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The susceptibility of aeronautical navigational aids to interference from adjacent-band broadcast transmissions

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THE SUSCEPTIBILITY OF AERONAUTICAL NAVIGATIONAL AIDS TO INTERFERENCE FROM ADJACENT-BAND BROADCAST TRANSMISSIONS

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Summary

Measurements to determine the susceptibility of some airborne navigation receivers to interference from v.h.f./f.m. sound transmissions are described. The measurements were designed to investigate both the response to interference radiated in-band and to intermodulation in the receivers. The results of the measurements were submitted to an ITU Planning Conference and the decisions of the Conference are given together with an indication of the effects on broadcast planning.

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Foreword

The 1979 World Administrative Radio Conference extended (with effect from 1st January 1982) the frequency band available for v.h.f./f.m. sound broadcasting in Region 1 from 100 MHz to 108 MHz. Now the frequency band from 108 MHz to 136 MHz is used by aeronautical navigation systems which generally operate with low-level signals and some of which are "safety-of-life" systems. In Region 2 (The Americas) broadcasting and aeronautical services have operated in adjacent bands for some years and there have been reports of a significant number of cases of interference to the aeronautical services. Accordingly the ITU Regional Administrative Conference charged with deciding technical standards to be used when planning the extended broadcasting band was requested to study means of avoiding such interference. In the United Kingdom studies were co-ordinated by a Technical Working Group (TWG) having representatives of interested parties with a Home Office Chairman. Under the auspices of the TWG, measurements of the characteristics of a number of aeronautical equipments were carried out jointly by the BBC and the Civil Aviation Authority (National Air Traffic Services) – CAA (NATS). The results of this work were contained in a report appended to the UK submission to the Conference; this report is reproduced as Sections 1–10 inclusive of the present report.

The First Session of the Regional Administrative Conference for FM Sound Broadcasting in the VHF Band was held in Geneva in August–September 1982, being the first part of a two-part planning conference. The decisions of this Conference departed in a number of respects from the results given in the UK report and these are outlined in Section 11.

On the advice of CAA/NATS the measurements carried out by BBC and CAA/NATS were confined to Instrument Landing System (ILS) receivers. The Conference, however, decided to extend consideration to VHF Omnidirectional Range (VOR) and to VHF communications. Interference to the two latter systems is not considered in this report.

1. Introduction

The World Administrative Radio Conference in 1979 gave Region 1 an allocation of the band 87.5 MHz to 108 MHz for f.m. sound broadcasting; thus those transmissions would become adjacent in frequency to aeronautical navigational services operating in the band 108–118 MHz. Of the two services operating in this band, i.e. VOR and ILS, only ILS seems likely to be affected in any critical way. This paper considers possible interference mechanisms and describes measurements of protection ratios on five ILS localiser receivers.

2. Interference Mechanisms

2.1. Adjacent band interference

The broadcast transmission if sufficiently strong will break through into the ILS channel or cause the ILS receiver to lose sensitivity. This mechanism has been called "brute force" interference.

2.2. Radiated intermodulation

When two or more broadcast transmissions are radiated from a single antenna, or from adjacent antennas, intermodulation products will be generated, albeit at low level. An intermodulation product (i.p.) of sufficient strength falling in or near an ILS channel will cause interference.

2.3. Internal receiver intermodulation

When an ILS receiver is subject to strong signals from two or more broadcast transmissions, intermodulation products will be generated in the receiver. If the frequency relationships are such that a product falls on the wanted channel, interference will result.

3. Intermodulation Products

When signals are applied to a non-linear resistance, various harmonic and sum-and-difference terms are generated. The non-linear resistance may be asymmetrical (rectifying) giving rise to even harmonics and certain sum and difference terms as well as a d.c. component, or it may be symmetrical giving rise to odd harmonics and certain sum and difference terms. The latter are particularly important in that some of these fall on frequencies adjacent to the original signals and may be radiated efficiently by the antenna.

Consider signals $a \cos 2\pi t f_a$, $b \cos 2\pi t f_b$, $c \cos 2\pi t f_c$ applied to a symmetrical non-linear resistance where fc > fb > fa. The following third-order products will fall in the upper adjacent frequency band:

$c^2 a \cos 2\pi t (2f_c - f_a)$
$c^2 b \cos 2\pi t (2f_c - f_b)$
$b^2 a \cos 2\pi t (2f_b - f_a)$ (where $f_b - f_a > f_c - f_b$)
$a b c \cos 2\pi t (f_b + f_c - f_a)$

Fifth order terms may also be produced of the types:

$c^3 b^2 \cos 2\pi t (3f_c - 2f_b)$
$c^3 ba \cos 2\pi t (3f_c - f_b - f_a)$
$c^2 ba^2 \cos 2\pi t (2f_c + f_b - 2f_a)$

In the above expressions the amplitude multipliers indicate the dependence of the amplitude of the intermodulation product on the amplitude of the generating components. Thus for the intermodulation product

$a\, b^2 \cos 2\pi t (2f_b - f_a)$

an increase of 1 dB in level of the signal of $\cos 2\pi t f_a$ will result in a 1 dB increase in the level of the i.p. whereas a 1 dB increase in the signal $b \cos 2\pi t f_b$ will result in a 2 dB increase.

4. Modulation of the broadcast transmissions

Band II broadcast transmissions in Region 1 are frequency-modulated with a maximum deviation of 75 kHz. In a stereophonic transmission the pilot-tone deviates the carrier by between 8% and 10% of the maximum so that the deviation will remain finite even in quiet passages. Other subcarriers will be present to carry data or for control purposes so that the carrier will not be undeviated in a monophonic transmission either. It may also be noted that the maximum deviation of a third order intermodulation product will be three times as great as that of the constituents. It is therefore necessary to consider deviations of the broadcast transmission lying in the range 5 kHz–225 kHz.

5. The ILS system

5.1. ILS system technical details

A channel spacing of 50 kHz is employed in the band 108–112 MHz and the use of the band employs an interleaving pattern between ILS and a further ICAO navigational system (VOR) viz.

108.10 MHz ILS
108.15 MHz ILS
108.20 MHz VOR
108.25 MHz VOR
.
.
111.80 MHz VOR
111.85 MHz VOR
111.90 MHz ILS
111.95 MHz ILS

Guidance in the horizontal plane is provided by two overlapping beams with separate amplitude modulations (90 and 150 Hz) with the indication of deviation from the centre line obtained in the aircraft receiver by a measurement of the difference in the depth of modulation (DDM) of the signals from the two beams. The system specifications include all necessary system tolerances to ensure that a standardised indication (specified in μA) is provided on the cockpit indicators irrespective of the type and manufacture of the indicator itself. Additional and tighter system tolerances are applicable to the higher Category systems (CAT III) relating to the uniformity of the course beam structure to cater for those approaches in which automatic flight control coupled from the ILS signals is used. Large aircraft tend to universally employ coupled approaches, as do all aircraft when landing under reduced or zero visibility conditions. Interference to the system can affect either the audio identification or the actual guidance signals, or both. Disruptive interference to the identification or any undue significant effect on the guidance signals must be considered as potentially highly dangerous.

