European Radiocommunications Committee (ERC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

ERMES / TV E-5 COMPATIBILITY

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1. EXECUTIVE SUMMARY

1.1 The results of theoretical, laboratory and field studies have been considered during this exercise in order to assess the mechanisms that can lead to ERMES transmitters affecting VHF Television channel E-5 services within Europe, and assess the magnitude of the problem.

1.2 Findings indicate that a significant problem exists and that dependant upon the severity of the impairment, solutions may have to be selected on a case by case basis as necessary.

1.3 Viable options identified by the committee for alleviating the problem are as follows in no particular order:

- The use of ERMES channels that are within 25 kHz of a channel E-5 sound image frequencies should be avoided where possible, refer to Table 7;
- The power of the ERMES signal in areas where TV channel E-5 is in common use should be minimised where possible;
- Orthogonal polarisations should be used where possible (**both** polarisations are used for TV broad-casting in many countries);
- Care should be exercised in the siting of ERMES transmitters;
- The installation of in-line filters in the receiving system where necessary;
- Interference can be minimised by shifting the frequency offset of the TV transmitter (in multiples of line frequency);
- ERMES and TV operators need to take account of the potential problems in planning their networks;
- Further field trials should be undertaken to quantify the magnitude of the problem.

2. INTRODUCTION

2.1 ERMES stands for European Radio Message System intended for pan-European use.
The ERMES specification (pr ETS 300 133-4) provides for sixteen channels with centre frequencies defined by f_n=169.400 + n*0.025 MHz, where n = channel number = 1 to 16.

2.2 The actual use of the ERMES channels in each CEPT country will be a national matter, taking into account the need for frequency coordination between countries and CEPT Rec. T/R 25-07.

2.3 Affected television systems currently in use in member states include both B-PAL and L-SECAM, see CCIR report 624-4.

2.4 Tests in several CEPT countries have shown that interferences are likely to occur from ERMES to TV channel E-5. The purpose of this report is to evaluate the results of these tests and propose feasible solutions to identified problems.

2.5 During the introduction of the Swedish POCSAG system operating on ERMES channel 16, several problems were experienced. Around 500 cases of interference to TV channel E-5 were reported. The problems were usually solved by installing filters at the receiving location, however in some serious cases the POCSAG transmitter had to be moved away from the main lobe of the TV antennas.

3. THEORETICAL STUDY

3.1 Interference Mechanisms

3.1.1 The various carriers used in TV channel E-5 in Europe have nominal frequencies as follows:

Vision carrier,	f_V:	175.25 MHz	(176.0 MHz in France)
Sound carrier,	f_S:	180.75 MHz	(182.5 MHz in France)
Second sound carrier,	f_{S2}:	180.992 MHz	

The second sound carrier is used in the following countries:
Austria, Germany, Italy, the Netherlands and Switzerland.

NICAM carrier, f_N: 181.10 MHz, constant bandwidth: 520 kHz

NICAM on channel E-5 is used in the following countries:
Denmark, Finland, Iceland, Norway, Spain and Sweden.

3.1.2 The ERMES carriers are:

$$f_E = 169.4 \text{ MHz} + 25n \text{ kHz}, \quad n = 1 \text{ to } 16$$

i.e. Channel 1 = 169.425 MHz and Channel 16 = 169.800 MHz

3.1.3 The frequency difference between the vision carrier and the ERMES carriers is between 5.45 and 5.825 MHz (6.2 MHz and 6.575 MHz in France). According to CCIR recommendation 851, a protection ratio of -10 dB is required for a continuous CW interferer 6 MHz below the vision carrier.

ERMES can cause interference to the TV sound in two different ways:

i) either because some ERMES channels will occur as image frequencies of the sound carrier with respect to the vision carrier in the IF stage of the TV receiver, this will be the dominant interference mechanism in receivers with poor IF selectivity;

ii) or through the intermodulation product $2f_V-f_E$, since this product falls in the range 180.7 - 181.075 MHz (182.2 - 182.575 MHz in France).

