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FEDERAL COMMUNICATIONS COMMISSION
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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Replacement of Part 90 by	)	
Part 88 to Revise the Private	)	PR Docket 92-235
Land Mobile Radio Services	)	
and Modify the Policies	)	
Governing Them	)	

COMMENTS OF SECURICOR PMR SYSTEMS LTD.

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ITS COUNSEL

May 28, 1993

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COMMENTS OF SECURICOR PMR SYSTEMS LTD.

Securicor PMR Systems Ltd. ("Securicor PMR"), by its counsel, hereby submits its Comments on the Notice of Proposed Rule Making ("NPRM") in the above-captioned proceeding.[1] By the NPRM, the Commission has proposed to replace Part 90 of its Rules governing the Private Land Mobile Radio Services with new Part 88, and to implement policies promoting the "refarming" of the PLMR bands below 512 MHz to increase the efficiency of usage of those bands.

Securicor PMR's parent company, Securicor Group plc ("Securicor Group"), provides security services, parcel delivery services, communications services and business services throughout the United Kingdom and, increasingly, in Europe and other world markets. Among Securicor Group's communications businesses, Securicor Communications Ltd. is a partner (with British Telecommunications plc) in Cellnet which serves a large and growing cellular

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[1]Replacement of Part 90 by Part 88 to Revise the Private Land Mobile Radio Services and Modify the Policies Governing Them, 7 FCC Rcd. 8105 (1992).

customer base throughout the U.K. Securicor Telecoms supplies office based telephone key systems and PBXs. Securicor Datatrak provides advanced fleet management and vehicle location systems, and has recently brought to market a fully integrated command and information system.

Securicor PMR provides and operates trunked private mobile radio systems throughout the U.K. Securicor PMR for many years has fulfilled the internal land mobile communications needs of Securicor Group's large parcel delivery, cash-in-transit, security service and other fleets. In this capacity, Securicor PMR has been an active proponent of the development of emerging spectrally-efficient very narrowband ("VNBR") land mobile technologies and a frequent participant in matters before the Radiocommunications Agency ("RA") of the U.K.'s Department of Trade and Industry ("DTI") looking toward the establishment of standards and rules to govern the migration of U.K. PMR systems from their existing 12.5 kHz channelization to VNBR 5 kHz channelization.

Securicor PMR's affiliated company Linear Mobile Technology Ltd., indeed, has developed for commercial deployment the Linear Modulation, or "LM," 5 kHz PMR system that was described by Peter Hilton, Managing Director of Securicor PMR, during the FCC's May 6, 1993 roundtable discussion on the refarming initiative. A copy of the paper presented by Peter Hilton at the roundtable is attached to these Comments as Appendix 1. Briefly, the Securicor LM system uses the very latest techniques to give superior voice quality together with, currently, 9.6kb/s high speed data in a 5 kHz channel. The LM system meets the MPT 1376 U.K. specification for 5 kHz channelization. A post draft, pre-publication copy of that specification, which the DTI has authorized Securicor to provide the FCC, is attached as Appendix 2 to these Comments.[2]

The technology developed by Securicor PMR, from the original research by Bath and Bristol Universities in the U.K. has realized a performance that is considerably better than current 12.5 kHz FM systems and equals or betters current 25 kHz FM systems for voice quality. Securicor PMR's confidence in the capabilities of its 5 kHz LM technology is best evidenced by its intentions to employ that technology to fulfill Securicor Group's own fleet communications and dispatch needs in its core businesses. Copies of two DTI Reports analyzing the capabilities of 5 kHz technology, and confirming Securicor PMR's confidence in its LM technology, are attached hereto as Appendices 3 and 4.

Appendix 3 contains a September 1992 Report prepared by the Kenley Radio Technology Laboratory on a "Linear Modulation Co-Channel Compatibility Study" (the "Kenley Report") on behalf of the RA. The Kenley Report reflects the co-channel testing of developmental 5 kHz LM equipment to establish the rules for re-farming U.K. PMR congested bands by using 5 kHz Linear Modulation. As shown therein, that Report confirms that the LM technology is

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[2]The MPT 1376 specification is expected to become final within three months. The RA is now addressing two minor objections to the MPT 1376 specification cross-referencing the European Community's specifications for low power devices and electromagnetic compatibility. Securicor PMR is confident that these minor objections will be shortly resolved by the DTI without any modification to the MPT 1376 specification, and will advise the FCC of such action as a supplement to these Comments.

integrable with current FM PLMR technologies and does not require a discrete and separate spectrum allocation to function properly.

Appendix 4 contains an August 1990 "Report On the Relative Performance of Linear Modulation (TTIB-SSB) Compared to FM and AM Modulation, With Particular Reference to Interference Performance" prepared on behalf of the RA by Bradford, England University (the "Bradford Report"). The Bradford Report reflects exhaustive tests by the University using modified (for LM-TTIB) amplitude compandored single sideband equipment. The Bradford Report concluded, among other things, that the "general opinion of the trials team on the performance of the LM-SSB equipment under test was very favourable" and that "it is felt that LM-SSB will provide an effective mechanism for relieving the spectral congestion currently experienced in the PMR system, while causing little disruption to the existing PMR infrastructure." Bradford Report at 5-1 and 5-3. Although the Bradford Report noted (at 2-39 and 5-3) certain limitations on the then state-of-the-art LM-SSB equipment under tests concerning receiver intermodulation response and voice quality, those limitations expressed were due to the type of equipment used, rather than the technology. The present state of the art of LM

- more users independently served within the same spectrum;
- reduced transmitter average power for same range;
- increased handheld battery life by 2 to 4 times;
- further reduction in co-channel interference by the use of low input power, active Linear Power Amplifiers to combine many MHz of channels on the same site;
- full adjacent 5 kHz channel on-site capability giving more efficient use of channels; and
- lower noise floor due to improved (over FM) adjacent channel performance.