The ILS service area, i.e. the area over which the signal is provided to a given value and where it is protected from other ILS signals, is arranged to provide approach guidance in a sector extended from the touchdown point outwards such that aircraft can be guided by other means, e.g. radar control, into the approach "funnel" from which point ILS provides the guidance signal right down to touchdown point. The dimensions of this service area are shown in the diagram at Figure 1 where the point of origin is the localizer aerial, which is situated at that end of the runway furthest from the

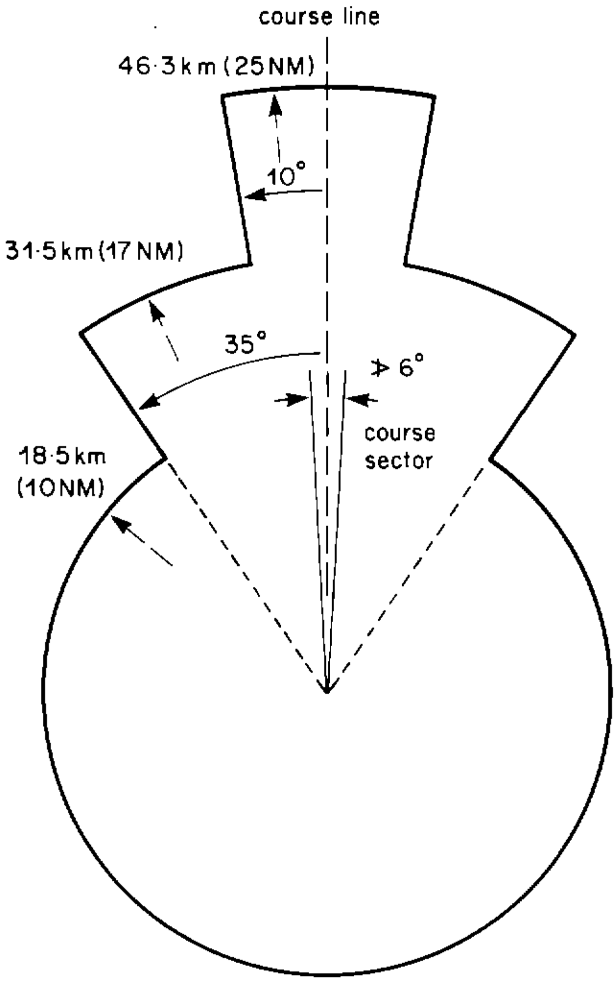

Fig. 1 – ILS Service Area.

approach path. Before an ILS is approved for use there is also an associated operational assessment of the approach path, its physical layout (i.e. obstructions) from which is derived a mandatory procedure for landing aircraft including obstacle clearance limits to ensure a safe approach even when aircraft are at the lower limits of the glide path beam.

The minimum field strength for the localizer signal is specified to be 40 μV/m for Category I systems (approach guidance down to a height of 200 feet) and 100 μV/m at 10 n miles, increasing to 200 μV/m near touch down for Category III systems (approach guidance down to and along the runway). This minimum signal strength is required over the horizontal areas specified in Fig. 1,* and in the vertical plane up to 7 degrees from the horizontal and at the touchdown point to 2000 feet, or to 1000 feet above the elevation of the highest point in the approach path whichever is the highest. In regard to the protection of the ILS signal, in the general case the figure of 40 μV/m would need to be assumed for the level of the wanted signal although in specific instances the higher figure of 100 μV/m might be appropriate.

* The backward service is not always specified.

5.2. ILS airborne equipment details

Different versions of ILS receiver were chosen for test in this investigation: 3 receiver types which might typically be found on large passenger carrying aircraft and 2 equipments from the General Aviation or Light Aircraft market. They each have one of the following approval classifications:

1 Fully approved
2 Limited approval (LA) Class 1

The fully approved equipments are for use on any aircraft without restriction but are, generally, used on larger passenger-carrying aircraft such as found in airline service. LA Class 1 receivers are restricted to aircraft weighing 5700 Kg or less i.e. General Aviation/Light Aircraft.

For commercial reasons the receivers tested will not be identified here under manufacturers type number but will be identified in numerical order from 1 to 5:

Receiver 1 is a fully approved ILS receiver
Receiver 2 is a fully approved ILS receiver modified specially for flight calibration purposes
Receiver 3 is approved under LA class 1
Receiver 4 is a fully approved equipment but would be found more often on general aviation aircraft such as executive aircraft
Receiver 5 is approved under LA class 1

6. Interference criteria

The presence of interference may be observed in different ways:

(i) change of localizer (course guidance) current
(ii) change of flag current or appearance of flag
(iii) change of a.g.c. current/voltage
(iv) impairment of audio channel

The localizer display is a centre-zero micro-ammeter with a calibrated scale over the range ±150 μA (or 5 dots on the pilot's instrument). When the difference in the depth of modulation (DDM) of the input signal was adjusted to give a deflection at 150 μA, or slightly below, the effect of an interfering signal was to reduce the deflection. There is no generally agreed "permissible" reduction but a value of 5% (i.e. 7.5 μA) of the full calibrated scale is used for the purposes of the tests. With the lowest input levels, some of the receivers tested showed a tendency for a random variation of deflection so that small changes, in some instances, are difficult to measure.

The "flag" is an electromechanical device incorporated into the course guidance indicator which indicates the quality of the course information to the observer. There are two types of "flag" operation, but both types sense the sum of the "left" and "right" guidance currents in some way. In the first type the flag is in effect a meter needle following the flag current. In the second type the flag is operated by a discrete signal when the sum of the guidance outputs falls below a predetermined level. The normal level of flag current (in the first type) is 350 μA, and the effect of interference is to reduce this.

Measurements of a.g.c. current were taken during the tests and showed reactions that differed from receiver to receiver. However this proved to be an insensitive method of assessing interference and is not used here.

The localizer receiver is provided with an audio frequency output which normally carries the identification of the particular ILS ground installation. This output was either monitored aurally or measured during the course of the tests but without a wanted signal being present. For some of the tests the modulation of the interfering signal was evident at unwanted signal levels lower than those needed to produce flag or guidance current effects: for Receiver 1 however, particularly where the interfering signal frequency had certain values of frequency offset, there was no audible effect.

7. Experimental arrangements

Reference was made in Section 5 to ILS localizer field strengths of 40 μV/m, 100 μV/m and 200 μV/m being specified for different ranges or system categories; the corresponding values in logarithmic measure are +32 dB(μV/m), +40 dB (μV/m) and +46 dB (μV/m). If the aircraft antenna were isotropic and the feeder from it to the receiver were loss free, the signal levels at the receiver would be 11.4 μV, 28.5 μV and 57 μV (−86, −78, −72 dBm) measured across 50 ohm at a frequency of 108 MHz. The wanted signal levels used in the tests were 8 μV, 20 μV and 40 μV

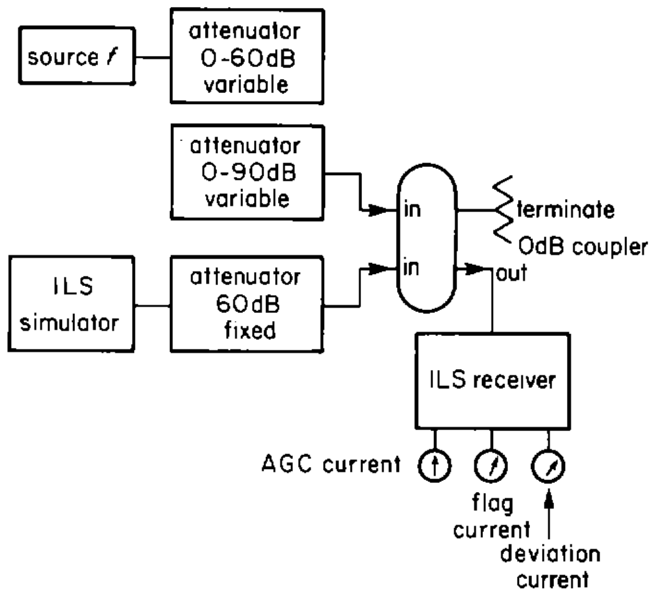

Fig. 2 – Arrangement for measurement of co- and adjacent-channel interference.

