RECOMMENDATION ITU-R SM.1140-0*

TEST PROCEDURES FOR MEASURING AERONAUTICAL RECEIVER CHARACTERISTICS USED FOR DETERMINING COMPATIBILITY BETWEEN THE SOUND-BROADCASTING SERVICE IN THE BAND OF ABOUT 87-108 MHz AND THE AERONAUTICAL SERVICES IN THE BAND 108-118 MHz

(Question ITU-R 201/2)

(1995)

Scope

This Recommendation serves as a basis for the test procedures for measuring aeronautical receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-118 MHz.

Keywords

Test procedures, aeronautical receiver characteristics, compatibility, sound-broadcasting

The ITU Radiocommunication Assembly,

considering

a) that, in order to ensure the efficiency of spectrum utilization, there is a need to assess the compatibility between the sound-broadcasting service in the band of about 87-108 MHz and the aeronautical radionavigation services in the band 108-118 MHz;

b) that International Civil Aviation Organization (ICAO) Annex 10 (see Definitions in Annex 1, Appendix 2) does not specify the receiver interference immunity characteristics necessary to fully assess this compatibility;

c) that the test procedures given in Annex 1 were used in the development of interference assessment criteria, appropriate to the ICAO Annex 10, 1998 receivers, as contained in Recommendation ITU-R SM.1009;

d) that in order to refine the interference assessment criteria contained in Recommendation ITU-R SM.1009 additional tests are required on aeronautical radionavigation receivers designed to meet the ICAO Annex 10 interference immunity criteria;

e) that there is a need for standardized test procedures,

recommends

1 that the test procedures given in Annex 1 should be used to determine the characteristics of typical aircraft instrument landing system (ILS) localizer "and very high frequency omni-directional radio range (VOR)" receivers with respect to compatibility with the sound-broadcasting service in the band of about 87-108 MHz;

2 that the results of tests performed according to the procedures given in Annex 1 be used to refine compatibility assessment criteria as may be appropriate. (see Recommendation ITU-R SM.1009.)

ANNEX 1

Test procedures

CONTENTS

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* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2001 and 2019 in accordance with Resolution ITU-R 1.

1 Background and introduction

1.1 In the past, difficulties were experienced when making direct comparisons of test results submitted by different administrations because of various interpretations of definitions and test criteria. For example, depending on a particular interpretation, this resulted in the use of:

– a minimum localizer signal level of –86 dBm or –89 dBm;

– a localizer course deflection current (see Note 1) of 7.5 μA or 9 μA;

– a standard localizer deviation signal of 0.093 DDM (see Note 1) or 90 μA;

– an FM pre-emphasis of 50 μs or 75 μs;

– a maximum FM signal deviation of ± 75 kHz peak, ± 32 kHz quasi-peak or ± 32 kHz peak;

– ITU-R coloured noise and pink noise sources with and without a stereo modulator.

NOTE 1 – Definitions are given in Annex 1, Appendix 2.

In addition, many test reports were limited to the use of minimum VOR/localizer signal levels and band-edge frequencies of 108.1 MHz for the localizer and 108.2 MHz for the VOR receiver.

1.2 ICAO has specified in its Annex 10, Part I (§ 3.1.4 for ILS localizer and § 3.3.8 for VOR) that:

– as from 1 January 1995, all new installations of ILS localizer and VOR receiving systems shall meet new interference immunity performance standards;

– as from 1 January 1998, all ILS localizer and VOR receiving systems shall meet new interference immunity performance standards.

The formula specified for the Type B1 interference 2-signal case is as follows:

$$2\,N_1 + N_2 + 3\,[24 - 20\,\log\,(\max(0.4;\,108.1 - f_1))\,/\,0.4] > 0$$

where:

f_1: broadcasting frequency (MHz) closest to 108.1 MHz

N_1, N_2: broadcasting signal levels (dBm) at the input to the aeronautical receiver for broadcasting frequencies f_1 and f_2, respectively

f_2: broadcasting frequency (MHz) furthest from 108.1 MHz.

However, difficulties in frequency planning and implementation were experienced in the application of this formula because:

– it does not address Type B1 interference, 3-signal intermodulation cases;

– it makes reference to the frequency 108.1 MHz rather than the actual ILS localizer and VOR systems;

– it does not take into account differences between ILS localizer and VOR systems;

– it does not contain a correction factor to account for improvement in immunity resulting from increases in wanted signal levels.

The Type B2 interference criteria specified in ICAO Annex 10 also does not contain a correction factor to account for improvement in immunity resulting from increases in wanted signal levels. ICAO Annex 10 does not specify any type A1 or A2 interference criteria.

1.3 The 1998 receiver immunity standards contained in ICAO Annex 10 were used in minimum operational performance standards (MOPS) developed by RTCA Inc. in Region 2 and its counterpart, EUROCAE, in Region 1. In particular, the applicable RTCA documents are:

RTCA/DO-195: Minimum Operational Performance Standards for Airborne ILS Localizer Receiving Equipment Operating Within the Radio Frequency Range of 108-112 MHz (1986);

RTCA/DO-196: Minimum Operational Performance Standards for Airborne VOR Receiving Equipment Operating Within the Radio Frequency Range of 108-117.95 MHz (1986).

These MOPS, however, address only receiver immunity aspects for Type B2 interference (see § 2.2.3) and for the 2-signal Type B1 interference case (see § 2.2.2), for a limited set of test frequencies and signal levels.

1.4 The development of realistic compatibility assessment criteria and techniques requires that the immunity characteristics be explored for the full range of localizer frequencies (i.e. 108.10-111.95 MHz), VOR frequencies (i.e. 108.05-117.95 MHz), FM broadcasting frequencies and signal levels.

1.5 This Recommendation specifies test procedures for determining the interference immunity characteristics of ICAO Annex 10 1998 ILS localizer and VOR receivers with respect to Type A1, A2, B1, and B2 interference from broadcasting stations. These test procedures were developed by Radiocommunication Task Group 2/1 studying aeronautical/broadcasting compatibility and were used in the bench testing of the ICAO Annex 10 1998 receivers at the Federal Aviation Administration (FAA) Technical Center, Atlantic City, New Jersey, United States of America in 1993-94 and subsequent cross-check tests conducted by other organizations.

2 Interference mechanisms

2.1 Type A interference

2.1.1 Introduction

Type A interference is caused by unwanted emissions into the aeronautical band from one or more broadcasting transmitters.

2.1.2 Type A1 interference

A single transmitter may generate spurious emissions or several broadcasting transmitters may intermodulate to produce components in the aeronautical frequency bands; this is termed Type A1 interference.

2.1.3 Type A2 interference

A broadcasting signal may include non-negligible components in the aeronautical bands; this interference mechanism, which is termed Type A2 interference, will in practice arise only from broadcasting transmitters having frequencies near 108 MHz and will only interfere with ILS localizer/VOR services with frequencies near 108 MHz.

2.2 Type B interference

2.2.1 Introduction

Type B interference is that generated in an aeronautical receiver resulting from broadcasting transmissions on frequencies outside the aeronautical band.

2.2.2 Type B1 interference

Intermodulation may be generated in an aeronautical receiver as a result of the receiver being driven into non-linearity by broadcasting signals outside the aeronautical band; this is termed Type B1 interference. In order for this type of interference to occur, at least two broadcasting signals need to be present and they must have a frequency relationship which, in a non-linear process, can produce an intermodulation product within the wanted RF channel in use by the aeronautical receiver. One of the broadcasting signals must be of sufficient amplitude to drive the receiver into regions of non linearity but interference may then be produced even though the other signal(s) may be of significantly lower amplitude.

Only third-order intermodulation products are considered; they take the form of:

$f_{intermod}: \; 2f_1 - f_2$ two-signal case or

$f_{intermod}: \; = f_1 + f_2 - f_3$ three-signal case

where:

f_1, f_2, f_3: broadcasting frequencies (MHz) with $f_1 \geq f_2 > f_3$

$f_{intermod}$: intermodulation product frequency (MHz)

2.2.3 Type B2 interference

Desensitization may occur when the RF section of an aeronautical receiver is subjected to overload by one or more broadcasting transmissions; this is termed Type B2 interference.