3.1.4 In both cases, it is the same group of ERMES channels that would cause the most interference.

ERMES channel 14 (channel 4 in France) causes interference to f_S;

ERMES channels around 4 causes interference to f_{S2};

Adjacent ERMES channels are also likely to affect the sound;

ERMES channels 1 through 10 cause interference to the NICAM channel.

3.2 Calculation of Interference Distances

3.2.1 The interference distances calculated below are based on the protection ratios obtained in one set of laboratory tests.

3.2.2 With an ERP of 100 W the field strength at the distance d(m) in free space can be calculated as:

$$E(dB\mu V/m) = 20\log(7*10^7/d).$$

Assuming 0 dBd antenna gain and an input resistance of 75Ω, the conversion factor from field strength to input terminal voltage in the TV receiver is -11 dB. According to CCIR report 625-4, the antenna gain in band III can be taken as 7.5 dBd, and the cable losses are 1.5 dB. When the TV and ERMES transmitters are located in the same direction from the receiver, the separation distances are then as given in Table 1, column 3.

3.2.3 Angle separation between the TV and ERMES transmitting antennas will give a considerable improvement. According to CCIR recommendation 419-2, band III TV receiving antennas give 12 dB antenna discrimination for angle separations greater than 60°, see Table 1, column 4.

3.2.4 The distances shown in Table 1 are valid when the ERMES and TV transmissions have the same polarisation. If orthogonal polarisation is used polarisation discrimination will help to protect the TV service and thus reduce the necessary separation distances.

According to CCIR Rec. 419-3 a polarisation discrimination of 18 dB is considered typical in Band III. In the same recommendation it is also stated, that polarisation discrimination varies statistically with locations and that a value of 10 dB will be exceeded at 90% of locations.

As the distances in question are short, interference from ERMES transmissions into TV must be assumed continuous, hence the polarisation discrimination value of 10 dB has been used in the calculations. The results of which are listed in Table 2.

It shall be noted, that according to CCIR Rec. 419-3 polarisation discrimination can only be used inside the sector defined by the "Beam width" of the receiving antenna, i.e. ± 60° for a Band III antenna. Outside of this sector the values given in Table 1, column 4 shall be used.

3.3 Signal Level and Field Strength

3.3.1 The tests on television receivers, the results of which were used to calculate interference distances, were made with wanted receiver input signal levels of 80, 70 and 60 dBμV respectively. Based on the values given in CCIR Report 625-4 for cable loss, antenna conversion factor and antenna gain, these input levels correspond to field strength values of 85 dBμV/m, 75 dBμV/m and 65 dBμV/m.

3.4 Fringe Area Situation

3.4.1 According to CCIR Rec. 417-4 the lowest field strength for which protection can be claimed is 55 dBμV/m in Band III. Coverage is actually achieved with this value in some European countries.

Assuming that the protection ratios measured for a wanted input signal level of 60 dBμV are also valid for 50 dB μV (field strength = 55 dBμV/m), the separation distances will be as listed in Table 3.

3.4.2 In the Tables 1 to 3 the interfering ERMES field strength has been calculated by the formula valid for free space propagation. This formula cannot be used for terrestrial distances greater than a few kilometres, depending on the effective antenna height.

The distances given in Table 3 have therefore been recalculated using the formula for free space propagation for distances up to 5 kilometres and the CCIR Rec. 370-5 VHF 50%, 50%, land curves extrapolated down to 5 km for distances above 5 km. The results are listed in Table 4 for an ERMES antenna height of 75 metres, and in Table 5 for an ERMES antenna height of 300 metres.

4. LABORATORY AND FIELD STUDIES

4.1 Influence of the Television Receiver Design

4.1.1 As stated in section 3 of this paper, there are two ways by which the interference to the sound occurs: by intermodulation and by breakthrough at the sound image frequencies. Which phenomenon is the most important depends on the input signal level and the receiver design.