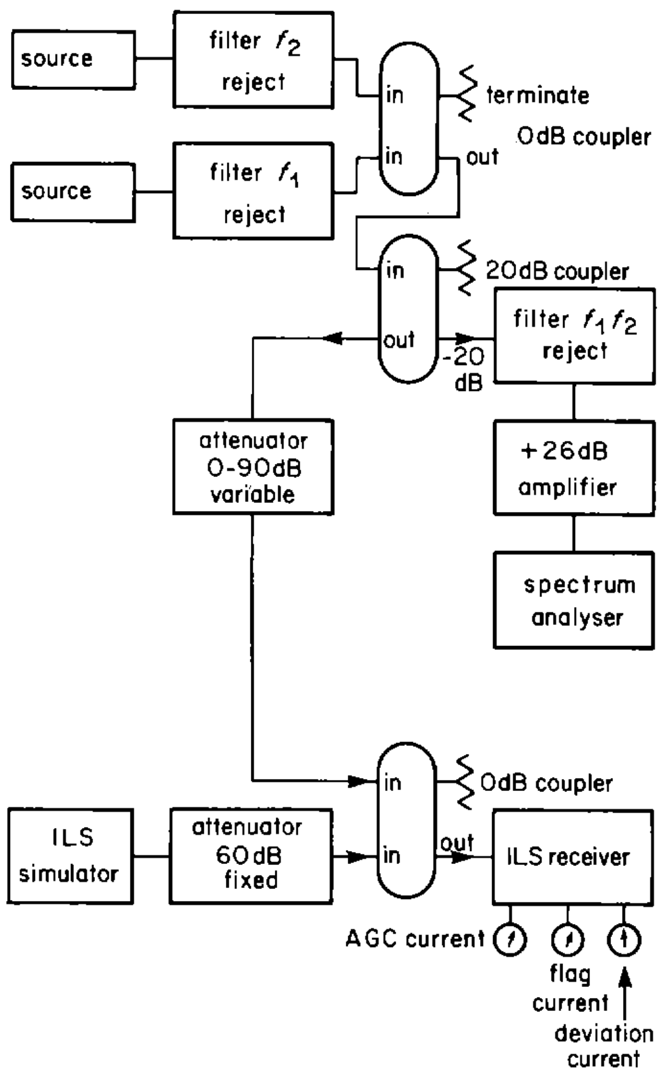

Fig. 3. – Arrangement for measurement of receiver intermodulation.

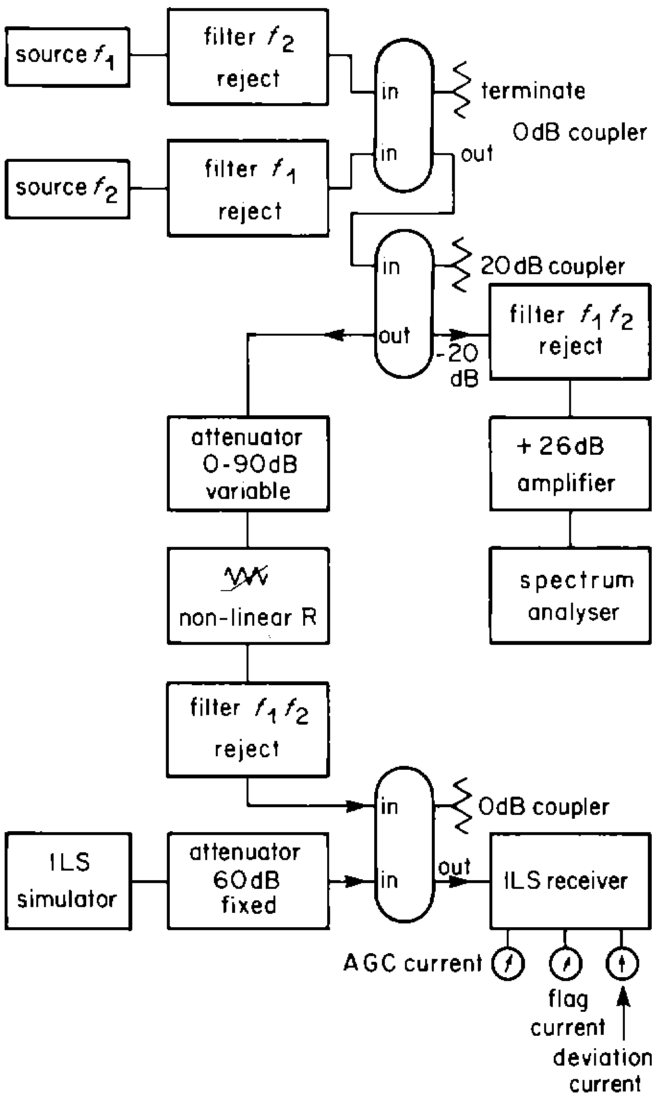

Fig. 4 – Arrangement for measurement of co-channel interference with wide deviation.

(−89, −81, −75 dBm) so that in effect the antenna gain for the wanted signal was assumed to be 3 dB less than isotropic.

Two basic experimental arrangements were used. That shown in Fig. 2 was used for the measurements of co-channel, adjacent-channel and adjacent-band interference. A signal from an interfering source f, was combined with a simulated ILS signal and applied to the receiver. The modulation on the ILS signal was set to give a localizer current near full scale and input levels at the receiver were set at the levels given above.

The arrangements for the measurement of receiver intermodulation shown in Fig. 3 needed great care to ensure that the intermodulation product was being generated in the localizer receiver and not to any significant extent elsewhere. The level of directly-generated intermodulation was less than −95 dB relative to each of the sources f_1 and f_2, which were maintained equal.

In order to assess the effects of deviation most of the measurements were made with just two values, 5 kHz and 75 kHz; the former gives most interference when co-channel and the latter when adjacent-channel. Measurements of the effect of an intermodulation product radiated from a transmitter required a deviation of 225 kHz (see section 4). As the available signal generators were not able to produce deviations greater than 100 kHz measurements using a deviation of 225 kHz were made by generating an intermodulation product in a non-linear resistance using the arrangement of Fig. 4.