Other internal receiver mechanisms, such as spurious responses, may be incorrectly identified as B2 interference. These responses can be identified by the extremely frequency-sensitive nature of the interference when tested in the unmodulated RF mode.

3 Signal characteristics

3.1 ILS signal characteristics

The localizer portion of an ILS signal operates in the frequency range 108-111.975 MHz. The radiation from the localizer antenna system produces a composite field pattern which is amplitude modulated by a 90 Hz and a 150 Hz tone. The radiation field pattern produces a course sector with one tone predominating on one side of the course and the other tone predominating on the opposite side.

3.2 VOR signal characteristics

The VOR operates in the frequency range 108-117.950 MHz and radiates a radio-frequency carrier with which are associated two separate 30 Hz modulations. One of these modulations, called the reference phase, is such that its phase is independent of the azimuth of the point of observation. The other modulation, called the variable phase, is such that its phase at the point of observation differs from that of the reference phase by an angle equal to the bearing of the point of the observation with respect to the VOR.

3.3 FM broadcasting signal characteristics

FM broadcasting stations operate in the frequency range 87-108 MHz. These stations radiate a frequency modulated signal with, either:

– ± 32 kHz quasi-peak deviation with 50 μs pre-emphasis of the baseband signal; or

– ± 75 kHz peak deviation with 75 μs pre-emphasis of the baseband signal.

Noise modulation in accordance with Recommendation ITU-R BS.559 is used to simulate an FM broadcast audio signal.

4 Test set-up

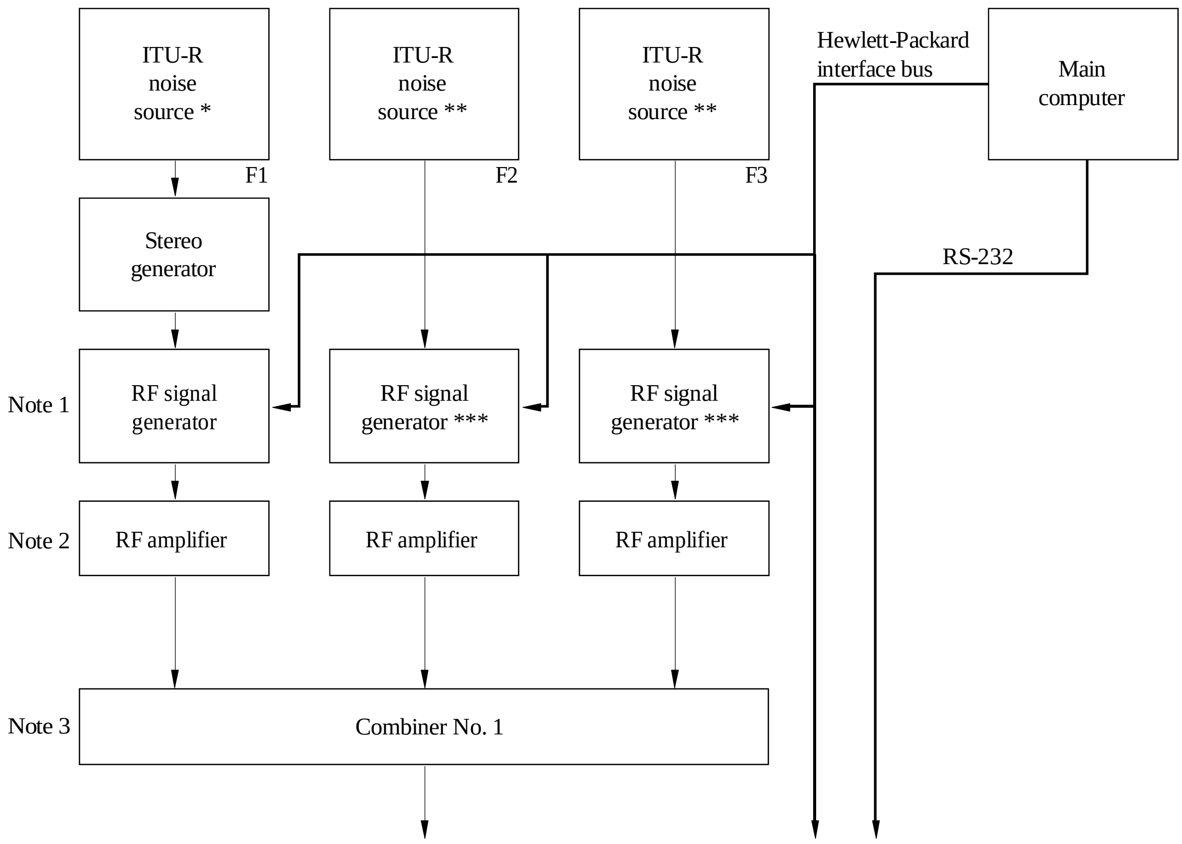
4.1 Overview of test set-up

A suitable test set-up (including important equipment characteristics) is shown in Figs. 1a, 1b and 1c.

This test should preferably utilize a semi-automated test set-up consisting of a computer for test execution, test equipment control, and data collection. The main computer should adjust both the desired and undesired signal generator outputs and provide the interface to the receiver under test to record the course deflection current and flag voltage.

Digital receiver testing may require the use of an additional computer to interface with the ARINC 429 bus.

FIGURE 1 a



Note 1
Noise floor, F = – 136 dBc/Hz
Maximum RF, M = + 8.0 dBm
Noise level, N = – 128 dBm/Hz

Note 2

Gain = 22 dB	M = + 30 dBm
Noise figure = 7.0 dB	N = – 99 dBm/Hz
Maximum output = + 30 dBm	
Reverse isolation = 55 dB	

Note 3

Insertion loss = 5 dB	M = + 25 dBm
Isolation ≥ 20.0 dB	N = – 104 dBm/Hz

* Modulation off for B2 tests
** Used for B1 offset only
*** Signal off for A1, A2 and B1 tests
F1 > F2 > F3

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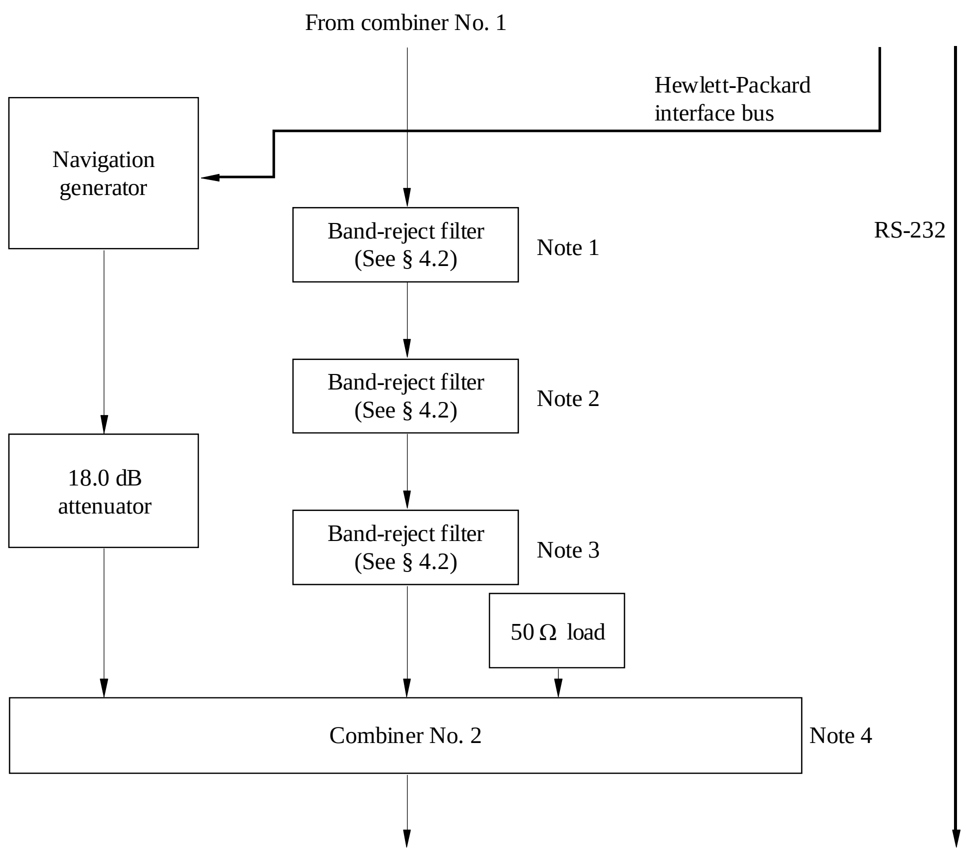
FIGURE 1b



