 dBW e.i.r.p. identifies in its section “Terms, conditions and restrictions’ exclusion zones areas where use of some LPFM frequencies are not permitted.

Those restrictions are based on calculations which included current FMBC and aeronautical frequencies licences and also those frequencies planned to be operating prior to and when the new 2011 FMBC management right begins. Any additional LPFM exclusion zones required for the implementation of new FMBC services will require approval of RSM Manager Licensing. If approved, an amended will be gazetted in a new GUL for LPFM services before the implementation of the new FMBC services is permitted.

8. Data Preparation for Potential Incompatibility Assessment

The determination of potential incompatibilities for type B1 and B2 interference requires:

- The identification of ILS and VOR coverage areas (DOC) and aeroplane flight paths during both landing approaches and on route between aerodromes.
- The selection of test point locations.
- The identification of horizontal and vertical distances between each test point location and each FMBC and LPFM transmitter.
- The identification of ILS and VOR frequencies, their field strengths at those test points and Lc correction factors described in SM1009, Annex 1, 4.2.3.3, used at each test point.
- The preparation of a schedule of all current and planned FMBC, LPFM and aeronautical services in the band 88 to 117.95 MHz in the area around an aerodrome or remote test point, likely to be equal to or greater than the aeronautical receiver cut-off level.
- The calculation of FMBC, LPFM and aeronautical signal levels at each test point.
- The identification of potential receiver two and three frequency IM (B1) components within the bandwidths of the wanted ILS and/or VOR services.
- The calculation of the IM component amplitudes and individual margins.
- The summation of the IM component margins.
- The calculations of B2 signal levels and their summation.

The complexity of the SM1009 Annex 1 formulae used for calculating field ILS, VOR and FMBC field strengths for up to 30 of test points and several frequencies for ILS and VOR FMBC services suggests that the only appropriate calculation process must be based on the use of computer processes.

RSM initially (2003) developed a single test point calculator that gave results for one ILS or VOR frequency based on a macro driven Excel spreadsheet. Recently a new process has been developed allowing calculations at multiple test points and multiple ILS/VOR frequencies using a similar structure that can provide quicker results. The new FMBC AERO process requires the preparation of test point and frequency schedules in the formats shown in Appendices C and D, and allows the full variations of the SM1009 formulae to be utilised. Appendix E, RSM FMBC AERO Spreadsheet Operation and Adjustments describes the recent product and its use.

The preparation of data required for the calculation of potential B1 and B2 incompatibilities is discussed in the following sections.

8.1. Identification of ILS and VOR DOCs

The ILS DOCs at Whenuapai, Auckland, Ohakea, Christchurch and Dunedin aerodromes and the Wellington southern landing approach conform in most respects to the dimensions identified in SM1009 Annex 1, 3.2.1. The Wellington aerodrome northern landing approach ILS DOC is constrained by local terrain and buildings and is shown in Appendix A.

When considering the dimensions of DOC areas for ILS services and therefore the limits of ILS test point locations it should be noted that DOC areas are only those areas where the received ILS signal level is equal to or greater than 32 dBµV/m, (ICAO requirement).

VOR transmit antennas are omni-directional and provide VOR DOC areas limited only to those areas where the received VOR signal level is equal to or greater than 39 dBµV/m, (ICAO requirement).

VOR services at regional aerodromes in New Zealand are located adjacent to the runways to facilitate landing approach requirements. Their antennas are typically at 5 meters above ground level and service coverage is often limited by local terrain to less than 80 km in some directions for aeroplanes below normal route altitudes.

VOR services remote from aerodromes are generally on high sites and provide reference headings for enroute aeroplanes for up to 600 km or radio line of site limits.

SM1009 Annex 1, 3.2.2 provides general information on the range of VOR services and includes a graph (Figure 2) showing coverage distance for various heights as a function of VOR transmitter e.r.p.

8.2. Test Point Location Selection and Adjustment

Test Points are effectively locations where aircraft receivers are required to perform ILS and/or VOR functions effectively. They are determined in accordance with SM1009 Annex 2 section 2, Location and Height of ILS and VOR Test Points and the Figure 4 Fixed test point locations within ILS DOC in that section.

SM1009 identifies the need for 31 standard ILS DOC test points and requires additional ones above any FMBC service in the DOC plus others at the boundary of the DOC adjacent to local FMBC services.

Test Points for VOR services used as landing navigational aids at Regional airports can be assigned in a manner similar to that used for ILS services. However, the low number of FMBC services in regional centres and the limitations associated with landing approach paths suggests that test points can generally be limited to key locations of the landing approach paths such as the landing decision point (MAPt on the landing charts), above population centres under those approach likely to include LPFM transmitters and above FMBC antennas.

Test points for VOR services remote from airports can include ILS test points plus points vertically above FMBC sites. These VOR services are normally used only for enroute aeroplanes flying at heights shown on AIP Enroute and Area charts. Reference to these charts can be used if the use of the SM1009 test point clearance heights in calculations indicates potential incompatibilities.

RSM experience of test point potential incompatibilities has indicated that calculations at some SM1009 ILS DOC test points may not be warranted. For example, where an FMBC service outside an ILS DOC that provides a signal level at the adjacent DOC boundary below the receiver cut-off level a test point at the adjacent point on the ILS boundary may not be necessary. This may also be true for a test point where the potential for IM or receiver overloading is easily identified as being less than those of another test point where those margins are satisfactory. Such a practice must be used with caution.

SM1009 test points are the minimum required and may need to be adjusted or increased. For example:

- Additional test points may be required at higher altitude populated areas within an ILS DOC to identify whether LPFM services can contribute to potential incompatibilities.
- Test points E, F on the extended runway centre line test points in an ILS DOC may be more appropriate if located at the landing decision point (MAPt).
- Where terrain limits ILS and/or VOR signal levels to below the required minimum values (32 dBµV/m and 39 dBµV/m, respectively) the test point height can be increased or the test point moved to an adjacent location where signal levels are above minimum.
- Low altitude test points within ILS DOCs may require two test points with different heights, the lower one for local aerodrome ILS and VOR services and the upper one for remote VOR services.
- Where the test point height does not represent the local maximum ground height in the vicinity of a landing approach (taking into account both the allowed lateral and parallel movement of an aeroplane with respect to the runway approach centre-line) should be raised to the local area maximum.
- Where test points do not represent actual or worst case interference situations additional test points should be used.

Having regard to these matters, RSM has reviewed the ILS DOCs at Whenuapai, Auckland, Ohakea, Wellington, Christchurch and Dunedin airports and determined that of the SM1009 recommended ILS DOC test points only some are useful for IM and receiver overload evaluations. The bases for this practice are that:

- Of the 12 DOCs 7 have few or nil population centres, are remote from FBM transmitters and have test points closer to the airports that have significantly higher potential incompatibilities that are well within the margins required.
- The other 5 DOCs have significant numbers of SM1009 test points in low or ni population areas that are remote from FMBC transmitters and have test points closer to the airports that have significantly higher potential incompatibilities that are well within the margins required.
- Those 5 DOCs have sufficient test points on the extended runway centrelines, above FMBC sites, on the DOC boundary adjacent to local FMBC transmitters outside the DOC and elevated likely LPFM areas that together properly represent worst case potential incompatibilities.
- Where any doubt has been felt calculations have been completed that demonstrated negligible potential incompatibilities.

8.3. Test Point Clearance Distances to FMBC/LPFM Services

In the absence of more accurate information, the identification of and calculation of horizontal and vertical distances between test points and FMBC or LPFM antennas is to be in accordance with the requirements of SM1009 Annex 2 GAM information.

SM1009 provides general guidance for clearance distances and also suggests use of actual local flight operational requirements. In New Zealand the flight operational information is available at http://aip.net.nz aerodrome landing charts and in AIP Area Charts and Enroute Charts. Those charts and use of local topographical maps can be used to provide more accurate clearance details.

The calculation of clearance distances between test points situated on aeroplane landing approaches and adjacent LPFM and FMBC services requires determination of:

- The ground plus antenna height for any actual FMBC services and possible LPFM services.
- The aerodrome landing threshold point height.
- The aeroplane minimum height at each test point.

This information can be deduced from local topographical maps and aerodrome landing chart details. Appendix B shows a typical aerodrome landing chart from which much of this information can be obtained.