8. Results of measurement

8.1. Effect of modulation material

An initial experiment was made with one receiver (Receiver 1) to determine whether the receiver was sensitive to the type of modulation on two broadcast transmissions generating in the receiver an i.p. of the same centre frequency as the wanted signal. Fig. 5 shows results obtained with Receiver 2 using tone, music and band-limited

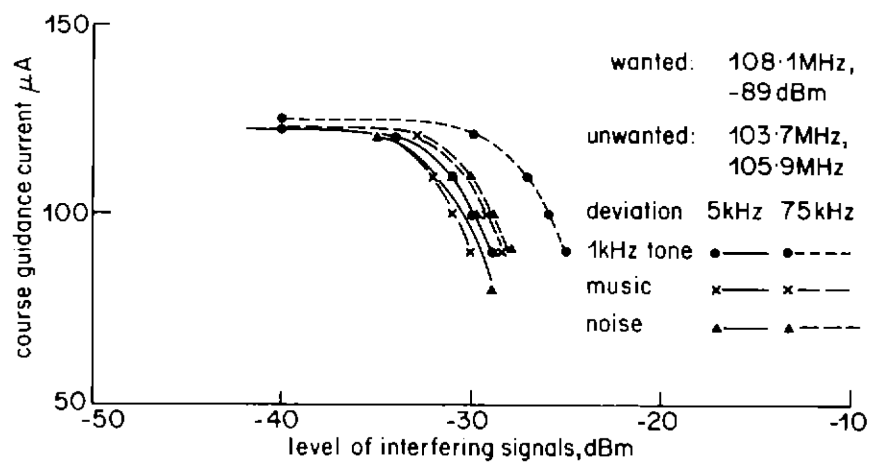

Fig. 5 – The effect of modulation on interference levels for Receiver 1.

noise with maximum deviations of 5 kHz and 75 kHz. It was concluded that the use of 1 kHz tone modulation would give representative results, and this was used in all the tests. Where it was necessary to generate an i.p. from two sources, modulation of 1 kHz was used on one and 5 kHz on the other to avoid a slow beat of the modulation frequencies.

8.2. Co-Channel interference (radiated intermodulation) (Type A in CCIR Report 929)

This test simulates the effects of an intermodulation product radiated from a broadcast transmitting station having two or more frequency assignments in use. It is not necessarily applicable to any other type of spurious emission that may arise. The centre frequency of the intermodulation product is assumed to be sufficiently near to that of the ILS localizer for some of the energy to fall within the ILS channel. The ILS frequency allocations are in pairs spaced by 50 kHz (108.1, 108.15, 108.3, 108.35 MHz etc.) and the broadcast frequency allocations are likely to be in multiples of 100 kHz so that the effects of interference are required to be known in steps of 50 kHz.

Fig. 6 shows the effect on the receivers tested using the 7.5 μA harmful interference criteria discussed in Section 6; the wanted signal level was set at −89 dBm. It may be noted that the receivers are most sensitive to the interference when the deviation is lowest (5 kHz). This is to be expected since the energy of the interfering signal is then concentrated within the ILS channel. As the deviation is increased the sensitivity to co-channel interference falls but interference centred on adjacent channels becomes more significant. With the maximum deviation of 225 kHz intermodulation products having centre frequencies within ±250 kHz of the ILS centre frequency will give discernible interference.

Measurements made with different levels of the wanted ILS signal demonstrated the linear nature of this interference mode (as far as the receiver is concerned) so that it is justifiable to give results in terms of the protection ratio, i.e. the required level of the wanted signal divided by the level of the unwanted signal. Thus when ratios are expressed in decibels, a positive value of protection ratio indicates that the wanted signal must be stronger than the unwanted signal and a negative value vice versa. It may also be noted that the absolute frequency scale of Fig. 6 may be changed to a scale of frequency difference relative to the ILS channel (a few measurements were made with ILS receivers tuned to channels higher than 108.1 MHz to verify that this was valid). These changes have been incorporated in Figs. 7 and 8 to give results that are applicable to any channel in the ILS frequency band.

For planning purposes it is necessary to take into account the performance of the poorest receiver and all the possible values of deviation of the interfering broadcast signal. This is done in Fig. 9 which is an envelope of the curves in Figs. 7 and 8.

8.3. Adjacent-band interference

Fig. 10 shows the maximum permitted levels of a single broadcast transmission into each receiver when the level of the wanted signal is 8 μV (−89 dBm) and its frequency is 108.1 MHz. It may be noted that for frequencies below 108 MHz the sensitivity of the receivers to interference falls off by 5–20 dB per MHz. It is also evident that Receiver 1 has the greatest sensitivity to interference of all the receivers, the margin being about

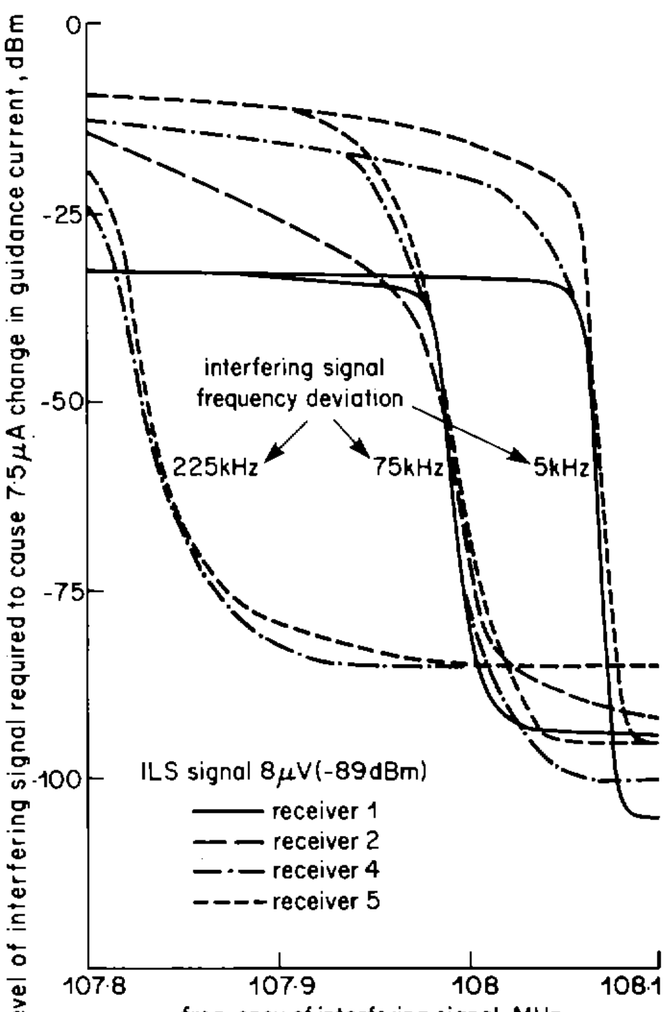

Fig. 6 – Interference close in frequency to the wanted signal.