4.1.2 Important is the selectivity of the receiver at the ERMES frequencies, when tuned to channel E-5. Since the ERMES frequencies are relatively close to the received frequency, not much selectivity is provided by the channel selector. The main selectivity is within the IF part of the receiver. This selectivity can only improve the breakthrough behaviour, which is dominant at input signal levels which are not too high.

The IF selectivity depends on the concept of the receiver front-end. Three main concepts are used:

i) Receivers for FM mono sound, in most cases, make use of the **inter-carrier** principle;

ii) Receivers for stereo sound (NICAM or analogue FM), in most cases, make use of the **Quasi Split Sound** (QSS) principle;

iii) Receivers for the L-SECAM standard (AM sound) make use of the **Split Sound** (SS) principle.

4.1.3 In the QSS and SS receiver a separate filter is used for the sound channel and this provides greater selectivity and rejection at the ERMES frequencies, reducing the disturbance in the sound channel. It can be said that receivers in the lower price range are built according to the inter-carrier principle. The difference in the performance in the presence of ERMES interfering frequencies can be up to 20 dB.

4.2 Measurement Results

4.2.1 Laboratory measurements on a limited sample of typical television receivers have been conducted in a number of CEPT countries. In this report the results of these measurements have been summarised in terms of protection ratios (C/I) in dB's. As the receivers were measured at different input signal levels, the worst case result has been taken, and the range of these results for all the television receivers measured, is given in Table 6.

4.2.2 The measurement criteria used by different laboratories were not identical, but in general the interference level was adjusted for a noticeable degradation of the sound or picture performance.

4.2.3 In the case of picture disturbances, generally speaking, all ERMES channels have the same influence.

For sound disturbances the situation is as follows:

i) for NICAM receivers ERMES channels 1 - 10 are most disturbing;

ii) for receivers with analogue sound, ERMES channels 4, 5 and 14 (and in some cases 13 and 15) are the most critical;

iii) for L-SECAM (AM sound) receivers, measurements are currently being conducted in France. These measurements could confirm that ERMES channels 3,4 and 5 are the most critical.

4.3 Field Measurement Results

4.3.1 The preliminary results of field trials conducted in Germany showed more optimistic results than those from the theoretical work and laboratory measurements contained in this report.

5. OBSERVATIONS

5.1 The use of existing TV receivers and channel 5 are **unavoidable**.

5.2 Not all countries use the same frequencies for the sound sub-carriers, and therefore the ERMES channels to be avoided may be **different** for neighbouring countries.

5.3 The use of the ERMES channels **adjacent** to that which falls directly on the image of the TV sound sub-carriers could also result in interference.

5.4 The tests on a limited sample of TV receivers shows the that the receivers employing the inter-carrier system were considerably more susceptible to sound interference than those employing the quasi-split sound system.

5.5 TV broadcasting uses frequency offsets to reduce co-channel interference. The particular offset used could affect the **magnitude** of the interference from a particular ERMES channel.

In order to improve the protection ratio between TV co-channel transmitters frequency offsets of the sound and vision carriers are determined during the planning phase. Frequency offsets in steps of 15625/12 Hz are implemented (1/12 of the line frequency). Offset steps toward higher frequencies are designated with a 'P' and toward lower frequencies with an 'M' i.e. 4P, 8M.

A maximum protection ratio between two transmitters is achieved with a frequency offset of 6 ± n* 12 (where n is an integer) steps. If the interference between three or more transmitters is to be reduced, an offset of 4 or 8 ± n* 12 (where n is an integer) steps are considered to be desirable. Depending on the choice of frequency offsets the level of "tolerable interference" between the TV transmitters using channel E-5 can be improved by as much as 19 dB.

Any interference problems which arise with the introduction of ERMES are mainly due to ERMES channels 4 and 14 (interference to analogue sound), and ERMES channels 1 to 10 (interference to NICAM). In view of the frequency offsets normally used by TV transmitters, interference problems may also be caused by ERMES channels 3, 5, 11, 13 and 15.

