European Radiocommunications Committee (ERC)
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COMPATIBILITY BETWEEN ERMES AND PMR SYSTEMS

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SUMMARY

Several papers detailing the results of practical measurements have been considered, all of these indicate that a significant and complex compatibility problem exists.

In summary the practical and theoretical studies confirmed the following problem areas:

i) Significant interference between ERMES and PMR base station receivers caused by adjacent channel interference, spurious emissions and blocking;

ii) Isolation of up to 90 dB may be required between adjacent systems in densely populated areas;

iii) Cost will be incurred by both PMR and ERMES operators;

iv) Good site engineering practice will be required at all sites where ERMES and PMR base stations are co-sited.

1. INTRODUCTION

This paper examines the potential compatibility problems between ERMES (European Radio Message System), and PMR systems operating around 170 MHz. As a result of both theoretical work, based on ETSI specifications, and practical work carried out under laboratory controlled conditions, the isolation requirements for different interference mechanisms were determined. These were expressed in dB's and translated into separation distances using appropriate propagation models.

2. BACKGROUND

ERMES is the Pan European Paging System and as such will be implemented across Europe. It is understood however that the implementation is likely to be different in various member states.

Radiocommunications systems operating in adjacent bands may adversely effect each other due to the presence of a number of potential interference mechanisms e.g. receiver blocking, receiver spurious responses, transmitter spurious emissions or the generation of intermodulation products within the transmitter or receiver.

Concerns have been expressed regarding the actual performance of PMR equipments, however laboratory tests have shown that they were well within specification. It has also been noted that there is a band of frequencies from the second adjacent channel to 1 MHz from the wanted channel where PMR receiver performance is undefined, limited testing however has revealed that extrapolation would appear to be appropriate. It is felt however that the **actual** performance should be specified.

The minimum isolation required between ERMES and PMR systems, for correct operation, can be calculated from knowledge of the equipments performance (obtained from the systems specifications, or actual tests carried out on equipments), and the transmitter power, receiver sensitivity and antenna gains etc.

This minimum isolation can then be translated into an interference distance through the application of an appropriate propagation model for different interference scenarios. This will yield a number of interference distances relating to the different interference mechanisms, frequency separations, transmitter powers and receiver sensitivities etc.

The interference distances for different scenarios may range from metres to kilometres, although some scenarios will of course be more likely to occur than others.

The interference scenarios considered as being significant are as shown below in order of perceived importance:

i) ERMES base station to PMR base station;
ii) ERMES base station to PMR mobile station;
iii) PMR base station (50 m) to ERMES mobile station;
iv) PMR base station (30m) to ERMES mobile station;
v) PMR mobile station to ERMES mobile station;
vi) ERMES base station to ERMES mobile station.

The probability of interference occurring within each scenario has not been addressed.

3. STUDY AND RESULTS

The theoretical field strength produced by the transmitter is:

$$E = ERP + 20\log f + 79.36,$$

where E is the field strength in dBμV/m,
ERP is the effective radiated power in dBm
f is the frequency in MHz.

At the frequency 169.5 MHz, the results would then be as shown below:

ERMES base station [dBµV/m]	178 (250)	174 (100)	168 (25)
PMR base station [dBµV/m]	171 (50)	164 (10)	
PMR mobile station [dBµV/m]	168 (25)	154 (1)	

Note : figures in round brackets are system ERP in Watts.

System parameters with derived values are shown below:

	ERMES[1)]	PMR[2)]
Receiver sensitivity (dBµV/m)	25	20
Minimum fs to be protected (dBµV/m)	54[4)]	20
Co-channel protection (dB)	10	8
Max allowed Co-channel interference fs (dBµV/m)	[44]	[12]
Adjacent channel power (dBc)	-70	-70
" " selectivity (dB)	60	70
Spurious response rejection (dB)	[51]	70
Spurious response immunity (dBµV/m)	76[5)]	[90]
Blocking ratio (dB)	[59]	84
Blocking threshold (dBµV/m)	84[5)]	[104]
EIRP of spurious emission (µW)	0.25	0.25
Spurious emissions fs (dBµV/m) (169.5 MHz)	[86]	[86]

1) The ERMES parameters are taken from ETS 300 133.
2) The PMR parameters are taken from ETS 300 086.
3) Values within square brackets are derived from the ETS parameters.
4) This is the field strength outdoors. The margin above the receiver sensitivity is necessary to ensure good reception indoors.
5) These values are assumed to be measured with the wanted signal level at the receiver sensitivity (25 dB µV/m). When the wanted signal level is 54 dBµV/m the spurious response immunity is assumed to be 54 + 51 = 105 dBµV/m and the blocking threshold 54 + 59 = 113 dBµV/m.