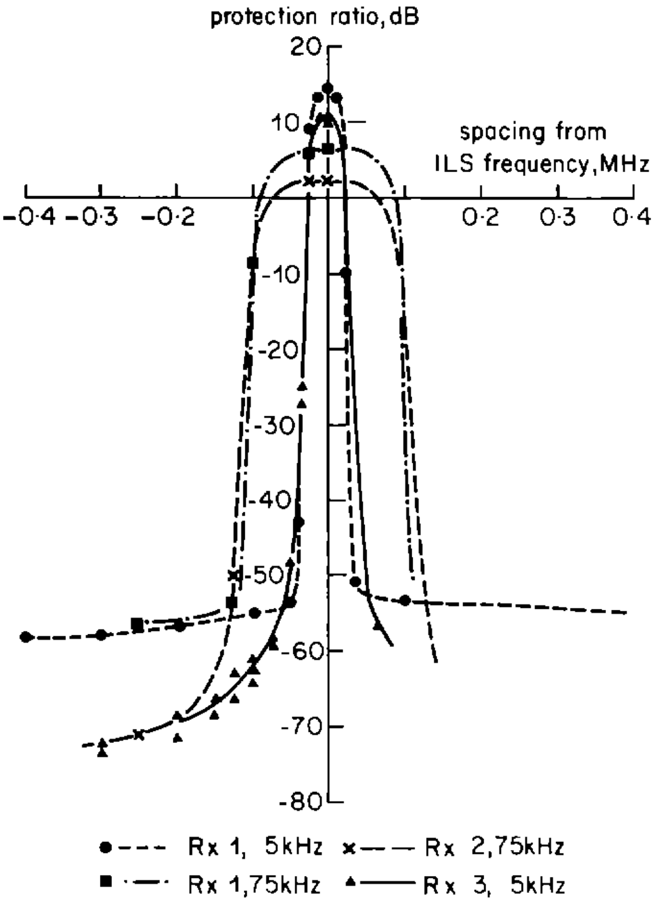

Fig. 7 – Responses of Receivers 1, 2 and 3 to a radiated inter-modulation product.

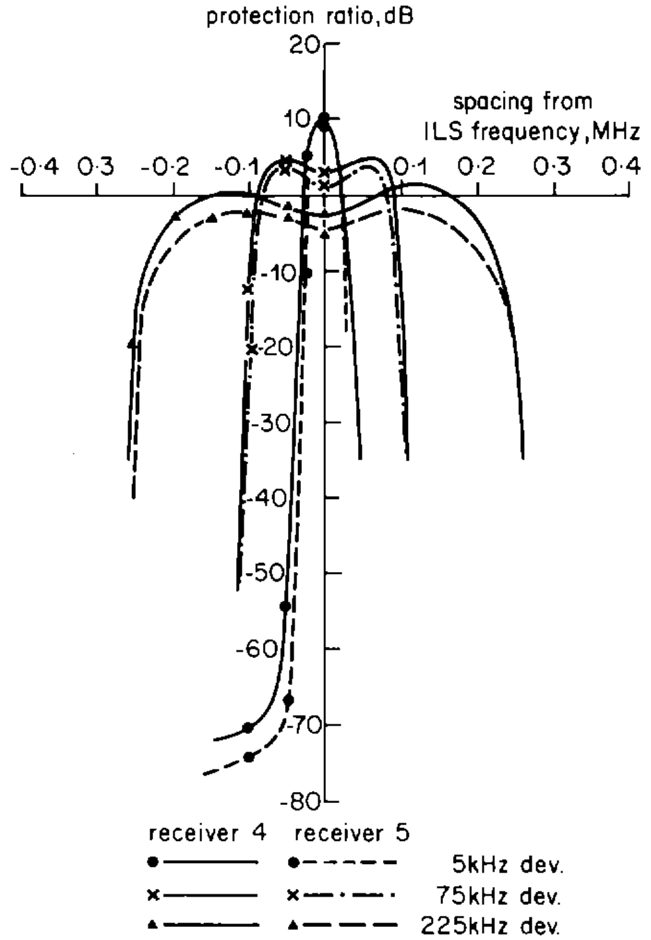

Fig. 8 – Responses of Receivers 4 and 5 to a radiated intermodulation product.

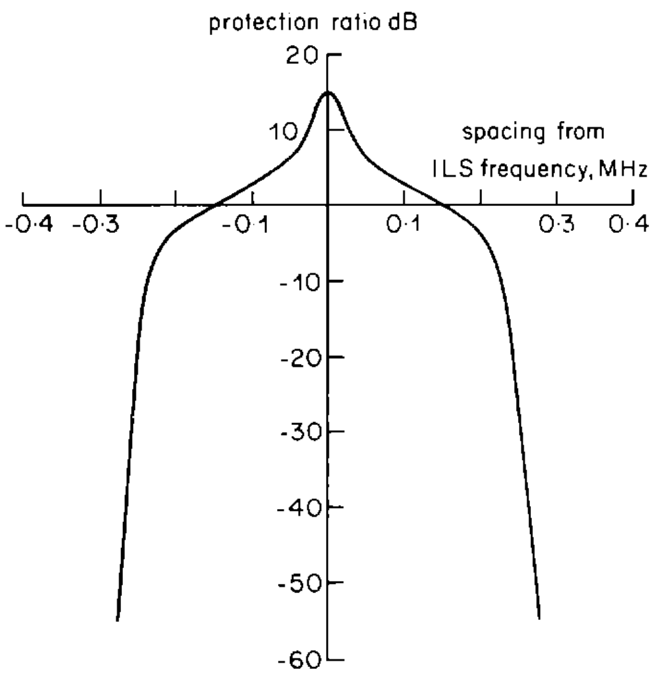

Fig. 9 – Protection ratio required for a radiated intermodulation product.

15 dB at frequencies above 107 MHz. Some measurements were made with Receiver 4 and Receiver 5 tuned to 110.1 MHz; they show that the permissible level of interference may be expressed in terms of a frequency difference from the ILS frequency. Additional measurements with the wanted signal at levels of 20 μV (−81 dBm) and 40 μV (−75 dBm) show that the interference mechanism is linear so that the results may be expressed in terms of a protection ratio as in Fig. 11.

8.4. Receiver generated intermodulation

Fig. 12 shows the effect of equal signals intermodulating in the receiver to give a third-order product at the frequency of the wanted signal for three levels of the wanted signal. The result of fifth-order intermodulation is also shown. It may be noted that a particular increase in wanted signal permits the interfering signals to rise by a lesser amount, i.e. the interference mechanism is therefore non-linear and the concept of protection ratio may not be used in this case.

Fig. 13 shows how the frequency separation

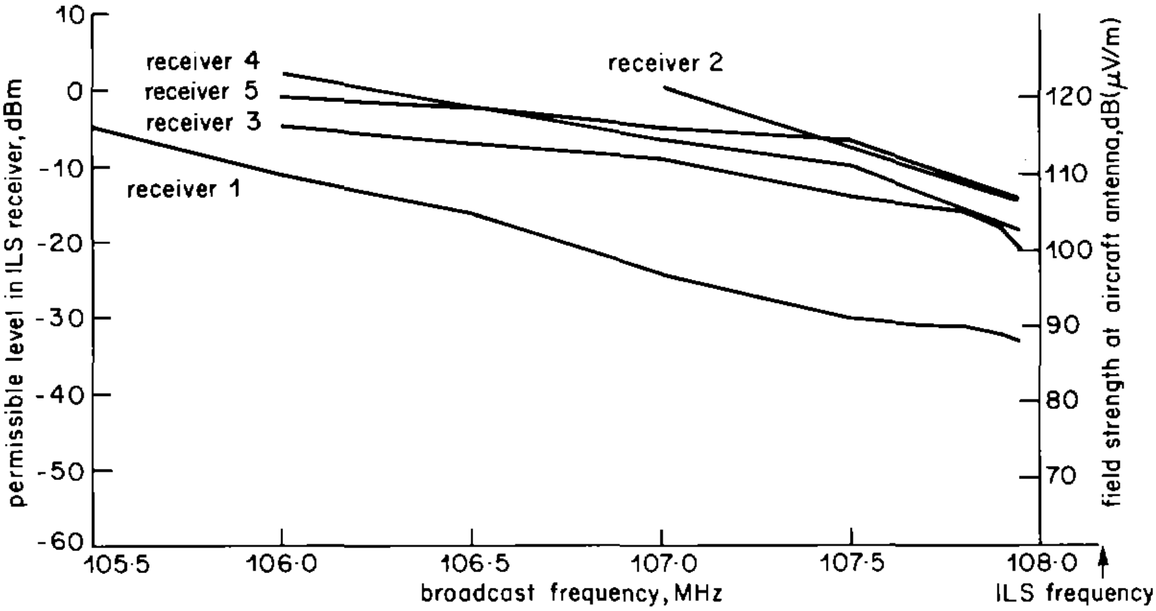

Fig. 10 – Maximum permissible level in ILS receiver of a single adjacent-band broadcast transmission.