Adjustment of clearance distances may be appropriate where:

- Test point heights are required to conform with minimum aerodrome landing approach altitudes or route altitude restrictions imposed by CAA AIP charts or rules, or local city council height restrictions;
- Test points are located in uninhabitable areas, such as under aircraft approaches over water, clearance for LPFM transmitters should be adjusted to the distance of the closest habitable area;
- Local terrain, mast or other structure is above the height an FMBC or LPFM antenna and aeroplanes would be required to maintain a higher clearance; and,
- The LPFM GUL, Terms, conditions and restrictions state exclusion zones for LPFM services.

Such adjustments can increase potential interference if clearance is reduced or reduce potential interference if clearance is increased.

Where potential incompatibilities are marginal, adjustments to clearance distances can be critical. In such cases the RSM practice is to identify the clearances required using the aerodrome landing charts and allow margins of safety as follows;

- for test points on a runway extended centreline the minimum aeroplane height is considered to be15% lower than the lowest descent slope indicated on the chart.
- on the landing approach route and within the Minimum Sector Altitude drawing the minimum aeroplane height is assumed to be 15% lower than indicated on the chart.

8.4. Test Point Aeronautical Frequency Selection

The frequencies at which coordination is required for ILS equipped aerodromes can be identified by completing an area search in the band 108 to 117.95 MHz within a radius of 100 km from the relevant aerodrome and identifying those ILS and VOR services required to be used at each test point location and height, near that aerodrome.

ILS frequencies operating in particular landing approaches are identified in the aerodrome landing charts (Appendix B) and only one ILS service will be operating at an aerodrome at a time, i.e., others are switched off.

Calculations for VOR services greater than 100 km from test points within minimum sector altitude zones shown in aerodrome landing charts (see Appendix A for a sample chart) are not required as radio path profiles indicate aircraft receivers will not be line of sight, i.e., low level test points will be outside the DOC of the remote VOR services. Test points located at higher levels may be within a remote VOR DOC but calculations have shown that FMBC signal levels at those altitudes are below IM trigger levels; hence receiver IM interference should not occur.

The frequencies at which coordination is required for test points above each high power FMBC transmitter site remote from the ILS DOCs at aerodromes can be identified by completing an area search in the band 108 to 117.95 MHz within a radius of 100 km from that site and identifying those VOR services expected to be used at the test point vertically above the mast, i.e., at heights based of SM1009 Annex 2, section 2.2. Calculations completed for all remote major multi-FMBC user sites have indicated no IM issues.

8.5. Test Point Wanted Signal Level Correction Factors

SM1009 Annex 1 provides equations for identifying IM component levels based on aircraft receiver performance. Those equations include the determination of a correction factor (Lc, refer SM1009, Annex 1, 4.2.3.3) that takes into account receiver performance at wanted signal levels in excess of or below the reference level. Lc has a major impact on potential IM levels and needs to be fully considered. Failure to fully evaluate the correction factors can result in excessive limitations on spectrum usage or under-estimation of receiver IM levels.

Identification of wanted signal levels at test points requires evaluation of distance between the ILS or VOR transmitter and each test point, and consideration of any radio path obstructions.

Where ILS field measurements are available from annual DOC surveys actual levels can be extrapolated or interpolated using distance ratios.

Airways Corporation aerodromes at Auckland, Wellington, Christchurch and Dunedin are operated by Airways Corporation Limited and are surveyed with equipment that identifies actual ILS signal levels at multiple test points within each DOC.

At the NZDF Whenuapai and Ohakea aerodromes annual field measurements record only that the ILS signal level is not less than the minimum required (32 dBµV/m) at the limits of the ILS DOC boundary remote from the runway. ILS signal levels can be interpolated from points on the boundary where the signal level at least 32 dBµV/m to the ILS transmitter. Areas and points where the signal levels are less than 32 dBµV/m are considered as being outside the ILS DOC.

The practice of interpolating and extrapolating field level measurements can also be used for extending measurements laterally as well as in a line between the measurement point and ILS transmitter provided details of the ILS antenna HRP are known. However, such practices must be applied conservatively to ensure maintenance of safety margins.

Both ILS and VOR services use duplex equipment and have online transmit power level monitoring that alarms at -3 dBc. To ensure that coordination calculations apply under low signal conditions ILS and VOR signal levels used to calculate the Lc correction factors are to be reduced 3 dB on test point schedules.

8.6. Frequency Schedule Preparation

A frequency schedule in the form shown in Appendix D is produced for use with the RSM Aero-FMBC coordination spreadsheet through the use of an RSM area search tool. The schedule identifies all licences within a radius of a point, usually the centre of an aerodrome when aerodrome ILS/VOR services coordination is required and a FMBC site when coordination is required remote from aerodromes.

The area search must include a search of all current and planned licences in the band 88 to 117.975 MHz and a radius large enough to include all licences whose transmitters provide signals at any test point in the area capable of exceeding the aeronautical receiver IM cut-off point. Calculations have shown that a search radius of 80 km will include most transmitters likely to exceed that cut-off level. However, care must be exercised to ensure FMBC transmitters adjacent to the area whose frequency is greater than 105 MHz and whose transmit power level is greater than 37 dBW are included. Graph G1 (Appendix G) shows the minimum distances between an aircraft receiver (test point) and FMBC transmitters of various frequencies and transmit powers for the receiver FMBC signal to be less than the IM cut-off level.

Once an area search has been produced duplicated licences and remote licences whose signal level will be less than the IM cut-off level at all test points can be removed to reduce processing time.

The area search must then be extended by the addition of all LPFM frequencies (106.7 to 107.7 MHz in 100 kHz steps) and any other likely future stations planned by RSM.

The frequency schedule used by RSM has a column for adjusting power levels when all test points are in the same general direction, i.e., can be used for adjusting the transmit power to cover antenna radiation pattern variations of services remote from an ILS DOC or specific VOR test point.

9. Determination of Interference Type B1 and B2 Incompatibilities

9.1. Type B1 Compatibility Assessment and Adjustment

Type B1 interference (receiver IM) compatibility assessment requires use of the methods given in SM1009, Annex 1, 4.2.3, and involves:

- The calculation of FMBC, LPFM and aeronautical signal levels at each test point.
- The calculation of receiver cut-off and trigger levels for each FMBC, LPFM and aeronautical service at each test point.
- Identifying all potential two and three frequency third order IM products cochannel with each of the ILS and VOR frequencies at each test point.
- Calculating the correction term for each IM component frequency offset given in SM1009, Annex 1, 4.2.3.2 Table 4 for each ILS and VOR frequency at each test point.
- Calculating the correction factor Lc as given in SM1009, Annex 1, 4.2.3.3 for each wanted ILS and VOR signal level at each test point.
- Calculating the individual potential IM components using SM1009, Annex 1, 4.2.3.1 formulae.
- Determining whether the incompatibility margin is adequate.

Where the margin is inadequate it will be necessary to identify the IM components which are the main contributors and whether adjustments can be made to the services producing those components that would improve the margin. The adjustments could include:

- Improving the accuracy of signal levels by making adjustments for antenna HRPs.
- Reducing the transmit power or altering the HRP or VRP of any planned FMBC service.
- Increasing the distance between the test points and services.

If adjustments are possible the calculation process should be repeated until the margins become acceptable.

9.2. Type B2 Compatibility Assessment and Adjustment

Type B2 interference (receiver IM) compatibility assessment requires use of the formula given in SM1009, Annex 1, 4.2.4, and involves calculating and summing the FMBC, LPFM and aeronautical signal field strengths at each test point.

9.3. Adjustments to Resolve Incompatibilities

When the results of calculations indicate potential incompatibilities consideration can be given to:

- reducing the power level of a planned FMBC signal
- increasing clearance distances to LPFM
- completing field measurement of FMBC and ILS/VOR services at test points
- reviewing clearances to flight paths with Airways, NZDF or CAA
- new calculations based on any adjustments.

10. Interpretation of Analysis Results

The accuracy of the results derived from use of SM1009 processes is significantly based upon:

- The care taken to establish test points and their horizontal distances and vertical clearances in relation to the location of FMBC and LMBC transmitters, aeronautical services DOCs and aeronautical flight rules.
- The use of realistic aeronautical and FMBC field strengths.
- The reliability of the calculation process used.
- The interpretations of SM1009 requirements.

10.1. Test Point Locations and Clearances

The test points established by RSM at all aerodromes using ILS and VOR services in NZ are based on SM1009, discussions with Airways navigation systems engineers and aeronautical route planners, and use of CAA flight rules. The test points specified in SM1009 for ILS DOCs are not fully implemented for the reasons noted above in 8.3 Test Point – Antenna Clearance Requirements. External engineers should verify for themselves that the practice described is justified.