In all of the following isolation calculations, the receiver antenna gain is assumed to be 0 dBi

Isolation due to Adjacent Channel

The required isolation between ERMES and PMR when they are operated in adjacent channels is determined by the greatest of two values:

i) the required isolation due to the adjacent channel power of the transmitter and,
ii) the required isolation due to the adjacent channel selectivity of the receiver.

These values are shown below:

ERMES TRANSMITTER - PMR RECEIVER

	(250W)	(100W)	(25W)
i) (dB)	96	92	86
ii) (dB)	88	84	78

PMR TRANSMITTER - ERMES RECEIVER

	(50W)	(25W)	(10W)	(1W)
i) (dB)	57	54	50	40
ii) (dB)	57	54	50	40

ERMES TRANSMITTER - ERMES RECEIVER

	(250W)	(100W)	(25W)
i) (dB)	64	60	54
ii) (dB)	64	60	54

Isolation due to Spurious Responses

The spurious response immunity applies to any frequency at which a response is obtained. The required isolation due to spurious responses is calculated as the difference between the radiated field strength and the spurious response immunity and is given below.

ERMES TRANSMITTER - PMR RECEIVER

	(250W)	(100W)	(25W)
(dB)	88	84	78

PMR TRANSMITTER - ERMES RECEIVER

	(50W)	(25W)	(10W)	(1W)
(dB)	66	63	59	49

ERMES TRANSMITTER - ERMES RECEIVER

	(250W)	(100W)	(25W)
(dB)	73	69	63

Isolation due to Blocking

The blocking specifications apply for frequency separations between 1 and 10 MHz. The required isolation due to blocking is calculated as the difference between the radiated field strength and the blocking threshold. The values are shown below.

ERMES TRANSMITTER - PMR RECEIVER

	(250W)	(100W)	(25W)
(dB)	74	70	64

PMR TRANSMITTER - ERMES RECEIVER

	(50W)	(25W)	(10W)	(1W)
(dB)	58	55	51	41

ERMES TRANSMITTER - ERMES RECEIVER

	(250W)	(100W)	(25W)
(dB)	65	61	55

Isolation due to Spurious Emissions

The required isolation due to spurious emissions is calculated as the difference between the field strength of a spurious emission and the maximum allowed co-channel interference power. The values are shown below.

Transmitters	ERMES	PMR	ERMES
Receivers	PMR	ERMES	ERMES
(dB)	74	42	42

Isolation due to Intermodulation

As a result of a separate study it is evident that there is a potential compatibility problem between ERMES and PMR in high band as a result of intermodulation products. This stems from the high transmit power of the ERMES equipment and its proximity to the PMR equipment. If ERMES transmissions are able to mix with PMR base transmissions, there is the possibility of intermodulation products falling in the base receive band. These products could be at a level sufficient to cause interference to PMR services.

Propagation Models

Interference from an ERMES base station to a PMR base station.

> In this case the free space formula is used. It is recognised that this model probably will underestimate the propagation loss for long distances (> 5 - 10 km), but since the acceptable distances are much shorter than that the model can still be used.

Interference from an ERMES/PMR base station to a PMR/ERMES mobile station.

> In these cases the HATA model is used when this gives a greater propagation loss than free space propagation. For other (shorter) distances the free space model is used.

Interference from a PMR mobile station to an ERMES mobile station.

> For propagation between two mobiles the free space formula is used for distances up to 15 meters, and the plane earth model is used for greater distances. For urban areas, the same model with an additional attenuation B = 9 dB due to urban clutter is used.

Separation distances

Separation distances, in metres, are given overleaf. These are the distances that would be required to achieve the desired isolation <u>in the absence of any additional measures such as filtering</u>.

ERMES BASE to PMR BASE

	(250)	(100)	(25)
Adjacent channel	8913	5623	2818
Spurious responses	3548	2239	1122
Blocking	708	447	224
Spurious emissions	708	708	708

ERMES BASE to PMR MOBILE

	(250)			(100)			(25)		
	U	S	O	U	S	O	U	S	O
Adjacent channel	564	885	2855	430	634	2174	286	448	1445
Spurious responses	327	513	1656	249	391	1261	166	260	838
Blocking	126	198	638	96	150	447	64	100	224
Spurious emissions	126	198	638	126	198	638	126	198	638

PMR BASE (50m) to ERMES MOBILE

	(50)			(10)		
	U	S	O	U	S	O
Adjacent channel	40	62	100	25	39	45
Spurious responses	73	115	282	45	71	126
Blocking	42	66	112	26	41	50
Spurious emissions	14	18	18	14	18	18

PMR BASE (30m) to ERMES MOBILE

	(50)			(10)		
	U	S	O	U	S	O
Adjacent channel	37	57	100	23	36	45
Spurious responses	66	103	282	42	65	126
Blocking	39	61	112	25	38	50
Spurious emissions	14	18	18	14	18	18

PMR MOBILE to ERMES MOBILE

	(25)		(1)	
	B=9	B=0	B=9	B=0
Adjacent channel	20	33	5	14
Spurious responses	33	56	14	25
Blocking	21	35	6	16
Spurious emissions	6	17	6	17

ERMES BASE to ERMES MOBILE

	(250)			(100)			(25)		
	U	S	O	U	S	O	U	S	O
Adjacent channel	64	100	224	49	76	141	32	51	71
Spurious responses	118	185	596	90	141	400	60	93	200
Blocking	68	107	251	52	82	158	35	54	79
Spurious emissions	14	18	18	14	18	18	14	18	18

U = urban area S = suburban area O = open area.