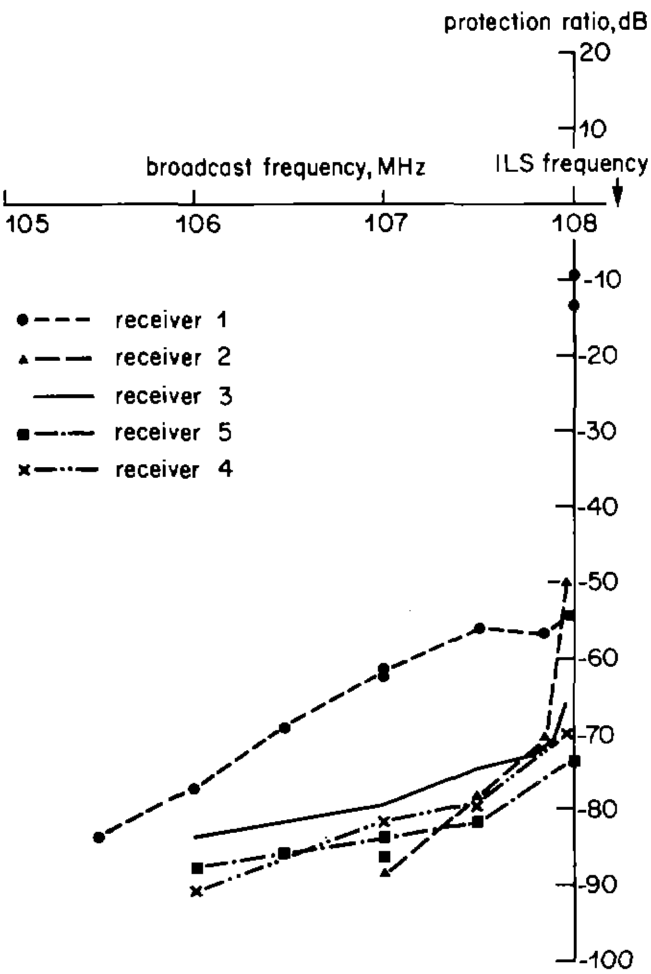

Fig. 11 – Protection ratio for a single adjacent-band broadcast transmission.

between the two interfering signals affects the permissible level; in each case the frequencies of the interfering signals were chosen so that the third-order product coincided with the wanted ILS frequency. Receiver 1 and Receiver 4 show considerably more tolerance to widely-spaced transmissions whereas Receiver 5 shows little difference with spacing. This may reflect the slope of the r.f. rejection characteristics for each receiver although other mechanisms may be responsible. The receivers are less sensitive to deviations of 75 kHz than those of 5 kHz, as would be expected from Figs. 7 and 8.

It is concluded that when the above conditions apply, i.e. when the interfering carriers have the worst frequency relationship with the ILS, and the latter is at its lower field strength limit, +32 dB (μV/m), the level reaching the receiver should not exceed −32 dBm for broadcast signals spaced 2.2 MHz or more. This level corresponds to a field strength at the aircraft antenna of +89 dB (μV/m). If the ILS field strengths are at the higher levels of +40 dB (μV/m) and +46 dB (μV/m) the corresponding permissible interfering field strengths are +93 dB (μV/m) and +96 dB (μV/m).

When the frequency relationships are such that the i.p. falls near, but not on, the ILS frequency, the curve of Fig. 9 may be used as a derating curve until the point at which the curves of Fig. 11 become the dominant requirement.

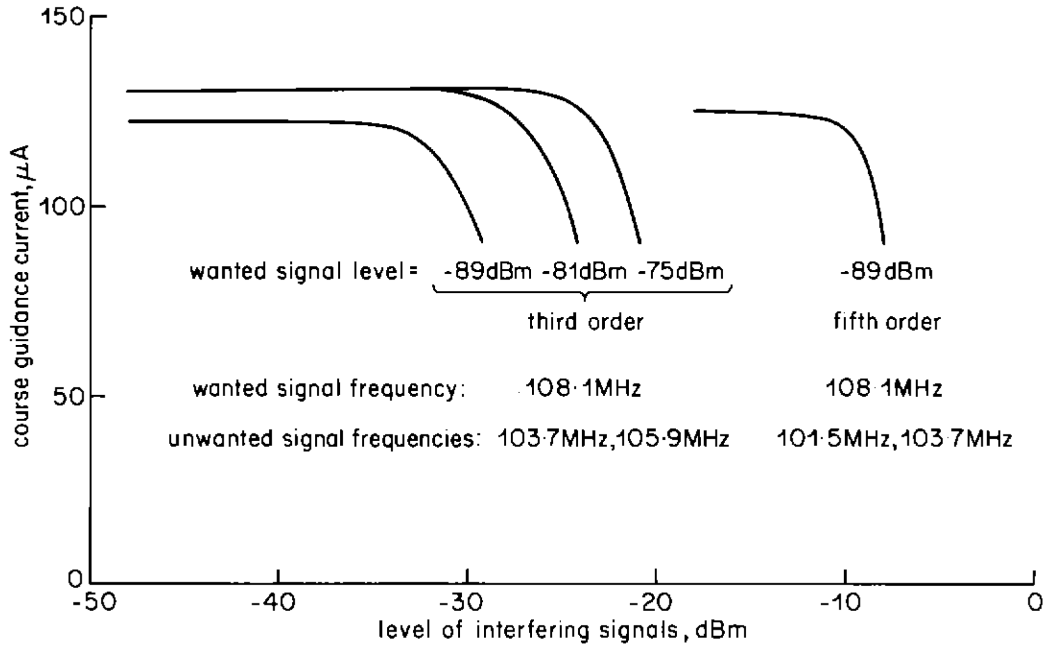

Fig. 12 – Intermodulation generated in Receiver 1.

9. Implications for broadcast transmissions

Broadcast transmitting aerials commonly have significant directivity in the vertical plane so that an aircraft flying directly over a transmitter may experience lower field strength than one several kilometres away passing through the main beam. To take this into account it would be necessary to look at specific flight paths and transmitter locations in detail. For an initial assessment it will be assumed that the broadcast transmitter is omnidirectional in horizontal and vertical planes, that only the horizontally-polarised component of the transmission gives rise to interference and that the field strength at the aircraft may be calculated assuming free-space conditions. Fig. 14 shows the range at which interference will occur as a function of protection ratio for a range of effective radiated powers (e.r.p.) from the broadcast transmitter. Each interference mechanism may be considered in turn.