Note 1
Tuned-cavity filter
Insertion loss = 0.5 dB
Rejection = 18 dB
3 dB bandwidth = 0.2 MHz

M = + 24.5 dBm
N = – 122.5 dBm/Hz

Note 2
Tuned-cavity filter
Insertion loss = 0.5 dB
Rejection = 18 dB
3 dB bandwidth = 0.2 MHz

M = + 24 dBm
N ≤ – 140.0 dBm/Hz

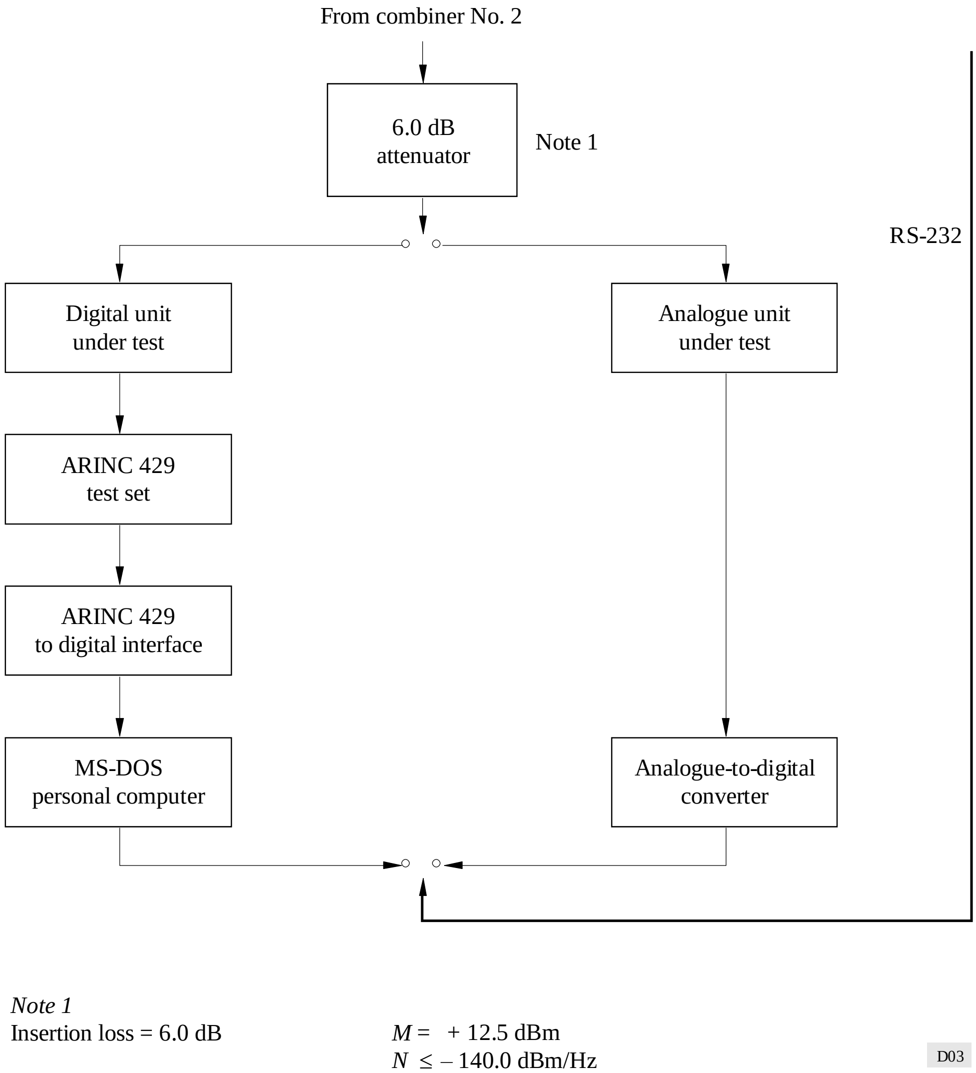
Note 3
Tuned-cavity filter
Insertion loss = 0.5 dB
Rejection = 18 dB
3 dB bandwidth = 0.2 MHz

M = + 23.5 dBm
N ≤ – 140.0 dBm/Hz

Note 4
Insertion loss = 5.0 dB
Isolation = 20 dB

M = + 18.5 dBm
N ≤ – 140.0 dBm/Hz

FIGURE 1c



4.2 Test set-up description

4.2.1 The ITU-R noise source for the stereo signal is composed of a white noise generator, a Recommendation ITU-R BS.559 noise filter, and a 50 or 75 μs pre-emphasis filter.

4.2.2 In either case, the noise signal, S1, should be fed to the stereo generator with the left channel signal level in phase with, but 6 dB greater than, the right channel. It is then modulated to give an FM stereo signal. This stereo signal (f_1) should be used in the A1, A2, and B1 tests (see Fig. 1a).

4.2.3 Frequencies f_2 and f_3 are used only during B_1 testing. During the B_1 coincident tests, f_2 and f_3 are unmodulated. For the B1 offset test, both f_2 and f_3 are monaural signals from the ITU-R noise source described above. The frequency modulation function is performed by the RF signal generators.

4.2.4 The B2 tests should use an unmodulated RF signal f_1.

4.2.5 The high signal levels required by the ICAO future immunity criteria receivers necessitate additional amplification which should be provided by RF amplifiers. A maximum signal level of at least + 15 dBm at the receiver's input should be used during these tests.

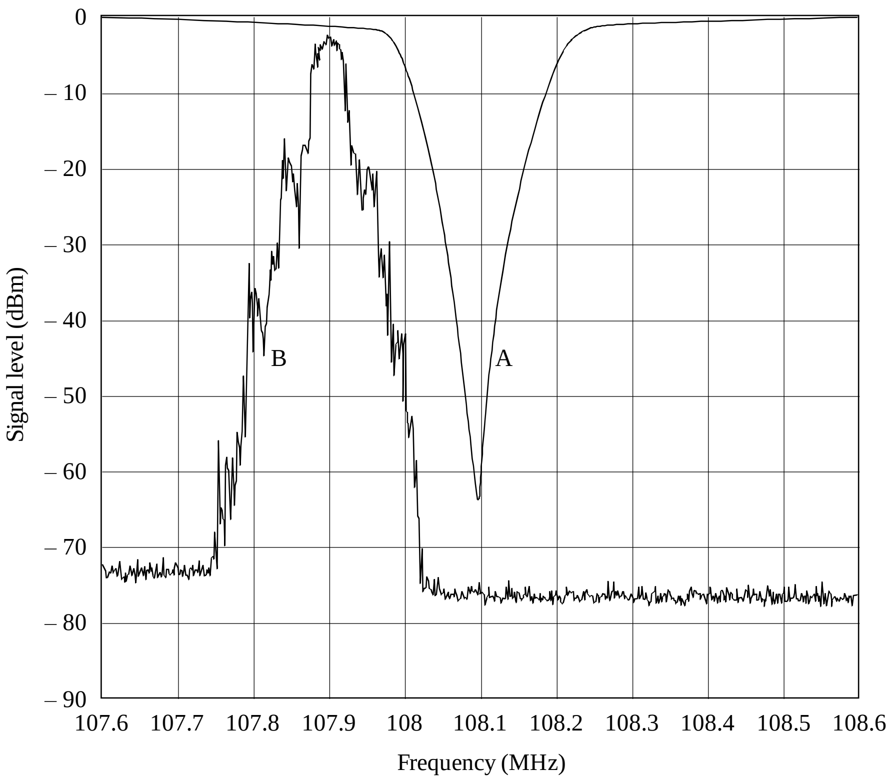
4.2.6 The three band-reject filters should be tuned to the desired frequency in order to reject any desired frequency component or RF noise that may be produced in the FM signal circuitry. The filters should produce a rejection of at least 54 dB.