RSM experience suggests that particular attention is required to locations and clearances for test points close to aeroplane landing decision points and hill tops near to or beneath aerodrome landing approaches.

10.2. Aeronautical and FMBC Field Strengths

The aeronautical and FMBC field strengths used in initial RSM calculations to identify that signal levels are equal to or greater than the cut-off level are based on SM1009 free space path loss formulae using license transmit power levels and without adjustments for antenna HRPs. Subsequent calculations are then adjusted to account for:

- ILS values derived from field measurements included in the test point schedule.
- FMBC value variations due to antenna HRPs.
- FMBC values derived from field measurements if available.
- More accurate path loss values based on path obstructions, clearances, reflections and clutter.

When establishing ILS and VOR signal levels it is essential to ensure levels are not over estimated as such levels could increase correction factor Lc unrealistically and result in a less than conservative coordination result.

The number of FMBC, LPFM and aeronautical frequencies and test points involved in calculations means that adjustments to signal levels would normally be limited to signals contributing to significant IM components that are close to or exceed the minimum potential incompatibility level.

A concern relating to FMBC signal strengths is the accuracy of transmitter power levels for services using modulation enhancement technology. Overseas experience suggests that such technology can raise instant transmitter power levels over licensed levels significantly and for certain programme types increase mean power levels up to 4 to 8 dB for considerable periods. RSM is currently considering this matter and the impact on safety margins within the SM1009 processes.

10.3. Calculation Reliability

The reliability of the calculation process depends upon checks to ensure SM1009 formulae are properly implemented, the IM component frequencies are correctly identified, adjustments are correctly identified and applied, and perhaps the use of sample calculations using other methods to independently verify the results. On these matters it is noted that:

- The application of the SM1009 formulae use has been independently verified as being implemented correctly and that referenced cells checked in terms of the relevance of the parameters cell identification.
- IM component frequencies have been verified against those of another IM calculator.
- The correct identification of adjustments, particularly vertical clearance distances and ILS and VOR field strengths, are accurately and conservatively determined, and correctly located in the test point schedule. A check that the use of an accurate Lc is properly applied can be made by manually calculating signal levels, and ensuring these are used appropriately in the potential interference calculations at specific ILS and VOR frequencies.
- RSM had independent verification of its original coordination tool in 2001 and recently had independent comparisons between the old and new tools that indicated differences of less than 0.02 dB in potential interference levels.

10.4. Interpretation of SM1009 and its Parameters

The process used by RSM to determine the level of potential IM conforms to the GAM of SM1009 because the calculations of FMBC, LPFM and ILS/VOR signals are based on free space path loss with no allowance for clutter loss or reflections, or FMBC field measurements.

When interpreting the results of the coordination process, it should be noted that:

- SM1009 processes have been developed over more than 30 years and are significantly based on the known aeronautical receiver parameters, standard ICAO ILS and VOR DOC dimensions and internationally sourced statistical FMBC data. Use of the SM1009 processes provides a margin of safety that must not be reduced.
- the identification of clearance heights between FMBC antennas and test points should include a 15% margin to allow for aircraft height excursions below recommended minimum heights.

The resolution of whether a process used complies with the GAM process or otherwise will depend upon the extent to which detailed analysis of the signal strengths or field measurements of the significant FMBC IM component contributors are used.

RSM's interpretation on this matter is that the results produced by calculations using FMBC transmit power level adjustments for antenna HRP variations and ILS signal levels based on the extrapolation of field measurement results, are:

- within the intent of the GAM; and therefore
- IM components can be compared individually with the minimum level of potential incompatibility required by SM1009.

Where measured values or detailed path loss analysis adjustments are completed for FMBC services contributing to significant IM components the coordination result is outside the intent of the GAM and a power sum of significant IM components must be compared with the minimum level of potential incompatibility required.

11. Certification of FMBC, ILS and VOR Licences

Engineers intending to issue certificates for FMBC, ILS, or VOR licences should ensure that they have fully identified all test point location, clearance, frequency and wanted signal level data, and also all likely FMBC and aeronautical services that can contribute to IM products. They must also be fully confident that the analysis process used is thoroughly reliable.

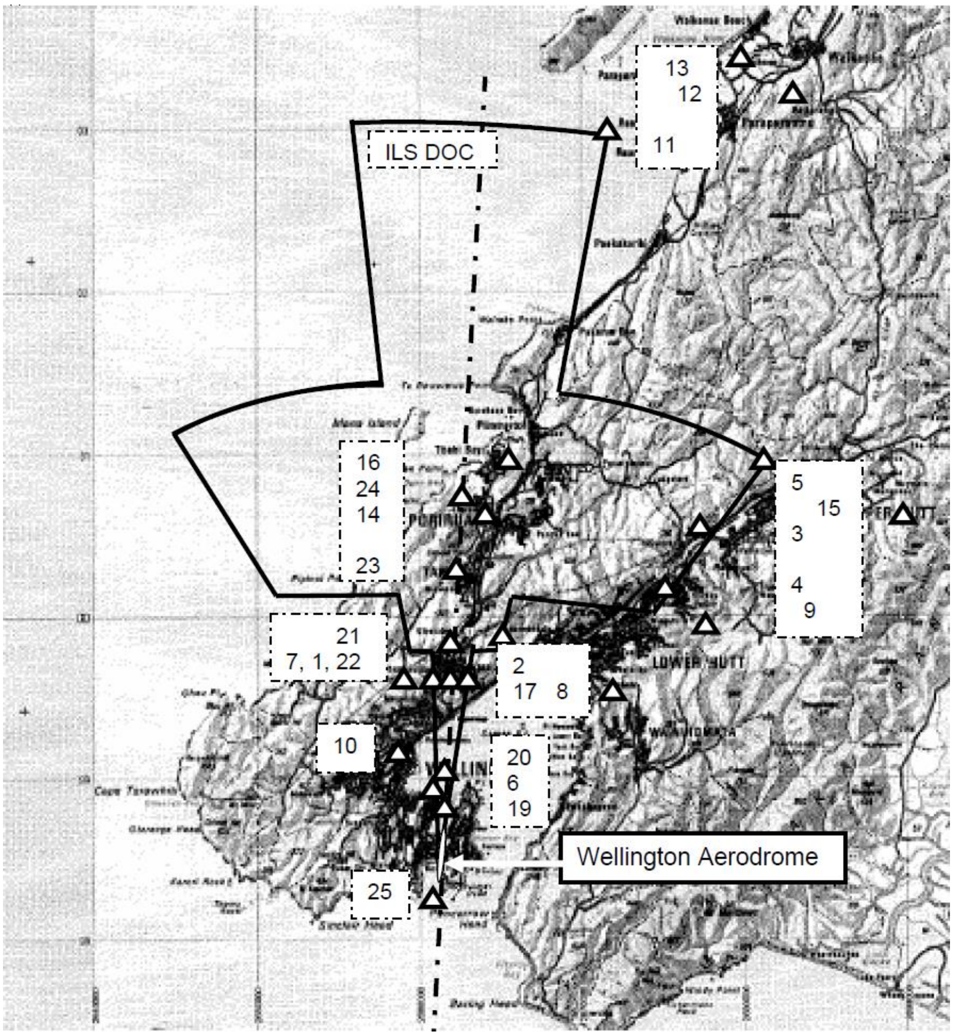
When interpreting the results of their analysis they must ensure that potential incompatibilities do not exceed the SM1009 requirements.

When certifying licences engineers should be aware that the information included in this document is a summary of the more significant issues that RSM have managed in the development of the related processes and certification of FMBC services since 2001, and that additional advice information may need to be obtained from CAA, Airways Corporation, RSM and NZDF. Such information should first be requested through RSM, Manager Licensing.