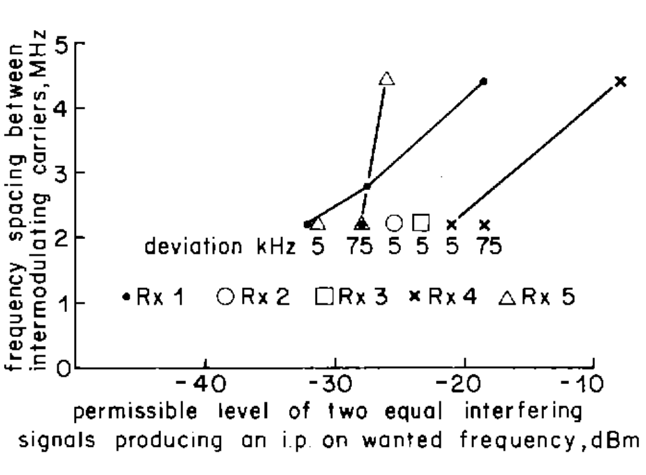

Fig. 13 – Intermodulation in ILS receivers from two equal broadcast signals.

9.1. Co-channel interference (radiated intermodulation)

From Fig. 11 it may be seen that a protection ratio of 14 dB is sufficient for the worst of the ILS receivers measured. ITU regulations [1] for spurious emissions of transmitters having a mean power above 25 W require that the spurious components in the transmission line to the broadcast antenna shall not exceed a power of 60 dB below the fundamental or 1 mW, whichever is the lower. Thus a high-power transmitter just meeting this requirement* would have an interference range of 75 km. In practice broadcast transmitters in the United Kingdom meet the ITU requirements with a margin in hand and an e.r.p. of 1 mW would be typical for the i.p. from 125 kW transmissions spaced 2.2 MHz (i.e. a relative level of −81 dB). A typical interference range is then 30 km. This is still quite large and the broadcaster should aim for a relative i.p. level of −95 dB or less when specifying transmitter combining units. However, there is no certainty that such levels will be obtained with a common aerial installation.

9.2. Adjacent band interference

The highest frequency that is likely to be used for broadcast transmissions, assuming a channel

* A typical antenna gain, and free-space propagation are assumed in this calculation.

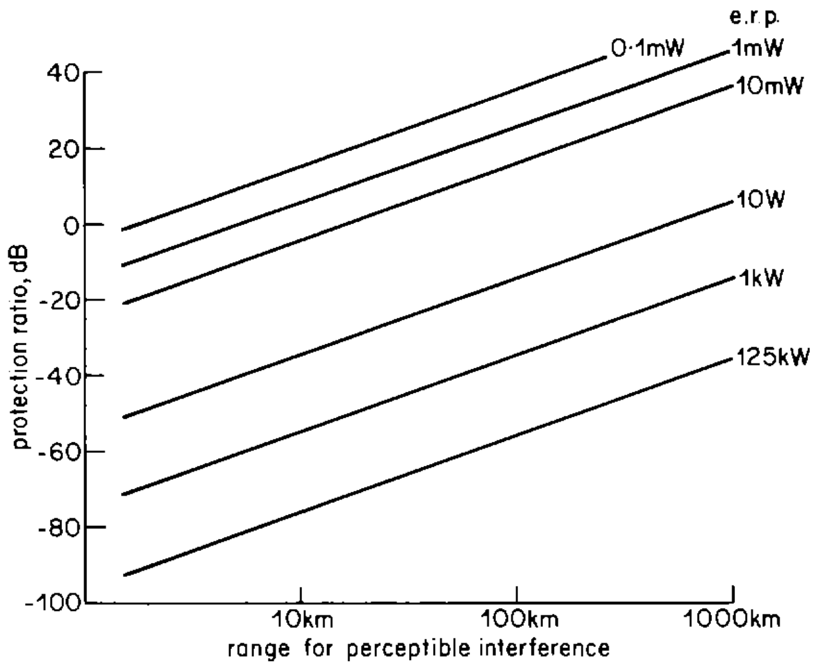

Fig. 14 – The relation between protection ratio and interference range.

spacing of 100 kHz is adopted, is 107.9 MHz. All the ILS receivers listed showed a slow increase in discrimination between this and lower frequency channels. The protection ratio of the poorest receiver (Receiver 1) at 107.9 MHz is −55 dB for which the corresponding interference range for a 125 kW station is 110 km. However, the other receivers would require ranges of 20 km or less. For a frequency of 107 MHz, the interference ranges become 50 km for Receiver 1 and less than 7 km for the other receivers. No measurements have been made with two or more carriers present but it is suggested for this mechanism that a power summation be made at the input to the ILS receiver with adjustment for different protection ratios if appropriate.

9.3. Receiver intermodulation

It is shown in Section 8.4 that for the ILS signal at its lowest specified limit and interfering broadcast transmissions on frequencies 2.2 MHz and 4.4 MHz below the ILS frequency (i.e. such that they can intermodulate to produce a term centred on the ILS frequency), the maximum field strength of each at the aircraft antenna is +89 dB(μV/m) for Receiver 1 and Receiver 5. If the broadcast transmissions have an e.r.p. of 125 kW it follows that the interference range is 90 km. For Receivers 2, 3 and 4 the interference ranges are respectively 44 km, 35 km and 27 km.

10. Response of the aircraft antenna

The measurements described above take no account of the frequency response of the aircraft antenna, which could reduce the levels of the broadcast signals reaching the receiver. It would not help in respect of radiated intermodulation.

CCIR Report 929 [2] suggests that the response for a navigation antenna to broadcast signals should be 3 dB plus 1 dB/MHz below 108 MHz, in which the first term was intended to represent the losses between antenna and receiver. Such a response would be of benefit in reducing receiver-generated intermodulation especially for the lower broadcast frequencies.

(This concludes the Report attached to the UK submission to the ITU Conference.)

11. The decisions of the ITU Conference (First Session)

The decisions of the Regional Administrative Conference for FM Sound Broadcasting in the VHF Band (Region 1 and certain countries concerned in Region 3), First Session, Geneva 1982 are contained in the Report to the Second Session of the Conference [3], which is to be held in 1984. Those relating to compatibility between the broadcasting and aeronautical services are contained in

Chapter 5 of the report and extend to fifteen pages. The main differences between the Conference decision and the UK submission will be highlighted here.

11.1. Radiated intermodulation

This was designated type A1 interference. The protection ratios given in the UK submission were accepted with the addition of a 3 dB margin for multiple interference entries resulting from FM broadcast emissions. Accordingly the curve of Fig. 9 was raised by 3 dB.

11.2. Adjacent-band interference

Where interference resulted from power in the aeronautical band radiated from a broadcast transmitter at a closely spaced frequency (i.e. from the far-out sidebands), it was designated type A2 interference. The Conference considered that there were insufficient data available to define the typical levels of power of FM broadcast transmissions between 200 kHz and 500 kHz from the carrier and called for further studies.

11.3. Receiver-generated intermodulation

An effect resulting from intermodulation products generated within the aircraft receiving installation was designated type B1 interference. Different criteria were defined for the cases of two and three unwanted signals. Where the intermodulation involves two unwanted signals, taking the form $2f_1 - f_2 = f_a$ it was decided that unacceptable degradation of receiver performance may occur if

$$1.71\,N_1 + N_2 + 60 \geqslant 0$$

where N_1 and N_2 are the levels, in dBm, of the two broadcasting signals at the frequencies f_1 and f_2 respectively at the receiver input and f_a is the receiving frequency.