6. CONCLUSIONS

6.1 It is clear, both from past experiences and test results, that there will be some cases of interference from ERMES transmitters to the reception of TV channel E-5. The interference can affect both the sound and the picture. Interference distances can be expected to range from at least 100 metres up to several kilometres, depending on the received signal level, the relative positions of the antennas, polarisation and local terrain.

6.2 Critical Frequencies

In the case of picture disturbances, generally speaking, all ERMES channels have the same influence.
For **sound disturbances**, the ERMES channels identified as being particularly problematic are shown in table 7.

6.3 Frequency Offsets used by TV Broadcasting

Interference between ERMES and TV broadcasting on channel E-5 can be minimised by shifting the frequency offset of the TV transmitter. Such shifts must be in steps equal to the line frequency (15625 Hz) to maintain the mutual protection between co-channel TV transmitters. When shifting three times the line frequency or less, no action has to be taken on the receiver side. When shifting more than three times the line frequency, cable head-ends might need readjustment.

6.4 Choice of ERMES Transmitter Locations (based on existing TV transmitter locations)

If the ERMES and TV transmitters can be co-located, all of the ERMES channels can be used. However, this assumes that the ERMES e.r.p. in all directions is lower than the TV transmitter e.r.p. by more than the required protection ratio (this difference can be less in the case of orthogonal polarisation).
If this requirement can be met, the interference potential of a particular ERMES transmitter can be minimised by choosing the same, or near locations, for the ERMES transmitter as the TV broadcasting E-5 transmitter.

6.5 Choice of ERMES Transmitter Locations (based on existing TV receiver locations)

ERMES transmitters emitting signals which may cause interference, should be located at a maximum distance from TV receiving antennas. The distance should not be less than 100 metres in the case of orthogonal polarisation, and greater in most cases, especially if the ERMES transmitter is located at the edge of the coverage area of an E-5 transmitter. Such a mode of procedure will generally ensure that the ERMES signal will be lower than the TV signal by more than the required protection ratio at the input of the TV receiver. If the same type of polarisation is used, a greater separation distance should be chosen.
If this requirement cannot be met for practical reasons, the protection ratio can be improved by inserting a narrow band-elimination filter capable of being tuned to the ERMES frequencies in front of the input of the active electronic components of the TV receiving installation. If this solution should be adopted, appropriate arrangements should be made regarding the installation and financing of these filters.

6.6 TV Receiver Performance

The present interference problems are essentially due to the inability of many existing television receivers, to adequately reject unwanted signals in their adjacent channel.

The measurements, conducted on typical receivers, identified an extremely large spread in the adjacent channel rejection performance of television receivers.

All of the receivers tested however, complied with current European standards.

7. RECOMMENDATIONS

7.1 The use of ERMES channels that are within 25 kHz of a frequency spacing from the E-5 vision carrier that is equal to the frequency spacing between the E-5 vision carrier and either of the E-5 sound carriers, should be avoided where possible.

7.2 The power of the ERMES signal in areas where TV channel E-5 is in common use should be minimised where possible.

7.3 Orthogonal polarisations should be used where possible (**both** polarisations are used for TV broadcasting in many countries).

7.4 Care should be exercised in the siting of ERMES transmitters.

7.5 The installation of in-line filters when necessary, in front of the active components of the TV receiving installation, will improve compatibility. If this recommendation should be adopted, appropriate arrangements should be made regarding the financing of supply and installation of these filters.

7.6 Interference between ERMES and TV broadcasting on channel E-5 can be minimised by shifting the frequency offset of the TV transmitter. Such shifts must be in steps equal to the line frequency (15625 Hz) to maintain the mutual protection between co-channel TV transmitters.

7.7 Discussions should take place between the administrations and both ERMES and TV operators to make everyone aware of the problem and enable the ERMES operators to take into account in the planning of their networks.