Appendix A: Wellington Aerodrome Northern ILS DOC and Test Points

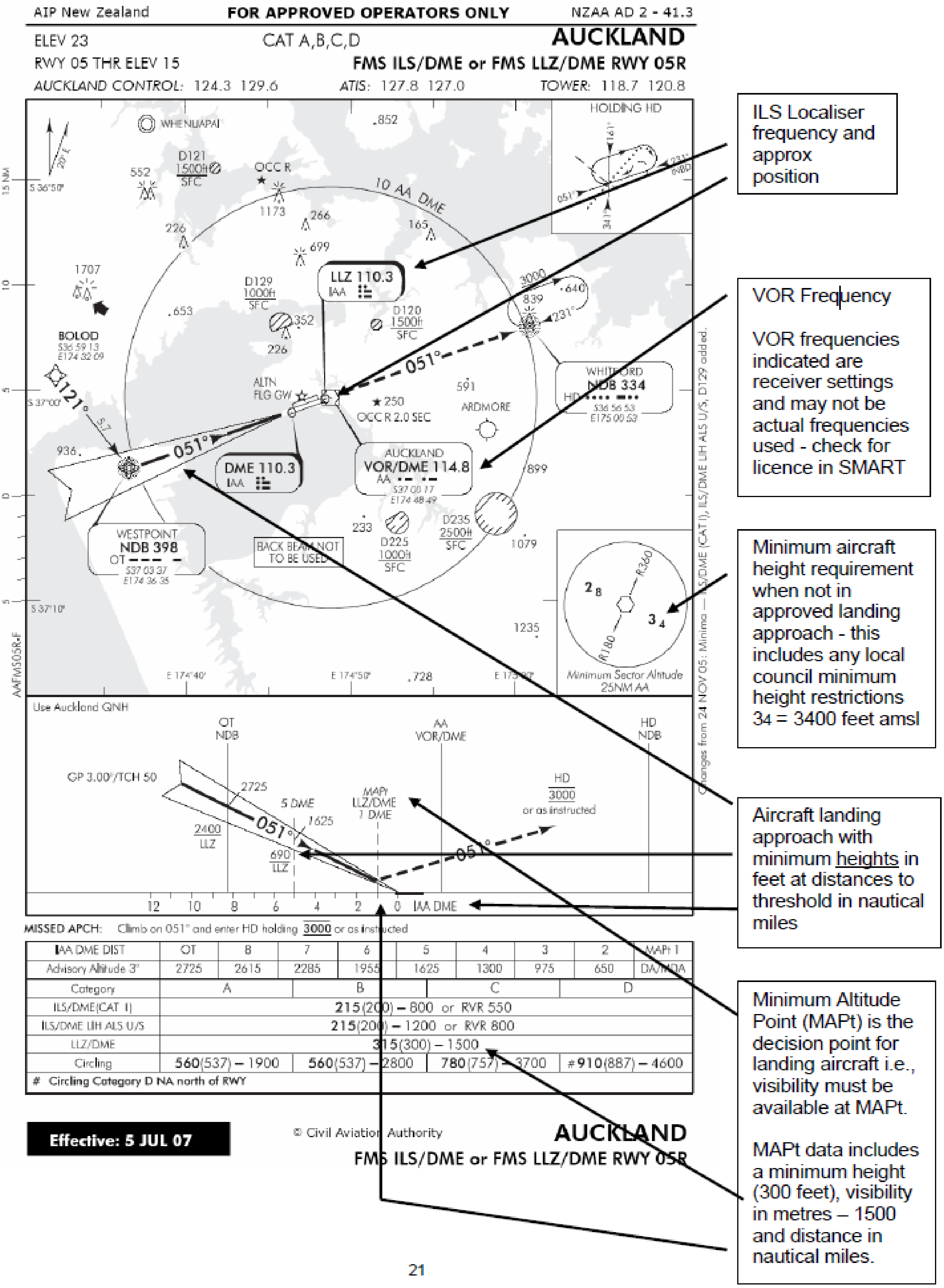
Test point schedule

1 Adj Kaukau	2 Adj Towai	3 Haywards
4 Adj Fitzherbert	5 Adj Climie	6 Pt Jerningham
7 Kaukau	8 Towai	9 Fitzherbert
10 Tinakori	11 Adj Ngarara	12 Forest Heights
13 Ngarara	14 Porirua LPFM	15 Climie
16 Porirua Rhema	17 Adj Towai (Newlands)	18 Adj Blenheim
19 Wn RWT 16E	20 Wn RWT 16F	21 Wn RWY 16G
22 Wn RWT 16H'	23 Wn RWY 16I	24 Wn RWY 16J
25 Wn RWY 34E	(Adj = adjacent to = on DOC boundary)	



Appendix B: Typical Aerodrome Landing Chart

Route bearings shown below are with respect to magnetic north



Appendix C: Typical RSM Test Point Schedule and its Preparation

Figure C1 – Wellington Test Point Schedule

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1																				
2																				
3												VOR	VOR	ILS	ILS	ILS	ILS	ILS	ILS	VOR
4	TP no	TP ID	Site Name	Map Ref	Longitude	Latitude	Ground + Ant Height m	Test Point Height m	TP Clearance to Antenna	TP Clearance to LPFM		112.3	114.6	110.3	109.9					116
5	1	TP1	Adj Kaukau	R27 604956	174.7941504	-41.2341646	260	600		560		x	x	x						x
6	2	TP2	Adj Towai	R27 648968	174.8463195	-41.2225362	260	600		300		x	x	x						x
7	3	TP3	Haywards	R27 774062	174.9939893	-41.1354224	390	600	160	210		x	x	x						x
8	4	TP4	Adj FitzHerbert	R27 743008	174.9585177	-41.1846651	100	600		490		x	x	x						x
9	5	TP5	Adj Climie	R26 827112	175.0556961	-41.0893070	460	600		500		x	x	x						x
10	6	TP6	Pt Jerningham	R27 608890	174.8005434	-41.2935070	200	600		600		x	x	x						x
11	7	TP7	Kaukau	R27 591955	174.7786714	-41.2328774	550	700	480	480		x	x							x
12	8	TP8	Towia	R27 718955	174.9301224	-41.2328774	355	505	560	560		x	x							x
13	9	TP9	Fitzherbert	R27 743968	174.9595863	-41.2206737	387	687	560	560		x	x							x
14	10	TP10	Tinakori	R27 578911	174.7642279	-41.2751531	325	625	560	560		x	x							x
15	11	TP11	Adj Ngarara	R26 772293	174.9853682	-40.9275042	10	600		560		x	x	x						x
16	12	TP12	Forest Heights	R26 873381	175.1027442	-40.8461583	566	866	560	560		x	x							x
17	13	TP13	Ngarara	R26 829374	175.0507752	-40.8533988	67	600	533	490		x	x							x
18	14	TP14	Porirua LPFM	R27 641048	174.8359692	-41.1506483	25	600	575	490		x	x	x						x
19	15	TP15	Climie	S27 902049	175.1467704	-41.1443977	850	2000	560	560		x	x							x
20	16	TP16	Porirua Rhema	R27 673085	174.8731378	-41.1167272	170	600	430	430		x	x	x						x
21	17	TP17	Adj Towai Newlands	R27 630957	174.8251316	-41.2327795	270	439		169		x	x	x						x
22	18	TP18	Adj Blenheim		174.5800000	-41.5300000	0	600		5000		x	x		x					x
23	19	TPWn16E		R27 614870	174.8057308	-41.2213755	0	79		79				x						
24	20	TPWn16F		R27 615900	174.808652	-41.284374	0	171		171				x						
25	21	TPWn16G		R27 617930	174.810296	-41.257330	0	376		376		x	x	x						x
26	22	TPWn16G'	Newlands Peak	R27 618923	174.811638	-41.262713	250	421		171		x	x	x						x
27	23	TPWn16H	Newlands Water Towe	R27 620945	174.813504	-41.243770	260	439		179		x	x	x						x
28	24	TPWn16I		R27 622990	174.814774	-41.203221	377	568		191		x	x	x						x
29	25	TPWn16J		R27 6250424	174.816764	-41.145548	475	648		163		x	x	x						x
30	26	TPWn34E		R27 610815	174.804782	-41.360987	0	123		123			x		x					x
31																				