These filters should not be used in the A1 tests. They may be left in the circuit to maintain an impedance match between the FM signal circuitry and the receiver if they are detuned several MHz away from the aeronautical frequency. A plot of the filter characteristics is shown in Fig. 2.

NOTE 1 – Practical limitations of existing test equipment require the use of band-reject filters for the A2 tests to reduce the noise floor of the signal generator and spurious emissions on the aeronautical frequency to the –140 dBm/Hz level specified in this Recommendation. Unfortunately, the filters have the side-effect of attenuating some FM modulation components of the simulated broadcast signal. It may be possible to obtain a more realistic simulation by using an actual FM broadcast transmitter, a high-powered crystal oscillator, or a signal generator with a noise floor comparable to that of an FM transmitter. The cause of the difficulties in the A2 tests needs further investigation.

FIGURE 2

Plots of typical filter response and typical FM spectrum



Centre frequency = 108.1 MHz
Span = 1.000 MHz
Reference level = 10.0 dBm
Scale = 10 dB/division
Attenuation = 20 dB
Resolution bandwidth = 3.00 kHz
Video bandwidth = 3.00 kHz
Sweep time = 333.4 ms

Curves A : filter response
B : typical FM spectrum

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4.2.7 The navigation signal generator which produces the localizer and VOR signals is isolated from the FM signals by at least 18 dB. This prevents the high level FM signals from entering the navigation generator and producing intermodulation products there.

4.2.8 The combined FM and navigation signals should be connected to the navigation receiver’s input through a 6 dB attenuator which provides impedance matching between the test set up and the receiver.

4.2.9 The output of the analogue navigation receiver should be recorded by the data collection computer through an analogue-to-digital (A/D) converter.

4.2.10 For the digital receiver, the ARINC 429 data should be fed to an ARINC 429 test set. The ARINC 429 data should be converted to digital data in the IBM-PC compatible computer. The main computer should be used to run the test program and collect data.

4.2.11 RTCA DO-195 and its EUROCAE equivalent recommends a statistical method for determining the maximum on-course errors of ILS localizer receivers based on a 95% probability and limits centring error to 5% of the standard deflection. Receiver compatibility is analysed using a similar technique. Five per cent of the standard localizer deflection is given by (0.05 × 0.093 DDM) or 4.5 μA (0.00465 DDM) and a 95% probability may be achieved by utilizing plus or minus two standard deviations, 2σ, of the normal distribution. An equivalent deflection of 4.5 μA for the VOR is 0.3° change in bearing indication.

4.2.12 The measurements are conducted by collecting a number of output-deflection samples (from the ARINC-429 bus for digital receivers and through an analogue-to-digital converter for analogue receivers) and then computing the mean and standard deviation of the data. The standard deviation for the baseline case (no interfering signals) is multiplied by two to get the baseline 2σ value and 4.5 μA (0.00465 DDM) is added to the baseline 2σ value to get an upper limit for the 2σ value with interfering signals present. The interference threshold is defined as the point where the 2σ value exceeds the upper limit.

4.2.13 The sampling rate for analogue receivers should be one sample every 50 ms in order to maintain consistency with the ARINC-429 specifications for digital receivers. A minimum of 50 samples must be taken in order to assure good statistical computational accuracy but more importantly to assure that data are evaluated over a time interval sufficient to mitigate the correlation effect of the very narrow post-detection receiver bandwidth (on the order of 1 Hz) on random noise.

4.2.14 This method of measuring receiver compatibility may be approximated by a change in the course-deflection current of 7.5 μA (0.00775 DDM) lasting for more than 200 ms in any 2-s window (the technique used for earlier measurements) provided the receiver is operating at least 10 dB above its sensitivity limit.

4.3 Test precautions

4.3.1 The test set-up must have a noise floor at the receiver input no greater than –140 dBm/Hz in order to avoid contamination of the data.

4.3.2 The band reject filters used must not significantly attenuate sidebands of the FM signal, which will cause undesirable amplitude modulation of the input signal(s).

4.3.3 Sufficient isolation must be provided between signal generators to assure that no significant intermodulation components are generated within the generators.

4.3.4 When simulating ILS and VOR signals, equipment specifically designed for that purpose should be used.

4.3.5 Precautions should be taken to prevent test receivers from over-heating.

4.3.6 The set-up of the FM test signal waveforms is critical to Type A1, A2, and B1 interference frequency off-set testing; because of the steep slopes of these signals at the off-set frequencies, small changes in bandwidth produce large changes in amplitude. Since the waveform shape is so critical that even an extremely careful setup of the equipment does not guarantee that the spectrum analyser waveforms will match, a visual matchup of plotted waveforms should be conducted to ensure compatibility with previous measurements. Adjustments to the waveforms should be made by varying the audio level to the generator, not by adjusting the deviation control.

4.3.7 Unlike the “avalanche” effect in Type B1 interference testing, the Type A1 interference effect is a “soft” interference effect; interference effects in some cases may tend to fluctuate over a 10-15 s sampling period. These longer sampling periods may be used if needed to obtain repeatable results.

4.3.8 To help insure that test results are comparable to previously gathered data, the test set-up and procedures may be confirmed by conducting spot tests on a receiver previously tested in the Atlantic City test, if available.

4.3.9 It is important to note that other internal receiver mechanisms, such as spurious responses, may be incorrectly identified as B2 interference. Spurious responses detected during the B2 tests should not be reported as a B2 test result. Assessment criteria for spurious responses have not been established.

4.3.10 Modulation of the FM signal with coloured noise is not favoured in tests for the no localizer signal case as coloured noise may not give reliable test results. Further investigation is required to determine the validity of using ITU-R coloured noise modulation for testing of the no wanted signal case.

4.4 Test equipment

A list of the test equipment used during the 1993/1994 tests in Atlantic City is given in Appendix 1. Other test equipment may be used, but care should be taken with regard to the precautions identified in § 4.3.

5 Measurement techniques

5.1 FM test conditions

5.1.1 *Simulated programme material*: Coloured noise in accordance with Recommendations ITU-R BS.559 and ITU-R BS.641.

5.1.2 *Mode*: stereophonic

The modulating signal is applied in phase to the left and right channel with a 6 dB difference in level between channels.

5.1.3 *Deviation*: ± 32 kHz quasi-peak in accordance with Recommendation ITU-R BS.641.

NOTE 1 – Previous tests carried out in Region 1 have used ± 32 kHz quasi-peak deviation while tests carried out in Region 2 have used ± 75 kHz peak deviation. The use of ± 32 kHz quasi-peak deviation in accordance with ITU-R Recommendations is reflected in this test procedure.

5.1.4 *Pre-emphasis*:

– Region 1 and parts of Region 3: 50 μs

– Region 2: 75 μs

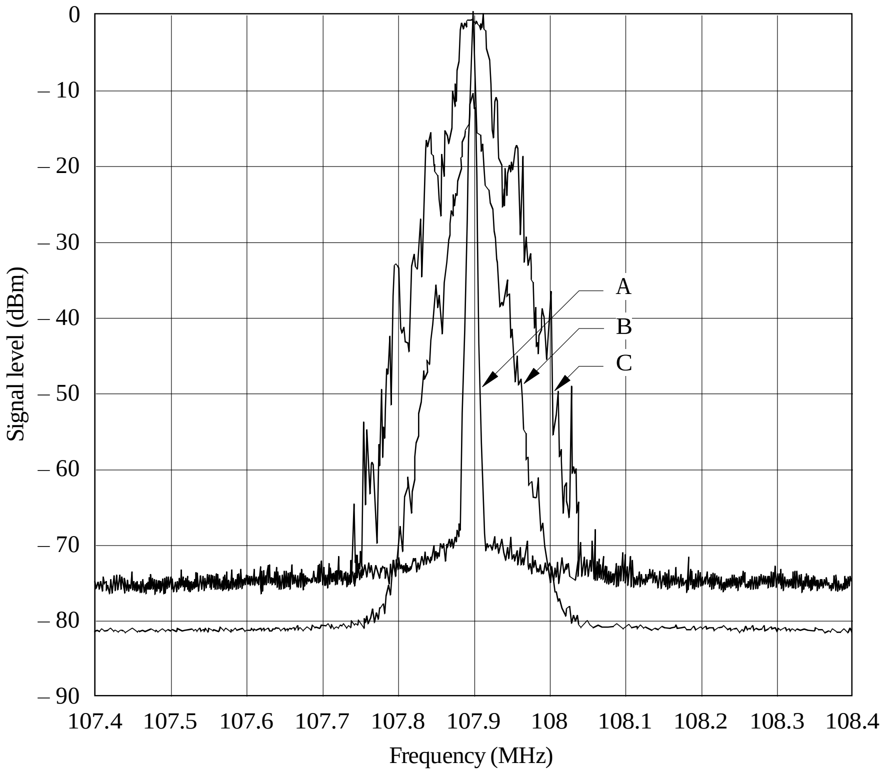
Spot check using 75 μs with ± 75 kHz peak deviation. If results vary significantly with those using 50 μs with ± 32 kHz quasi-peak deviation, testing should be duplicated using 75 μs/± 75 kHz.

5.1.5 *Waveforms*: It is essential that FM test signals used for testing have the correct waveforms. Figures 3a and 3b are a sample representation of the required waveforms for ± 32 kHz quasi-peak deviation/50 μs pre-emphasis and ± 96 kHz quasi-peak deviation/50 μs pre-emphasis. Figures 4a and 4b are a sample representation of the required waveform for 75 kHz peak deviation/75 μs pre-emphasis and 225 kHz peak deviation/75 μs pre-emphasis.

5.1.6 *Signal level(s)*: Initially introduced at a low level (i.e. at least 10 dB below the expected threshold) and increased until the interference threshold is reached. Near the interference threshold, the signal level is changed in 1 dB steps.

FIGURE 3a

Plots of FM spectrum using ± 32 kHz quasi-peak deviation/50 μ s pre-emphasis



Reference level = 10.00 dBm
Attenuation = 20 dB
Average = 50 sweeps
Centre frequency = 107.900 MHz
Resolution bandwidth = 3.00 kHz
Video bandwidth = 3.00 kHz
Span = 1.000 MHz
Sweep time = 333.4 ms
Curves A : carrier reference
B : average
C : peak

FIGURE 3b

Plots of FM spectrum using ± 96 kHz quasi-peak deviation/50 μ s pre-emphasis

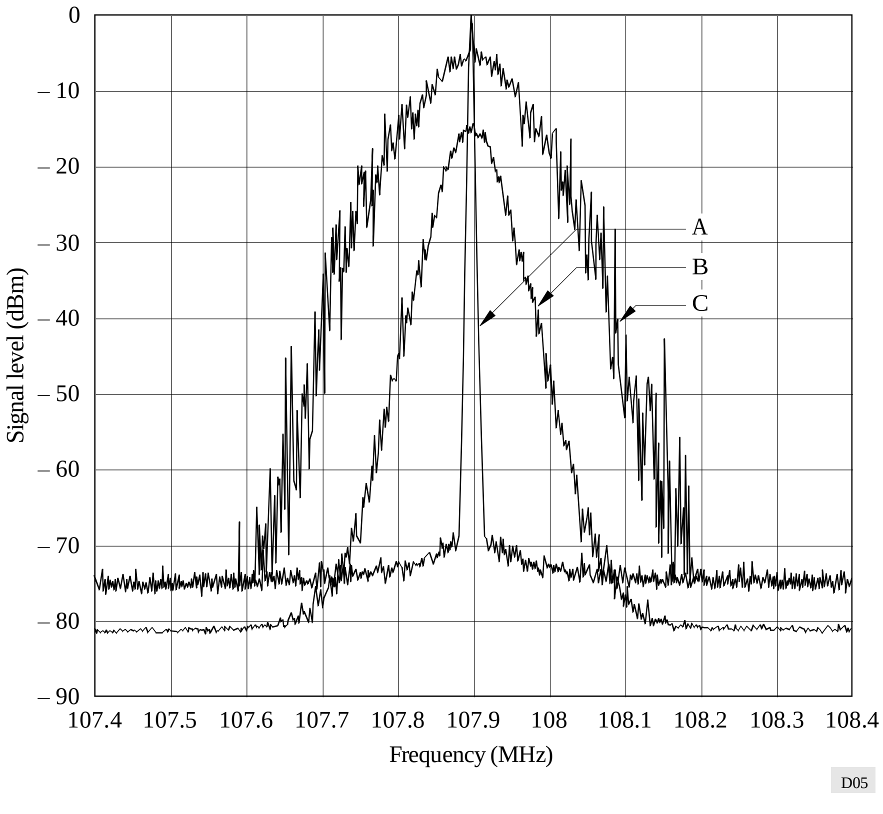


FIGURE 4a

Plots of FM spectrum using ± 75 kHz peak deviation/75 μs pre-emphasis

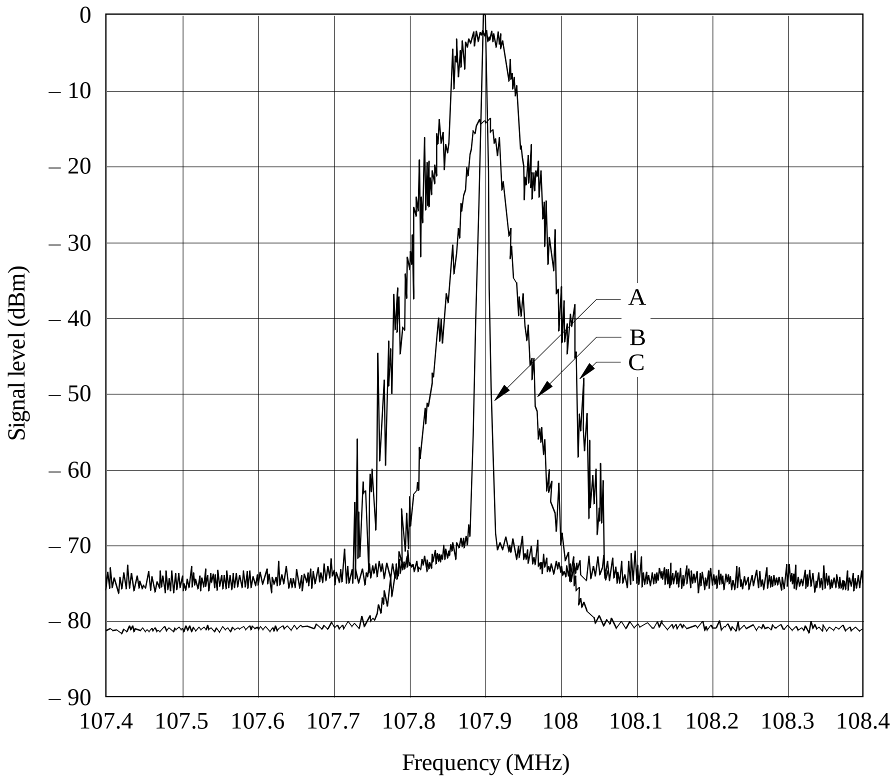
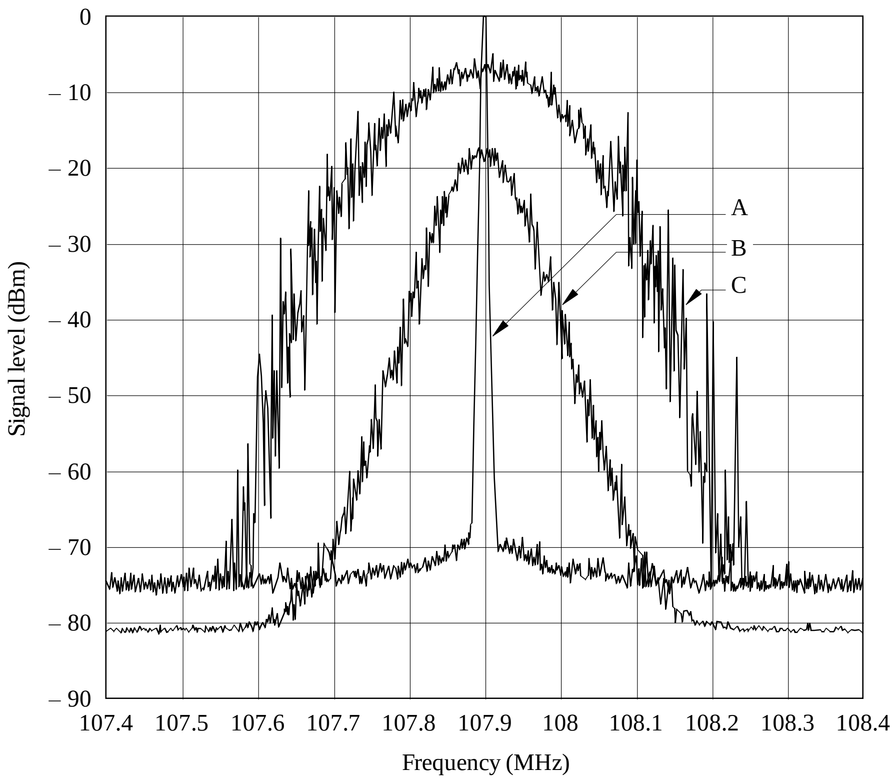