7.8 Further field trials should be undertaken to quantify the magnitude of the ERMES to TV channel E-5 interference problem. This is due to a number of factors including the large spread in television receiver adjacent channel rejection performance identified, and the uncertainty regarding the relative number of receivers with good and poor rejection in actual use.

TABLE 1.

FREE SPACE, CO-POLAR, SEPARATION DISTANCES (FOR 100 W ERMES ERP)			
Wanted Signal Level (dBµV)	Protection Ratio (dB)	Separation Distance (metres)	
		Same Direction	Angular Separation >60°
80	-18 to -5	500 to 2200	130 to 550
70	-25 to -5	700 to 7000	180 to 1800
60	-28 to -10	1600 to 12000	400 to 3000

TABLE 2.

FREE SPACE, CROSS POLAR, SEPARATION DISTANCES (FOR 100 W ERMES ERP)		
Wanted Signal Level (dBµV)	Protection Ratio (dB)	Separation Distance (metres)
80	-18 to -5	160 to 700
70	-25 to -5	220 to 2200
60	-28 to -10	500 to 3900

TABLE 3.

FREE SPACE, FRINGE AREA, SEPARATION DISTANCES (FOR 100 W ERMES ERP)		
Wanted Signal Level 50 dBµV (55 dBµV/m)	Protection Ratio (dB)	Separation Distance (metres)
Co-polar, same direction	-28 to -10	5000 to 39000
Co-polar, angle separation	-28 to -10	1200 to 10000
Cross-polar, same direction	-28 to -10	1600 to 12000

TABLE 4.

FRINGE AREA SEPARATION DISTANCES (FOR 100 W ERMES ERP) Extrapolated from CCIR Rec. 370-5, $h_{eff\ ERMES}$ = 75 m		
Wanted Signal Level 50 dBµV (55 dBµV/m)	Protection Ratio (dB)	Separation Distance (metres)
Co-polar, same direction	-28 to -10	5000 to 8000
Co-polar, angle separation	-28 to -10	1200 to 8000
Cross-polar, same direction	-28 to -10	1600 to 5500

TABLE 5.

FRINGE AREA SEPARATION DISTANCES (FOR 100 W ERMES ERP) Extrapolated from CCIR Rec. 370-5, $h_{eff\ ERMES}$ = 300 m		
Wanted Signal Level 50 dBµV (55 dBµV/m)	Protection Ratio (dB)	Separation Distance (metres)
Co-polar, same direction	-28 to -10	5000 to 16000
Co-polar, angle separation	-28 to -10	1200 to 8000
Cross-polar, same direction	-28 to -10	1600 to 9000

TABLE 6.

SUMMARY OF MEASUREMENT RESULTS Range of WORST CASE Protection Ratios For Just Noticeable Performance Degradation		
Protection Ratios for Worst Case Wanted Signal Level	Sound Protection Ratio (dB)	Picture Protection Ratio (dB)
NICAM receivers	-6 to -19 dB	-5 to -26 dB
Stereo receivers (quasi split sound)	-10 to -20 dB	-20 to -40 dB
Mono receivers (inter-carrier)	+8 to -10 dB	-20 to -40 dB
VCR	-20 to -30 dB	-30 dB

TABLE 7.

ERMES CHANNELS AFFECTING TV SOUND RECEPTION				
ERMES Channel	ERMES Frequency	**Critical Frequencies**		
		NICAM	ANALOGUE SOUND	L-SECAM
1	169.425	✓		
2	169.450	✓		
3	169.475	✓	✓	✓
4	169.500	✓	✓	✓
5	169.525	✓	✓	✓
6	169.550	✓		
7	169.575	✓		
8	169.600	✓		
9	169.625	✓		
10	169.650	✓		
11	169.675	✓		
12	169.700			
13	169.725		✓	
14	169.750		✓	
15	169.775		✓	
16	169.800			

Note: The actual ERMES channel causing maximum interference, may differ from area to area as a result of the particular frequency offset employed at the local TV broadcast transmitter in that area.