	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
1											VOR Power dBW eirp	VOR Power dBW eirp	VOR Power dBW eirp					
2											21.0	21.0	21.0					
3											112.3	114.6	115.6			112.3	114.8	115.6
4	FMBC Vertical Power Discr dB	LPFM Vertical Power Discr dB		Ref ILS DOC Measurement Point	Ref TP Dist to ILS km	Ref ILS Sig Level dBm	TP Dist to ILS km	Misc Adjustment			VOR distance to Test Point km	VOR distance to Test Point km	VOR distance to Test Point km		ILS measured signal level dBm	VOR signal level dBm	VOR signal level dBm	VOR signal level dBm
5		-1		H	12	-80	11.5	-3			12.0	36.6	84.4		-82.6	-59.3	-69.0	-76.3
6		-1		Y4	31.5	-79	13.6	-3			15.0	42.0	87		-74.7	-61.3	-70.2	-76.5
7	-4	-1		C	31.5	-92.4	27	-3			27.3	53.3	103.4		-94.1	-66.5	-72.3	-78.0
8		-1		C	31.5	-92.4	18	-3			19.0	76.0	95		-90.5	-63.3	-75.4	-77.3
9		-1		C	31.5	-92.4	34	-3			35.0	70.0	105		-96.1	-68.6	-74.6	-78.2
10				F	6	-71	5	-3			6.0	38.0	84		-72.4	-53.3	-69.3	-76.2
11	-14	-1						-3			12.0	35.4	82.8			-59.3	-68.7	-76.1
12	-4	-1						-3			29.0	47.9	94.8			-67.0	-71.4	-77.3
13	-4	-1						-3			18.0	81.0	97.5			-62.9	-75.9	-77.5
14	-4	-1						-3			27.0	35.0	97.9			-66.4	-68.6	-77.6
15		-1		Y6	43.5	-83.4	46	-3			56.0	65.0	110		-86.9	-72.7	-74.0	-78.6
16	-4	-1						-3			60.0	73.0	128			-73.3	-75.0	-79.9
17	-4	-1						-3			58.0	69.0	124			-73.0	-74.5	-79.6
18	-4	-1		H	12	-78.2	21.5	-3			21.0	38.7	90		-86.3	-64.2	-69.5	-76.8
19	-4	-1						-3			35.5	66.0	115			-68.8	-74.1	-79.0
20	-4	-1		Y6	43.5	-83.4	30.4	-3			24.0	44.0	95.7		-83.3	-65.4	-70.6	-77.4
21		-1		H	12	-78.2	12	-3			18.0	41.0	88.5		-81.2	-62.9	-70.0	-76.7
22				C	31.5	-101	31.5	-3			19.0	60.0	60		-104.0	-63.3	-73.3	-73.3
23				E	3	-65.5	3	-3				39.0			-68.5		-69.6	
24				F	6	-69.9	6	-3				39.0			-72.9		-69.6	
25		-1		G	9	-72.8	9	-3			11.0	39.0	85.7		-75.8	-58.6	-69.6	-76.4
26		-1		H	12	-78.2	11.2	-3			13.2	39.0	86		-80.6	-60.2	-69.6	-76.4
27		-1		H	12	-78.2	12.4	-3			14.4	39.0	86.3		-81.5	-60.9	-69.6	-76.5
28		-1		H	12	-78.2	15	-3			17.0	39.0	86		-83.1	-62.4	-69.6	-76.4
29		-1		H	12	-78.2	21.5	-3			23.0	39.0	88		-86.3	-65.0	-69.6	-76.6
30				E	3	-64.3	3	-3				39.0	71.3		-67.3		-69.6	-74.8

Appendix C (Continued) Test Point Schedule Spreadsheet Preparation

The test point schedule in the Figure C1 above is required for use with the RSM FMBC-AERO coordination spreadsheet. The layout of data in the test point schedule is specific to the FMBC-AERO spreadsheet because its macros expect to see specific data in particular cells.

The schedule identifies all test point location details unique to each point, i.e., a test point number, location name and map references (particularly latitude and longitude which are used to calculate distance information for the calculations), vertical clearances between FMBC and LPFM services and the test point clearances, ILS and VOR test frequencies, FMBC and LPFM vertical radiation power adjustments, ILS field measurement reference distance and field strength values, miscellaneous adjustment for ILS/VOR power reduction, VOR to test point distances. The test point schedule spreadsheet uses the data to calculate ILS and VOR signal levels required to be received at each test point.

Information in the schedule has the following requirements, purposes and preparation requirements:

A. Column A contains a sequential number that is as a reference used to identify test points in the FMBC-AERO spreadsheet macro and various worksheets.
B. Columns B, C and D provide convenient reference information and are not used in FMBC-AERO.
C. Columns E and F are used in FMBC-AERO together with data in the frequency schedule to calculate radio paths lengths for signal strength calculations at test points. The data in the columns may be copied from the site information in the frequency schedule when available or translated from the test point map reference using map conversion tool in RSM TOOLS.
D. Columns G and H are derived from map, licence, SM1009 and aerodrome landing chart information and used together with SM1009 guidance and other information contained in this document to complete columns I and J.
E. Columns I and J generally provide minimum vertical clearance distance for test points above FMBC and LPFM services that are used in FMBC-AERO field strength calculations. Test point clearances in column J of greater than 600 meters are horizontal distances and consequently there is no corresponding vertical power discrimination reduction in column V. This occurs because previous coordination has shown the need for a clearance distance greater than the vertical distance available. In such cases an LPFM exclusion zone will have been recorded in the LPFM GUL Terms, conditions and restrictions.
F. Columns K, W, AC and AD are intentionally left blank.
G. Columns AI, AJ, AK and AL are not copied in the Load Test Point sequence and are calculated in the FMBC-AERO TestPointsFile worksheet
H. Columns L to T inclusive are available of identifying the VOR and ILS frequencies applicable at each test point. Row 3 in each column is used in FMBC-AERO to identify the type of service (ILS or VOR) and apply relevant formula and other data. Row 4 is the frequency of the service and also used in FMBC-AERO. Rows 5 to 31 identify with an ‘x’ the services and frequencies used at each test point with the FMBC-AERO macros. NOTE; Columns L, M and T must be used only for VOR services and columns N to S must be used for ILS services.
I. Columns U identifies vertical power adjustments applied in FMBC-AERO due antenna vertical radiation patterns for test points above FMBC transmitters. The adjustment

values are derived using SM1009 guidance, The Registrar of Radio Frequencies licence data and/or information requested from licence holders or site operators.

J. Columns V identifies the vertical power adjustments applied in FMBC-AERO due to LPFM antenna vertical radiation patterns at each test point. There is no adjustment when the TP clearance for LPFM is 600 m or greater. See E above.
K. Columns X, Y and Z are derived from flight test data provided by Radiola (on behalf of NZDF for Whenuapai and Ohakea aerodromes) and Airways Corporation (all other aerodromes). (The flight test data is held in RSM's R drive, Licensing, Aeronautical, Aero Correspondence.) The data is used in column AI together with data in columns AA and AB to calculate ILS field strengths at each test point the ILS frequency is used.
L. Column AA includes distances from the test point to ILS service based on map measurements. The data is used in column AI together with data in columns X, Y, Z and AB to calculate ILS field strengths at each test point the ILS frequency is used.
M. Column AB is available for adjusting ILS and VOR signal levels as might be required to simulate lower transmit power levels due to ILS or VOR transmitter power supply or maintenance issues. Based on discussions with Airways Corporation a figure of -3 dB is used.
N. Cells AE6 to AE31 and AF6 to AF31 include distances from the test point to VOR services at each test point the VOR service coordination is required. The distances can be based on map measurements or area search data if available.
O. Cells AE3, AF3 and AG3 must include VOR transmit power in dBW eirp.
P. Cells AE4, AF4 and AG4 identify the relevant VOR frequency and are copied directly from cells L3, M3 and T3 respectively
Q. Cells AJ4, AK4 and AL4 identify the relevant VOR frequency and are copied directly from cells L3, M3 and T3 respectively
R. Cells AI6 to AI31 include formulae and use data from appropriate cells to determine the ILS signal levels at each test point at which ILS service coordination is required. The data is used in the FMBC-AERO macros to identify Lc corrections.
S. Cells AJ6 to 31, AK6 to 31 and AL6 to 31 include formulae and use data from appropriate cells to determine the VOR signal levels at each test point and VOR service at which coordination is required. The data is used in the FMBCAERO macros to identify Lc corrections.

Where columns or cells are not required for calculations they must to left blank and not removed.

Cells that include distance information for use in calculations should not include a '0'.