FIGURE 4b

Plots of FM spectrum using ± 225 kHz peak deviation/75 μs pre-emphasis



Reference level = 10.00 dBm
Attenuation = 20 dB
Average = 50 sweeps
Centre frequency = 107.900 MHz
Resolution bandwidth = 3.00 kHz
Video bandwidth = 3.00 kHz
Span = 1.000 MHz
Sweep time = 333.4 ms
Curves A : carrier reference
B : average
C : peak

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5.1.7 *Frequency*: As required for specific test.

NOTE 1 – RTCA/DO-195 specifies frequency modulation of the highest FM frequency in an intermodulation product with pink noise or ITU-R coloured noise and a peak frequency deviation of ± 75 kHz. A stereo modulator is not used.

5.2 Test results

The ICAO Annex 10 1998 receivers under test may or may not have in-band selectivity. Therefore, wanted signal frequencies have been selected at band-edge and mid-band in order to examine possible differences in results. However, data need not be taken at all specified test combinations if obvious data trends are detected.

5.3 ILS localizer receiver test procedures

5.3.1 Interference thresholds

5.3.1.1 With a localizer signal

– An increase in the 2σ (two standard deviations from the mean) value of the course-deflection current of at least 0.00465 DDM (4.5 μA) over the baseline 2σ value measured with no interfering signal present;

– the appearance of the warning flag for 1 s, whichever comes first.

5.3.1.2 With no localizer signal

– Warning flag out of view for more than 1 s.

– This test is only carried out to verify correct receiver flag operation in accordance with RTCA/DO-195 MOPS.

5.3.1.3 Localizer test conditions

a) *Course deflection*: 0.093 DDM (spot check at 0 DDM).

b) *Signal level*: –98, –86, –70, and –55 dBm, and the no localizer signal case.

c) *Frequency*: as required for specific test.

NOTE 1 – The ICAO and RTCA/DO-195 reference signal level is –86 dBm. The reference level derived in § 3.4 of Annex 1 of Recommendation ITU-R IS.1009 is –98 dBm. Results for this level are valid only if FM signal interference is sufficiently above the noise threshold to comprise the primary cause of failure.

5.3.2 Particulars for Type A1 transmitter interference test

a) *Method of defining protection criteria*: The protection ratio (dB) at a specified f is equal to the localizer signal level (dBm) minus the lowest level of unwanted signal (dBm) required to cause interference.

b) *Frequencies*:

Case No.	f_{loc}	f
1	108.10	$108.10 + \Delta f$
2	110.10	$110.10 + \Delta f$
3	111.95	$111.95 + \Delta f$

where:

f_{loc}: localizer frequency (MHz)

f: unwanted signal frequency (MHz)

Δf: frequency difference between the localizer signal and the FM signal (i.e. the intermodulation product)

0, ± 0.05, ± 0.10, ± 0.15, ± 0.20 and ± 0.30 MHz

c) *Maximum Deviation of FM signals*:

– for $\Delta f = 0$, deviation = ± 32 kHz quasi-peak;

– for all other Δf, deviation = ± 96 kHz quasi-peak.

NOTE 1 – The unwanted signal is a simulated intermodulation product (i.e. a spurious emission).

– Spot check at $\Delta f = 0$ using 75 µs with ± 75 kHz peak deviation. If results vary significantly from those using 50 µs with ± 32 kHz quasi-peak deviation, testing should be duplicated using 75 µs with ± 75 kHz peak deviation.

– Spot check at $\Delta f = \pm 200$ kHz using 75 µs with ± 225 kHz peak deviation. If results vary significantly from those using 50 µs with ± 96 kHz quasi-peak deviation, testing should be duplicated using 75 µs with ± 225 kHz peak deviation.

– The maximum deviation of ± 32 kHz quasi-peak will likely maximize interference effects when the unwanted signal frequency equals the wanted signal frequency.

– Maximum deviation of ± 96 kHz quasi-peak, is used to simulate the maximum bandwidth of a third order intermodulation product (i.e. 3 × ± 32 kHz), and will therefore tend to maximize interference effects when the unwanted signal frequency is off-set from the wanted signal frequency.

– The spectrum of an actual Type A1 signal will be complex depending upon the modulation of the contributing signals.

5.3.3 Particulars for Type A2 interference test

a) *Method of defining protection criteria*: The protection ratio (dB) at a specified f is equal to the localizer signal level (dBm) minus the lowest level of FM signal (dBm) required to cause interference.

b) *Localizer frequency*: 108.10 and 108.15 MHz.

c) *FM frequency*: 107.9 and 107.8 MHz.

NOTE 1 – Data are taken with the unwanted signal modulated and then unmodulated. If the protection ratios are the same, then the unwanted signal is causing Type B2 interference; if the protection ratios with the modulation are higher, then the sideband energy from the unwanted signal is being received in the receiver passband, causing Type A2 interference. Testing should be stopped when the FM signal level is greater than or equal to +15 dBm.

5.3.4 Particulars for Type B1 interference test

5.3.4.1 Intermodulation product coincident with localizer frequency

a) *Method of defining protection criteria*: Minimum FM equi-signal level (dBm) required to cause interference at Δf^3:

$$\Delta f^3 \text{ (MHz)}^3 = (f_{loc} - f_1)^2 (f_{loc} - f_2) \qquad \text{2-signal case}$$

$$= (f_{loc} - f_1)(f_{loc} - f_2)(f_{loc} - f_3) \qquad \text{3-signal case}$$

where

f_{loc}: localizer frequency (MHz)

f_1, f_2, f_3: FM frequencies (MHz) and $f_1 > f_2 > f_3$.

b) *Localizer frequency*: 108.1, 109.1, 110.1, and 111.9 MHz.

c) *FM frequencies*:

– as per Table 1 for 2-signal case: $2 f_1 - f_2 = f_{loc}$

– as per Table 2 for 3-signal case: $f_1 + f_2 - f_3 = f_{loc}$

NOTE 1 – Only f_1 needs to be modulated when the calculated intermodulation product is coincident with desired localizer frequency.