4. PRACTICAL TESTS

PMR Receivers

The measured performance of the PMR receivers with regard to sensitivity, adjacent channel and blocking was better than the specification required.

Comparison of the unwanted signal levels required to produce identical reductions in SINAD in the laboratory showed that, apart from the adjacent channel, there was negligible difference between the degradation caused by a PMR, or an ERMES, interferer.

The close-in unwanted signal rejection performance of the two PMR receivers tested was quite different. One rejected unwanted (PMR) signals 25 kHz away as effectively as it did those 1 MHz away, the second receiver achieved this level of rejection when the unwanted (PMR) signals were in excess of 100 kHz away.

Comparing the results of the laboratory tests conducted using a simulated ERMES signal, and those obtained in the field using an operational NEC PB-510V ERMES transmitter, indicates that broadband noise from an ERMES transmitter falling in the wanted channel will be the dominant interference mechanism with the better PMR receivers.
It should be noted however, that the broadband noise from the ERMES transmitter was not excessive and that similar, or higher, (relative) levels of broadband noise may be emitted from PMR transmitters.

Apart from identifying the need to consider the effects of broadband transmitter noise, the results of the practical tests support the theoretical calculations contained in this document.

ERMES Transmitter

Measurements were conducted on a pre production ERMES transmitter under laboratory conditions. The adjacent channel power was found to be better than that specified and furthermore the broadband noise was lower than that anticipated (typically -90 dBc in a 12½ kHz bandwidth).

5. OBSERVATIONS

The calculated separation distances, necessary for ERMES transmitters to operate in the adjacent channel to a PMR base station receiver, without causing interference is several kilometres.

Even with frequency separations in excess of 1 MHz, receiver blocking (ERMES and PMR) may cause compatibility problems at distances of several hundred metres.

Both PMR and ERMES specifications have an area, from the second adjacent channel to 1 MHz from the wanted channel, where the receiver performance is undefined.
Actual performance in this area will be of crucial importance to the magnitude of the compatibility problem.

The magnitude of the compatibility problem is likely to be greatest where the PMR base station sites are concentrated (where market demand is greatest).
i.e. cities, main conurbations and transport centres.

The measures necessary to provide solutions to the compatibility problems are expected to cause unforeseen economic costs to operators and users of the PMR and ERMES services.

The most significant compatibility problem is that of the ERMES transmitter affecting PMR base station receivers. Other interference scenarios may also cause compatibility problems, but to a lesser extent.

To avoid worsening interference problems good site engineering practice at least to the level of MPT 1331 (UK) or ETR 58 will be required at all sites where ERMES and PMR base stations are co-sited.

6. CONCLUSIONS

In many countries the ERMES channels are surrounded by PMR channels with base stations for both systems co-sited in urban areas. This work confirms that if ERMES is introduced without adequate precautions, a significant interference problem will exist.

A number of techniques have been suggested to improve the situation, and all of these techniques will be required at some sites. The solutions will be costly in many cases, and the mix of solutions will need to take into account the economics of both PMR and ERMES.

Various options to improve the situation are listed below in no particular order:

Ensuring adequate (spatial / vertical) separation.

Providing frequency separation.

Provide filtering.

Controlling power levels.

Tightening the specification(s).

None of the above options should be considered in isolation.

Notes:

Provide filtering.
Cavity filters (specifically Q-Circuit stop/pass) can be used to overcome interference problems in communications systems and their use is well proven. The cavity filter provides sufficient isolation (35-50 dB) only if the frequency separation is greater than 150 kHz. Below this figure the physical size and insertion loss severely limit their use. It should also be noted that these are generally narrow band devices, and that a broad band device capable of rejecting the entire ERMES band might be prohibitively large, costly and exhibit unacceptable insertion loss.
Cavity filters are only practical at base station sites. Simple band pass filters will generally only provide sufficient isolation if the frequency separation is in excess of 2 MHz.

Controlling power levels.
Excessive power limitation may prove counter productive however, for although it would reduce the size, it would also increase the number, of the affected areas.

Tightening the specification(s).

Further work would be necessary, in order to quantify the available scope for improvement on the various parameters within the specification.