Appendix D: Typical FMBC Frequency Schedule

Showing less than half actual list plus test frequencies for future FMBC and possible LPFM

Assignments within 70.0 km of R27/611840 between 88.0 MHz & 117.9 MHz
Sorted by Frequency

Location	Easting	Northing	Freq	BW kHz	dBW	Dist km	Bearing	Site Ht	Ant Ht	Licence	Chan
FOREST HEIGHTS	175.10274	-40.84616	88.6	256	28.0	60.2	24.6	442	25	202553	
TOWAI	174.93130	-41.23285	96.9	256	32.0	15.8	41.9	348	30	3504	FM259
MT CLIMIE(BCL)	175.14790	-41.14257	99.7	256	28.0	36.0	52.9	830	8	206054	FM315
KAUKAU	174.77798	-41.23514	100.0	256	46.0	11.7	348.7	425	122	13106	FM321
MT CLIMIE(BCL)	175.14790	-41.14257	100.0	256	28.0	36.0	52.9	830	8	13063	FM321
FITZHERBERT	174.95958	-41.22067	100.7	256	29.0	18.4	44.6	377	20	10350	FM335
FOREST HEIGHTS	175.10274	-40.84616	100.7	256	28.0	60.2	24.6	442	25	206239	FM335
TOWAI	174.93130	-41.23285	100.9	256	32.0	15.8	41.9	348	30		FM339
FOREST HEIGHTS	175.10274	-40.84616	101.5	256	27.0	60.2	24.6	442	25		FM351
KAUKAU	174.77798	-41.23514	101.7	256	47.0	11.7	348.7	425	65		Test
KAUKAU	174.77798	-41.23514	102.1	256	47.0	11.7	348.7	425	65	202204	FM363
KAUKAU	174.77798	-41.23514	102.5	256	47.0	11.7	348.7	425	65		Test
KAUKAU	174.77798	-41.23514	102.9	256	47.0	11.7	348.7	425	65		Test
KAUKAU	174.77798	-41.23514	103.3	256	47.0	11.7	348.7	425	65		Test
KAUKAU	174.77988	-41.23618	103.7	256	39.0	11.6	349.4	425	122	204125	FM395
TOWAI	174.93130	-41.23285	104.5	256	29.0	15.8	41.9	348	8	12390	FM411
TOWAI	174.93130	-41.23285	104.1	256	29.0	15.8	41.9	348	8	12390	Test
FOREST HEIGHTS	175.10526	-40.85061	104.9	256	28.0	59.8	25.0	560	10	12293	FM419
FOREST HEIGHTS	175.10526	-40.85061	106.3	256	29.0	59.8	25.0	560	10		Test
MT FREETH	173.98376	-41.29162	104.9	256	22.0	68.8	274.1	338	10		FM419
KAUKAU	174.77988	-41.23618	105.3	256	33.0	11.6	349.4	425	122		FM427
KAUKAU	174.77988	-41.23618	105.7	256	33.0	11.6	349.4	425	122		Test
KAUKAU	174.77988	-41.23618	106.1	256	33.0	11.6	349.4	425	17		FM443
FOREST HEIGHTS	175.10274	-40.84616	106.3	256	28.0	51.1	32.2	442	25		FM447
WELLINGTON(ILS)	174.80750	-41.31888	109.9	21	17.0	2.2	4.7	0	0	74938	
WELLINGTON(ILS)	174.80611	-41.33777	110.3	21	17.0	0.1	0.0	0	0	74946	
PALMER HEAD	174.81694	-41.33916	112.3	21	21.0	1.0	94.6	122	0	74915	
NARAWHIA	174.36131	-41.18783	114.6	21	21.0	40.7	294.1	520	0	105188	
LPFM			106.7	256	0.0	0					Test
LPFM			106.8	256	0.0	0					Test
LPFM			106.9	256	0.0	0					Test
LPFM			107.0	256	0.0	0					Test
LPFM			107.1	256	0.0	0					Test
LPFM			107.2	256	0.0	0					Test
LPFM			107.3	256	0.0	0					Test
LPFM			107.4	256	0.0	0					Test
LPFM			107.5	256	0.0	0					Test
LPFM			107.6	256	0.0	0					Test
LPFM			107.7	256	0.0	0					Test

Appendix E: FMBC AERO Spreadsheet Operation and Adjustments

The RSM FMBC AERO spreadsheet operation uses Frequency and Test Point schedule parameters and SM1009 formulae to calculate B1 and B2 interference margins using 10 worksheets. These are:

- Main Menu; which provides the spreadsheet management functions using control buttons to ‘Clear All Calculated Data’, ‘Load Area Search’ and ‘Load Test Points’ schedules, ‘Run all Calculations’, individual buttons to perform each of the six macros in sequence as an alternative to ‘Run all Calculations’, individual ‘View’ buttons to review macro results and ‘Generate Report” and “View Report’ buttons.
- Area Search File; which displays the Frequency area search data.
- Test Point File; which displays the Test Point schedule data.
- ILS/VORall, which uses a macro to identify and display component parameters and signal levels at each test point for each test point frequency and frequency schedule transmitter. The macro determines slant distances based on great circle distances calculated from the test point and each transmitter latitude and longitude, and the transmitter and test point vertical distances. The worksheet also calculates the test point receive IM cut off levels, for each ILS, VOR and transmitter signal level at each test point, and identifies whether each transmitter signal level exceed the IM cut off level or not.
- B1 ILS/VORall, which identifies whether each transmitter signal on ILS/VORall exceeds the receiver trigger level at each test point and each ILS/VOR frequency, using the Lc calculated from the test point schedule parameters, schedules all transmitter received signals as exceeding the cut off or trigger levels.
- 2f_im_ILSVORall, which for each test point and ILS/VOR frequency uses a macro to identify all two frequency IM components falling within the receiver bandwidth.
- 3f_ILSVORall; which for each test point and ILS/VOR frequency uses a macro to identify all three frequency IM components falling within the receiver bandwidth.
- Margins; which lists and summarises all two and three frequency IM components by test point and ILS/VOR frequency and then power sums these as either two or frequency sums.
- B2 summary, which identifies all receiver input signal levels and power sums then to provide total input signal level at each test point.
- Summary Report, which provides a report at each test point and each ILS/VOR frequency of total IM margin and B2 margin.

Initialising a new calculation process requires the clearance of existing calculations and the loading of the required area search and test point schedules. Starting the program takes 5 seconds to message screen (select ‘don’t update’ option) then approximately 30 seconds to main menu appearance and another 30 seconds or so to be ready to receive input. ‘Clearing all Calculated Data’ takes up to 30 seconds.

Loading the test point and frequency schedules takes less than 5 seconds each. Failure to use the exact format of the schedules will result in error messages.

Once the Test Point and frequency schedules have been loaded correctly the Main Menu button ‘Run all Calculations’ will run multiple macros in succession, taking some 5 to 50 minutes depending upon the size of the area search and test point schedules, and the number of services exceeding the aircraft receiver cut-off and trigger level values. Use of zero FMBC and LPFM height clearance distance data may cause error messages during the ‘Run Field Strength/Power Calculation’ macro. Viewing the results for that macro via the Main Menu screen will help identify cells in error and associated reference data for tracing to the error source, i.e., to particular incomplete area search and/or test point schedule entries.

The time taken to run the spreadsheet can be shortened initially by selecting a clearance distance higher than expected.

Subsequent iterative adjustments to clearance data and FMBC transmit power levels for the new services and rerunning the spreadsheet should enable the determination of acceptable parameters, should that be possible.

Should permitted IM margins be exceeded after the initial ‘Run all Calculations’ process has been completed, the following process can be followed to reduce or remove significant IM component field strength contributions:
1) After ‘Run all Calculations’ has been completed successfully, identify the significant IM components and their contributing signal sources for each test point with margins exceeded in the Margins worksheet.
2) Clear All Calculated data and use the ‘Run Field Strength/Power Calculation’ button to run the first calculation macro.
3) When the macro has completed, check the contributing signal source distance and power level parameters in the view screen associated with the ‘Run Field Strength/Power Calculation’ macro (worksheet ILS/VORall) for each significant IM component contributor at each test point where the margins are exceeded. Add adjustments in the ‘distance adjustment’ and ‘power adjustment’ columns where possible, i.e., to reflect antenna HRP variations, to lower the transmit power level of a planned service, to increase clearance distances for LPFM services or other variations. Entering an adjustment and selecting the ‘Enter’ key will update the Receiver input signal level (column Q in ILS/VORall) for each transmitter adjusted.
4) Run the individual ‘potsIM’, ‘2-f IMS’, ‘3-f IMS’ and ‘Calculated Margins’ macros in sequence and review new IM margins in the ‘Margins” worksheet. If considered realistic revisit the contributing signal source distance and power level parameters in the view screen associated with the ‘Run Field Strength/Power Calculation’ macro (worksheet ILS/VORall) and repeat step 4) until IM margins are satisfactory.

Test point clearances for LPFM services have be set for existing and planned licence expected to be operating in the new 2011 management right and should not need to be adjusted. Any variations required will require approval of RSM Manager Licensing and if approved, will need to be included in a revised GUL for LPFM services before the implementation of any affected FMBC service.

Appendix F: Intermodulation

A1-1 IM occurs when two or more signals mix together to form new signals of different frequencies.