TABLE 1

List of intermodulation products on localizer frequencies for the two-signal case

Frequencies (MHz)			Δf^3
f_1	f_2	f_{loc}	
107.9 107.5 106.5 103.5 98.1	107.7 106.9 104.9 98.9 88.1	108.1	0.01 0.43 8.19 194.70 2 000.00
107.9 104.5	106.7 99.9	109.1	3.45 194.70
107.9 105.5 100.1	105.7 100.9 90.1	110.1	21.29 194.70 2 000.00
107.9 105.3 101.9	103.9 98.7 91.9	111.9	128.00 575.00 2 000.00

TABLE 2

List of intermodulation products on localizer frequencies for the three-signal case

Frequencies (MHz)				Δf^3
f_1	f_2	f_3	f_{loc}	
107.9 107.5 107.1 106.5 104.5 101.5	107.5 106.5 105.5 104.5 100.5 95.3	107.3 105.9 104.5 102.9 96.9 88.7	108.1	0.09 2.11 9.36 29.95 306.40 1 639.00
107.9 106.5	107.5 103.5	106.3 100.9	109.1	5.37 119.40
107.9 107.9 107.5 106.5 104.5 99.5	107.5 105.3 104.5 102.5 98.5 98.7	105.3 103.1 101.9 98.9 92.9 88.1	110.1	27.45 73.92 119.40 306.40 1 117.00 2 658.00
107.9 107.5 105.5 101.5	107.5 105.5 101.5 100.3	103.5 101.1 95.1 89.9	111.9	147.80 304.10 1 118.00 2 654.00

5.3.4.2 Intermodulation product off-set from localizer frequency

a) *Method of defining protection criteria*: Minimum FM equi-signal level (dBm) required to cause interference. However, for an offset frequency f, the criterion as specified is the difference between the equi-signal levels required at f and those required when $\Delta f = 0$ (i.e., the non-offset case).

b) *Frequencies*:

– For a 2-signal receiver intermodulation product of the form: $2 f_1 - f_2 = f_{loc}$

Case 1: $2(105.5) - (102.9 + \Delta f) = 108.10$ MHz

where $\Delta f^3 = 35.15$ at $\Delta f = 0$

Case 2: $2(107.5) - (104.9 + \Delta f) = 110.10$ MHz

where $\Delta f^3 = 35.15$ at $\Delta f = 0$

Case 3: $2(107.9) - (103.9 + \Delta f) = 111.90$ MHz

where $\Delta f^3 = 128.00$ at $\Delta f = 0$.

– For a 3-signal receiver intermodulation product of the form $f_1 + f_2 - f_3 = f_{loc}$

Case 1: $106.5 + 104.5 - (102.9 + \Delta f) = 108.10$ MHz

where $\Delta f^3 = 29.95$ at $\Delta f = 0$

Case 2: $107.9 + 107.5 - (105.3 + \Delta f) = 110.10$ MHz

where $\Delta f^3 = 27.45$ at $\Delta f = 0$

Case 3: $107.9 + 107.5 - (103.5 + \Delta f) = 111.90$ MHz

where $\Delta f^3 = 147.80$ at $\Delta f = 0$

where: $\Delta f = 0, \pm 0.05, \pm 0.10, \pm 0.15, \pm 0.20$ and ± 0.30 MHz.

NOTE 1 – To maximize the interference effect of an off-set intermodulation product, the bandwidth of the intermodulation product must be maximized by modulating all FM signals.

NOTE 2 – FM signals f_2 and f_3 should be modulated by ITU-R noise sources (see § 4.2) fed directly into the modulation inputs of the FM signal generator (i.e. simulating a monophonic signal).

NOTE 3 – In Cases 2 and 3 of the three-signal offset intermodulation interference, care should be taken when interpreting the test results for ±0.3/0.2 MHz offset because a two-signal offset intermodulation interference with a ±0.1/0.2 MHz offset occurs simultaneously. Different frequencies should be selected to avoid this problem in future testing.

5.3.5 Particulars for Type B2 interference test

a) *Method of defining protection criteria*: lowest FM signal level (dBm) required to cause interference.

b) *Localizer frequency*: 108.1, 109.1, 110.1 and 111.9 MHz.

c) *FM Frequency* 107.9, 107.8, 107.7, 107.5, 107.3, 107.0, 106.0, 105.0, 104.0, 102.0, 100.0, 98.0, 93.0 and 88.0 MHz. Measurements will be discontinued for frequencies lower than that where the measured immunity level is greater than +15 dBm.

NOTE 1 – For distinction between Type A2 and Type B2 interference effects when using frequencies near 108 MHz, see Note 1 to § 5.3.3 c).

5.4 VOR receiver test procedures

5.4.1 Interference thresholds

5.4.1.1 With a VOR signal

– An increase in the 2σ (two standard deviations from the mean) value of the course deflection current of at least 4.5 μA (0.3°) change in bearing indication over the baseline 2σ value measured with no interfering signal present;

– the appearance of the warning flag for 1 s, whichever comes first.

NOTE 1 – For the interference threshold based on a change of the bearing indication, RTCA/DO-196 specifies a 0.5° change in bearing indication for the Type B2 test and a 1.0° change in bearing indication for the Type B1 test.

5.4.1.2 With no VOR signal

– Warning flag out of view for more than 1 s.

– This test is only carried out to verify correct receiver flag operation in accordance with RTCA/DO-196 MOPS.

5.4.1.3 VOR test conditions

a) *Bearing indication*: centring signal for an on-course indication of 000.

b) *Signal level*: –93, –79, –63 and –48 dBm and the no VOR signal case.

c) *Frequency*: as required for specific test.

NOTE 1 – RTCA/DO-196 tests the no wanted signal case in the Type B1/B2 interference tests.

NOTE 2 – The ICAO and RTCA/DO-196 reference signal level is –79 dBm. The reference level derived in § 3.4 of Annex 1 of Recommendation ITU-R IS.1009 is –91 dBm. Results for this level are valid only if FM signal interference is sufficiently above the noise threshold to comprise the primary cause of failure.

5.4.2 Particulars for Type A1 transmitter interference test

a) *Method of defining protection criteria*: the protection ratio (dB) at a specified f is equal to the VOR signal level (dBm) minus the lowest level of FM signal (dBm) required to cause interference.

b) *Frequencies*:

Case No.	f_{VOR}	f
1	108.20	$108.20 + \Delta f$
2	112.00	$112.00 + \Delta f$
3	117.95	$117.95 + \Delta f$

where:

f_{VOR}: VOR frequency (MHz)

f: unwanted signal frequency (MHz)

Δf: frequency difference between the wanted signal and the unwanted signal (i.e. the intermodulation product). 0, ±0.05, ±0.10, ±0.15, ±0.20 and ±0.30 MHz.

c) *Deviation of unwanted signals:* See § 5.3.2 c) for test conditions and comments.

5.4.3 Particulars for Type A2 interference test

a) *Method of defining protection criteria*: The protection ratio (dB) at a specified f is equal to the VOR signal level (dBm) minus the lowest level of FM signal (dBm) required to cause interference. This test should be performed once with the modulation on and off at the interference point to determine if A2 or B2 is the cause.

b) *VOR frequency*: 108.05 and 108.2 MHz.

c) *FM frequency*: 107.9 and 107.8 MHz.

NOTE 1 – See Note 1 to § 5.3.3 c).

NOTE 2 – The A2 test may be omitted for the test condition where the VOR frequency is 108.2 MHz and the FM frequency is 107.8 MHz.

5.4.4 Particulars for Type B1 interference test

5.4.4.1 Intermodulation product coincident with VOR frequency

a) *Method of defining protection criteria*: Minimum FM equi-signal level (dBm) required to cause interference at Δf^3,

$$\Delta f^3 \text{ (MHz)}^3 = (f_{VOR} - f_1)^2 (f_{VOR} - f_2) \qquad \text{2-signal case}$$

$$= (f_{VOR} - f_1)(f_{VOR} - f_2)(f_{VOR} - f_3) \qquad \text{3-signal case}$$

where:

f_{VOR}: VOR frequency (MHz)

f_1, f_2, f_3: FM frequencies (MHz) and $f_1 > f_2 > f_3$.

b) *VOR frequencies*: 108.2, 109.0, 110.0, 112.0, 115.0, 117.9 MHz.

c) *FM frequencies*:

– as per Table 3 for 2-signal case: $2 f_1 - f_2 = f_{VOR}$

– as per Table for 3-signal case: $f_1 + f_2 - f_3 = f_{VOR}$.

NOTE 1 – Only f_1 needs to be modulated when the calculated intermodulation product is coincident with desired VOR frequency.