For equal interfering signals:

$$N_1 = N_2 = -22\,\text{dBm}$$

This is 10 dB less stringent than was found necessary for the worst receiver in the UK tests. Theoretically, the coefficient of N_1 would be expected to be 2; the coefficient 1.71 arose from fitting a straight line to some experimental results submitted by France.

Where the intermodulation involves three unwanted signals, taking the form $f_1 + f_2 - f_3 = f_a$, it was decided that unacceptable degradation of receiver performance may occur if

$$N_1 + N_2 + N_3 + 73 \geqslant 0$$

For equal interfering signals

$$N_1 = N_2 = N_3 = -24.3\,\text{dBm}$$

This was a theoretical extension of the two-frequency case, allowing for the 6 dB higher level of a three-frequency term for a given degree of non-linearity.

11.4. Receiver desensitisation

Adjacent-band interference caused by the inability of the aircraft receiver to withstand a broadcast transmission at a closely-spaced frequency was designated Type B-2 interference. The Conference decided that an unacceptable degradation of ILS localiser receiver performance may be caused, due to desensitisation, if the level of a broadcasting signal exceeds −20 dBm at the receiver input on a frequency near the band edge (108 MHz). For broadcasting signal frequencies from 108 MHz to 106 MHz, it was decided that the threshold level increases linearly from −20 dBm to −5 dBm.

11.5. Filtering of broadcasting transmitters

The Conference decided that by fitting improved combining filters, and paying careful engineering attention to possible sources of non-linearity following the output stages of the transmitters, it is technically feasible to reduce the radiated power of the third-order intermodulation products to −85 dB relative to the effective radiated power. Fig. 15 shows ILS service areas in East Anglia in relation to the high-power v.h.f./f.m. transmitting station at Tacolneston. The broken line shows the range up to which interference to ILS could occur on the basis of the Conference criteria. Accordingly the broadcast frequencies need to be co-ordinated with the frequencies of all the ILS installations whose service areas are intersected by the circle, i.e. seven in the case of Tacolneston. This is a severe restriction on frequency planning.

12. Subsequent and future developments

The Conference decided that the criteria adopted would appear to constrain the full exploitation of the broadcast band from 100 to 108 MHz and recommended that the CCIR initiate studies both of the way that the immunity of airborne equipment could be improved and of the maximum

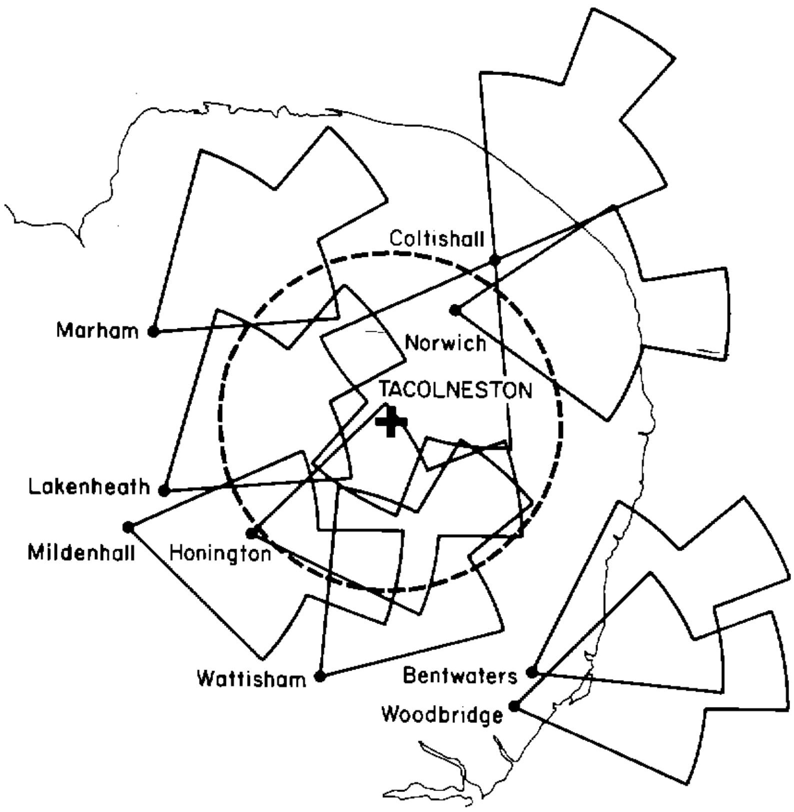

Fig. 15 – ILS service areas in East Anglia.

suppression of spurious emissions that could be achieved at broadcast transmitting stations.

In response, the CCIR formed two Interim Working Parties to carry out the studies, namely IWP 8/12 and IWP 10/8. IWP 8/12 was charged to consider by how much the value of immunity to FM sound broadcasting interference of the airborne equipment can be improved and issued a report after one meeting. This report, however, proposed criteria for existing equipment that were more stringent in some respects than those adopted by the Conference. A significantly better performance was promised for new equipment but the implementation time was so long that it would have little relevance to the 1984 Planning Conference. IWP 10/8 was charged to determine the maximum suppression of spurious emissions from broadcast transmitting stations, lying in the 108–137 MHz range, which can be maintained continuously. It met twice and produced a report supporting the Conference assumptions on achievable levels of spurious emissions, but held out some hope of improvements in specific cases. Material submitted by the UK to IWP 10/8 has been published in Reference 4.

As the above studies have not improved the chances of producing a broadcast frequency plan compatible with aeronautical usage in the adjacent-band, a Joint Interim Working Party 8–10/1 has been set up by the CCIR to give further study to the problem before the Second Session of the Conference. The terms of reference are given in Appendix I.

13. References

1. International Telecommunication Union, 1982, Radio Regulations, Appendix 8. Table of Maximum Permitted Spurious Emission Power Levels, Geneva 1982.

2. CCIR, 1982, Compatibility between the broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-136 MHz. Report 929, Vol. XIII, Geneva 1982.

3. International Telecommunication Union, 1982, Regional Administrative Conference for FM Sound Broadcasting in the VHF Band (Region 1 and certain countries concerned in Region 3). First Session Geneva 1982: Report to the Second Session of the Conference.

4. MILLARD, G.H. Intermodulation between v.h.f./f.m. broadcast transmitters and the protection of adjacent-band aeronautical services. BBC Research Dept. Report 1984/2.

Appendix I

JOINT INTERIM WORKING PARTY 8-10/1

Terms of Reference

Consider the reports of Interim Working Parties 10/8 and 8/12 as well as new contributions.

Determine whether further improvements in compatibility can be made, particularly as regards:

— the possibility of improving the immunity of receivers in the aeronautical radionavigation service to interference caused by FM broadcasting emissions (Recommendation CC, formerly terms of reference of IWP 8/12)

— the maximum obtainable suppression of spurious emissions in the band 108–137 MHz from broadcasting stations operating in the band 87.5–108 MHz (Recommendation DD, formerly terms of reference of IWP 10/8)

Prepare a consolidated draft report intended for submission by CCIR to the Second Session of the Regional Administrative Conference for FM Sound Broadcasting in the VHF Band (Region 1 and certain countries concerned in Region 3). The Joint Working Party shall report to the Interim Meeting of Study Group 8 (May–June 1984).

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