A1-2 IM products can occur in a receiver when a high level receive signal, i.e., a level above the 'trigger' level, overloads the receiver's input to the extent that the receiver becomes non-linear. A receiver operating in its non-linear zone will cause 2, 3 or more received signals to mix together to form new frequency components that can interfere with the wanted signal.

A1-3 Theoretical IM analysis identifies that the bandwidths of third order IM products should be the addition of the individual components, e.g., the bandwidth for 2f1-f2 and f1+f2-f3 IM products of FMBC signals should be 768 kHz. This suggests that because co-located FMBC services are space 800 kHz apart, and if all available FMBC assignments are being utilised, there will be no gaps in the IM spectrum in the 108 to 112 band. In practice, test results indicate that the bandwidths of FMBC IM products are likely to be up to twice the bandwidth of a typical FMBC signal and that there are clear gaps between the individual IM products into which the narrow bandwidth ILS/VOR assignments can be made.

A1-4 Further consideration suggests that IM products resulting from intermodulation between FMBC and local ILS/VOR signals will reduce the gaps in the IM spectrum if the ILS/VOR assignments are chosen without care. Specifically, the VOR frequency must be above the ILS frequency to ensure that ILS IM products do not include the VOR signal.

Appendix G: Graphs Illustrating Coordination Challenges

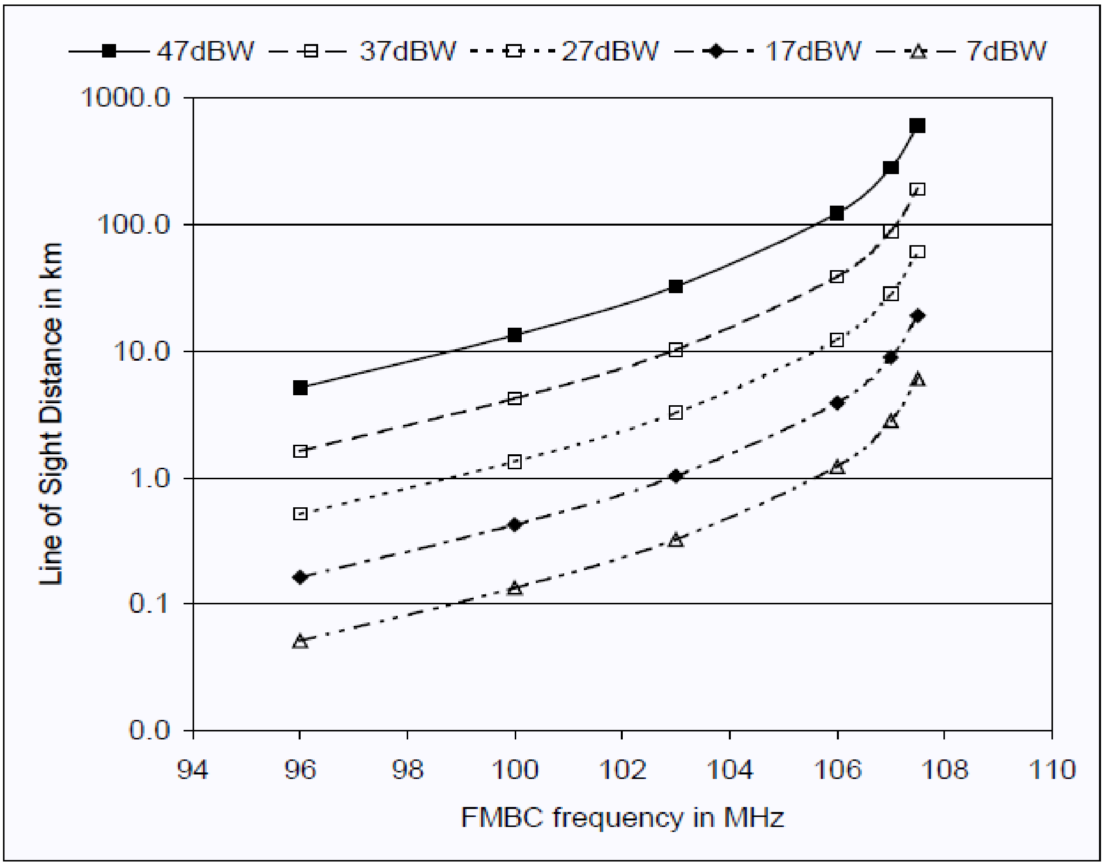
These graphs are included to illustrate the separation distances required between typical FMBC transmitters and ILS/VOR DOC areas. They are based on ITU-R SM.1009-1 recommendation (1009) methods. Detailed calculations are needed for particular FMBC and ILS/VOR DOC areas.

Graph G1

Graph indicating the minimum distance from a single FMBC station to an aircraft for the FMBC signal to be less than the IM cut-off level of the aircraft ILS receiver, for various FMBC frequencies and transmitter powers (eirp).

These B1 type interference contributory Cut-off levels are the same for all ILS frequencies in both Montreal and 1998 ICAO aircraft receivers.

The graph indicates that even low powered FMBC stations close to ILS/VOR DOC areas can contribute to IM interference in aeronautical receivers.

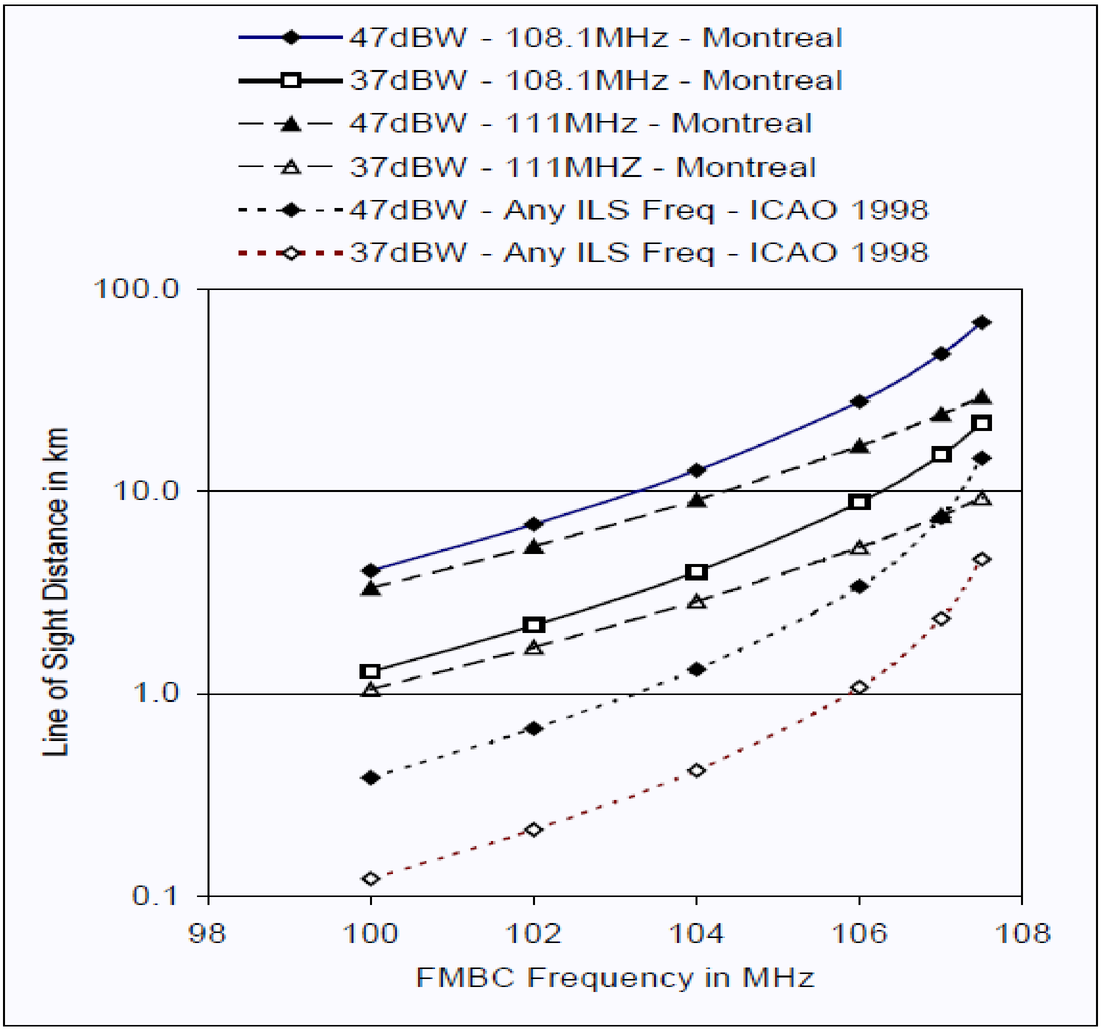


Graph G2

Graph indicates the minimum distance from a single FMBC station to an aircraft for the FMBC signal to be less than the IM Trigger level of both Montreal and 1998 ICAO aircraft receiver types, for various FMBC frequencies and transmitter powers (eirp), and ILS frequencies of 108.1 and 111 MHz; i.e., B1 interference Trigger level.