NOTE 2 – The test precautions in § 4.3.10 also apply to the VOR receiver.

TABLE 3

List of intermodulation products on VOR frequencies for the two-signal case

Frequencies (MHz)			Δf^3
f_1	f_2	f_{VOR}	
107.9 107.5 106.5 103.7 101.7 98.3	107.6 106.8 104.8 99.2 95.2 88.4	108.2	0.05 0.68 9.82 182.30 549.30 1 941.00
107.5 104.5	106.0 100.0	109.0	6.75 182.30
107.9 105.1	105.8 101.0	110.0	18.52 182.30
107.9 105.5 102.1	103.8 99.0 92.2	112.0	137.80 549.30 1 941.00
107.9 102.1	100.8 89.2	115.0	715.80 4 293.00
107.9 104.5	97.9 91.1	117.9	2 000.00 4 812.00

TABLE 4

List of intermodulation products on VOR frequencies for the three-signal case

Frequencies (MHz				Δf^3
f_1	f_2	f_3	f_{VOR}	
107.9 107.7 106.5 103.5 99.5	107.7 106.9 105.3 99.3 97.5	107.4 106.4 103.6 94.6 88.8	108.2	0.12 1.17 22.67 568.90 1 806.00
107.5 104.5	106.3 100.3	104.8 95.8	109.0	17.01 516.80
107.9 107.5 103.5	107.5 103.3 99.5	103.4 98.8 91.0	112.0	158.70 516.80 2 231.00
107.9 102.1	107.5 101.1	100.4 88.2	115.0	777.50 4 806.00
107.9 103.5	107.5 102.7	97.5 88.3	117.9	2 122.00 6 479.00

5.4.4.2 Intermodulation product off-set from VOR frequency

a) *Method of defining protection criteria*: Minimum FM equi-signal level (dBm) required to cause interference. However, for an offset frequency *f*, the criterion as specified is the difference between the equi-signal levels required at *f* and those required when $\Delta f = 0$ (i.e., the non-offset case).

b) *Frequencies*:

– For a 2-signal receiver intermodulation product of the form: $f_1 - f_2 = f_{VOR}$

Case 1: 2(105.7) – (103.2 + Δf) = 108.20 MHz

where Δf^3 = 31.25 at $\Delta f = 0$

Case 2: 2(107.9) – (103.8 + Δf) = 112.00 MHz

where Δf^3 = 137.90 at $\Delta f = 0$

Case 3: 2(107.9) – (97.9 + Δf) = 117.90 MHz

where Δf^3 = 2 000.00 at $\Delta f = 0$

– For a 3-signal receiver intermodulation product of the form: $f_1 + f_2 - f_3 = f_{VOR}$

Case 1: 106.5 + 105.30 – (103.6 + Δf) = 108.20 MHz

where Δf^3 = 22.67 at $\Delta f = 0$

Case 2: 107.9 + 107.50 – (103.4 + Δf) = 112.00 MHz

where Δf^3 = 158.70 at $\Delta f = 0$

Case 3: 107.9 + 107.50 – (97.5 + Δf) = 117.90 MHz

where Δf^3 = 2 122.00 at $\Delta f = 0$

where $\Delta f = 0, \pm 0.05, \pm 0.10, \pm 0.15, \pm 0.20$ and ± 0.30 MHz.

NOTE 1 – To maximize the interference effect of an off-set intermodulation product, the bandwidth of the intermodulation product must be maximized by modulating all FM signals.

NOTE 2 – FM signals f_2 and f_3 should be modulated by ITU-R noise sources (see § 4.2) fed directly into the modulation inputs of the FM signal generator (i.e. simulating a monophonic signal).

NOTE 3 – In Cases 2 and 3 of the three-signal offset intermodulation interference, care should be taken when interpreting the test results for ± 0.3/0.2 MHz offset because a two-signal offset intermodulation interference with a ± 01/0.2 MHz offset occurs simultaneously. Different frequencies should be selected to avoid this problem in future testing.

5.4.5 Particulars for Type B2 interference test

a) *Method of defining protection criteria*: Lowest FM signal level (dBm) required to cause interference.

b) *VOR frequency*: 108.2, 110.0, 112.0, 115.0 and 117.9 MHz.

c) *FM frequency*: 107.9, 107.8, 107.7, 107.5, 107.3, 107.0, 106.0, 105.0, 104.0, 100.0, 98.0, 93.0 and 88.0 MHz. Measurements will be discontinued for frequencies lower than that where the measured immunity level is greater than + 15 dBm.

NOTE 1 – Data are taken with the FM signal unmodulated, but spot checked using modulation.

NOTE 2 – Note 1 to 5.3.3 c) for localizer receivers to VOR receivers.

APPENDIX 1

TO ANNEX 1

Test equipment

The following test equipment shown in Table 5 is suitable for the test set-up shown in Figs. 1a, 1b, and 1c.

TABLE 5

Equipment	Note	Equipment used in Atlantic City tests
ITU-R noise source consisting of: white noise source ITU-R BS.559 filter		Heath AD-1309 Rhode and Schwarz SUF2Z4
FM stereo generator with 50 and 75 µ pre-emphasis filters		Marcom 203
RF signal generator	Maximum output *> 8 dBm* *Noise level* < 128 dBm/Hz	Hewlett Packard (HP) 8657B
RF amplifier	The gain and noise figure of the amplifier must permit an output level of 30 dBm with a noise level ≤ –99 dBm/Hz. With an output of 8 dBm from the signal generator, this may be achieved with an amplifier gain of 22 dB and a noise figure 7 dB. Maximum output ≥ 30 dBm Reverse isolation ≥ 35 dB	Mini circuits ZHL-1-50P3
Combiner	Insertion loss ≤ 5 dB Isolation ≥ 20 dB	Eagle HPC300
Navigation signal generator		Collins 479S-6A
Band reject filter	Insertion loss ≤ 0.5 dB Rejection ≥ 18 dB 3 dB bandwidth = 0.2 MHz	Sinclair FR20107 1
18.0 dB attenuator		Hewlett Packard 355C4 and Hewlett Packard 355D
50 Ω load		
6.0 dB attenuator		Mini circuits NAT-6
Test set conforming to ARINC 429		
Digital interface conforming to ARINC 429		
IBM-compatible personal computer (used to control and interface with digital receiver under test)		
Analogue-to-digital converter		RLC SBX-C186EB SBX-AIN-32
Computer used to control test set-up and record measured results		Hewlett Packard 9000/236

APPENDIX 2

TO ANNEX 1

Definitions

Course deflection current

The output of the receiver which is fed to the pilots indicator and to the autopilot. For the ILS localizer receiver, it provides left/right guidance proportional to the DDM of the 90 Hz and 150 Hz signals for a given angular displacement from runway centerline. For a VOR receiver, it provides a left/right guidance proportional to the phase difference of two 30 Hz signals.

DDM (Difference in Depth of Modulation)

The depth of modulation is the ratio of the amplitude of the modulation of the 90 Hz or 150 Hz signal to the carrier amplitude. The DDM is the modulation depth of the stronger signal minus the modulation depth of the weaker signal.

ICAO Annex 10

"International Standards, Recommended Practices and Procedures for Air Navigation Services: Aeronautical Telecommunications, Annex 10 to the Convention on International Civil Aviation, Volume I", International Civil Aviation Organization (Montreal, 1985).

Instrument Landing System

A radionavigation system specified in ICAO Annex 10 and agreed internationally as the current standard precision approach and landing aid for aircraft.

ILS localizer

The component of an ILS localizer which provides guidance in the horizontal plane. The transmitter with its associated antenna system produces a composite field pattern amplitude modulated with 90 Hz and 150 Hz. The radiation field pattern is such that when an observer faces the localizer from the approach end of the runway, the depth of modulation of the radio carrier due to the 150 Hz tone predominates on the right-hand side and that due to the 90 Hz tone predominates on the left hand side. The DDM is zero on the centreline of the runway and the extended runway centreline.

VHF omnidirectional range (VOR)

A short range (up to approximately 370 km or 200 nautical miles) aid to navigation which provides a continuous and automatic presentation of bearing information from a known ground location.