The graph indicates that medium powered FMBC stations above 102 and within 10km of ILS/VOR DOC areas have the potential to cause harmful IM interference in aeronautical receivers.

The graphs also indicate that Montreal receivers are significantly more susceptible to B1 IM harmful interference than the 1998 ICAO type.

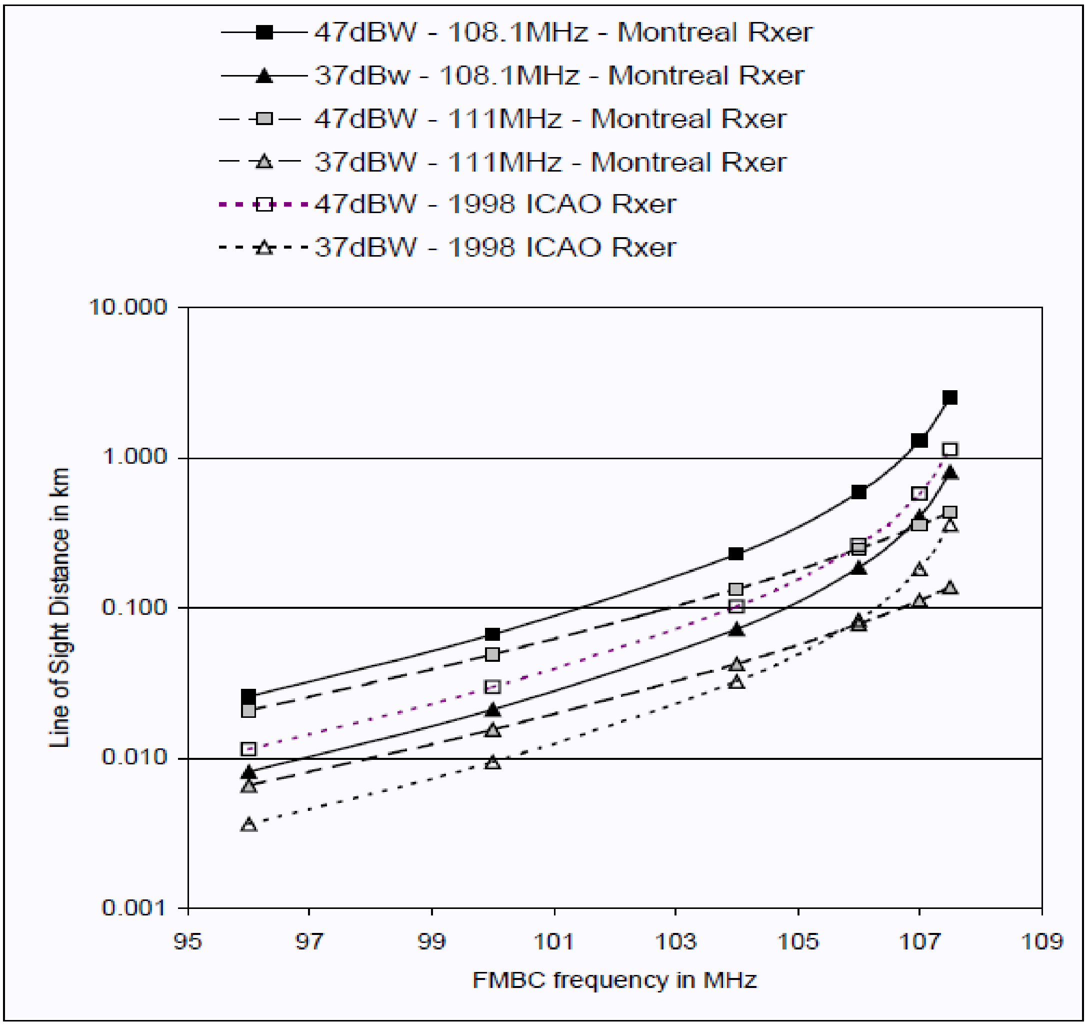


Graph G3

Graph indicates the minimum distance from a single FMBC station to an aircraft for the FMBC signal to be less than the Desensing interference level (B2) of both Montreal and 1998 ICAO aircraft receiver types, for various FMBC frequencies and transmitter powers (eirp), and ILS frequencies of 108.1 and 111 MHz.

The graph indicates that aeronautical receivers are significantly less sensitive to Desensing interference than to B1 interference.

The graphs also indicate that Montreal receivers are more susceptible to Desensing interference than the 1998 ICAO type, except for FMBC transmissions above 106 MHz.



Appendix H: Coordination Process

1 The aeronautical services/FMBC coordination process required is in three parts. These are:

i. the determination of the coordination margins at the point of the local ILS or VOR DOC area nearest to proposed new FMBC transmitter for existing services in the 88 to 117 MHz band.

ii. the determination of the coordination margins at the point of the local ILS or VOR DOC area nearest to proposed new FMBC transmitter, taking into account both the proposed new FMBC services and the existing services in the 88 to 117 MHz band.

iii. the determination of the coordination margins for each existing FMBC transmitter at points of the DOC area nearest to each of those existing FMBC transmitter taking into account both the proposed new and existing service in the 88 to 117 MHz band.

2 The first part requires the identification of the coordination point for the proposed new FMBC transmitter and of all radio licences in the band 88 to 117 MHz within line-of-sight of that coordination point. Once this is obtained the General Assessment Method (GAM) described in 1009 is used to identify the coordination margins that exist for each interference type.

3 The second part is to add the proposed new FMBC service to the GAM calculations completed in the first part.

4 The third part is to use the GAM to identify changes to the coordination margins at other points in the DOC. This requires either an intuitive approach in which the likely worst case for coordination is identified, perhaps based on the coordination point for the nearest high powered FMBC close to or under the DOC and using the GAM to re-assess the coordination margins at that point.

5 The alternative third part is to use a computer programme to calculate coordination margins at all test points as identified in 1009. Such a programme has yet to be identified.

6 Note that the above three-step process does not take into account the possibilities that may exist for varying DOC areas or ILS/VOR frequencies.

7 Further work is currently underway to produce a step by step process to automate some of the calculations required as part of the GAM.

8 This process needs to be part of and use similar methodologies to those that are already part of FMBC and other broadcast licensing coordination activities.

9 Should the addition of the new FMBC station reduce the coordination margin at any point in a DOC area to a level that is unacceptable, either the proposed FMBC transmit power must be reduced to a level where the margin is acceptable or if this cannot be achieved, the licence application declined.

Appendix I: Acronyms And Definitions

1009 ITU-R SM.1009-1 recommendation; one of a significant number of telecommunications performance recommendations agreed by the members of the International Telecommunication Union. This recommendation specifies how the coordination of FMBC services and aeronautical radio services such as ILS and VOR should be completed. New Zealand adheres to the recommendations.

CAA Civil Aviation Authority.

DOC Designated Operational Coverage areas; areas designated as requiring specified radio coverage for ILS, VOR and aeronautical radio services.

Eirp Equivalent isotropic radiated power, indicates power levels transmitted from an equivalent reference antenna.

FMBC Frequency modulated broadcast service; normally in 88 to 108 MHz band.

GBAS Ground Based Augmentation System, associated with GPS services.

GPS Global Positioning System, a satellite based radio location service.

GURL General User Radio Licence, a general licence available to users without the need for a licence application and for which equipment must be operated in accordance with the requirements in a Gazette Notice.

ICAO Convention on International Civil Aviation.

ILS Instrument Landing System, an aeronautical navigation system operating in the 108 to 112 MHz band.

IM Intermodulation, see attachment for explanation.

MBIE Ministry of Business, Innovation and Employment.

MPIS Maximum Permitted Interfering Signal level.

RCL Receive Coverage Location, a location designated in spectrum licence to be used for measurement of wanted and unwanted signal levels, particularly for FMBC services.

RSM Radio Spectrum Management Group.

VOR VHF Omnidirectional Range System, an aeronautical navigation system normally operating in the 112 to 117 MHz band.