Securicor's principal purpose in submitting these Comments is to provide for the record in this docket the attached Appendices and to clarify its belief that 5 kHz VNBR LM technology has been proven in the U.K.[3] Securicor commends the FCC for its leadership in promoting the introduction of VNBR technology both in the 220 MHz band and in this proceeding looking to refarm the U.S. Private Land Mobile Radio Bands below 512 MHz. Securicor is quite confident that the FCC will receive a full airing of the many issues encompassed in this docket from all segments of the U.S. PLMR community, and will therefore limit the balance of these brief Comments solely to its belief that the expeditious introduction of 5 kHz VNBR technologies in the U.S. will serve to promote the

[3] As manifested by the FCC's May 6, 1993 Refarming Roundtable, Securicor, of course, is not alone in its development of 5 kHz VNBR technology. The SEA and II-Morrow 5 kHz systems have already been type accepted with more in the pipeline.

interests of the private land mobile communications users both in the U.S. and worldwide.

Indeed, indications from current and potential users of PLMR services suggest they want 5 kHz VNBR today. This is for a number of reasons:

- more communications channels which could be trunked for even greater efficiency;
- high data rates, currently 9.6kb/s, with minimal error correction needed, because of its highly linear circuitry, making pictorial/graphical transmissions a reality;
- high quality voice with excellent recognizability;
- lower sensitivity to impulse noise; and
- backward compatibility for efficient migration route from current technology.

Given the progress of 5 kHz technology in the U.K., the rapid introduction of similar technology in the U.S. PLMR bands would facilitate international equipment compatibility and enhance the exportability of U.S. and U.K. equipment vendors alike. Moreover, because the U.S. in the 220 MHz band and the U.K. with the non-frequency specific MPT 1376 specification are the world leaders in the introduction of spectrally-efficient VNBR technology, a common U.S. and U.K. specification would send a clear signal to the International Telecommunications Union and thereby facilitate the adoption and expeditious deployment of VNBR systems in other nations. In contrast, because 12.5 kHz FM technology has been available and in use in the U.K. since 1973, the adoption in this docket of a 12.5 kHz specification would wed the U.S. PLMR community to outdated technology and impede the exportability of U.S. PLMR equipment. Securicor believes that the future world land mobile markets will require the most current technology, especially those markets in the most highly-industrialized nations.

For these reasons, Securicor encourages the FCC to fully embrace the opportunity presented by its proposal to refarm the PLMR bands below 512 MHz. We commend the U.K's. MPT 1376 specification to the FCC for all 5 kHz channels. Its acceptance would enable a thoroughly reviewed specification to be introduced at an early date with the opportunity of creating a world acceptable specification with all the benefits of exportable technology. A flexible approach allowing 5 kHz VNBR systems to be introduced in the PLMR bands as quickly as users demand while providing reduced interference protection to existing users over an agreed transition period appears to be a proven methodology for the introduction of new technologies.

In short, 5 kHz VNBR is here NOW. The technology has been field demonstrated, independently tested and, indeed, type accepted. To limit change to 12.5 kHz now simply will deny the U.S. PLMR community the benefits of both emerging technologies and as yet undeveloped ones.

Securicor would like to express its appreciation for the opportunity to participate in the FCC's Refarming Roundtable and to submit these Comments. We offer to make our facilities available for any further information the Commission may require.

Respectfully submitted,

SECURICOR PMR SYSTEMS LTD.

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May 28, 1993

Appendix 1

Future Private Mobile Radio Services - A Review of Options

Peter R. Hilton
Managing Director
Securicor PMR Systems Limited

April 29, 1993

Future Private Mobile Radio Services - A Review of Options

1.0 Introduction

The increasing congestion of the electromagnetic spectrum in the frequency range used for radio communication has been a matter of widespread concern for many years[1]. The particular concern of the FCC in relation to the potentially serious impact of congestion of those parts of the UHF and VHF spectrum used for the PMR service in the USA has been summarised in paragraphs 1 and 2 of the Introduction to the FCC "Notice of Proposed Rule Making" released November 6, 1992. A requirement for the phased introduction of new, spectrum efficient, standards is clearly identified in the Notice, and this paper aims to provide a review and comparison of the leading options open for consideration, and to provide a clear conclusion and recommendation for the preferred standard to be adopted for the PMR service.

The new standard, as a matter of practical necessity, will need to co-exist with existing PMR systems during a lengthy transition period. These systems have themselves evolved over many years, often under similar pressures to those we see today regarding the need to use the allocated spectrum more effectively. For these reasons it is useful to examine, briefly, the evolution of these systems in order to best understand the preferred approach to achieving optimum spectrum efficiency, whilst at the same time ensuring that the essential characteristics of the PMR service are retained.

Historically the service began with an air-interface consisting of analogue FM transmissions in 100 kHz exclusive channels, and commonly in the two-frequency simplex mode. Although a small minority of users chose AM, FM was the preferred mode of modulation primarily because it led to very cheap hardware. Constant amplitude Class C power amplifiers were both efficient and inexpensive to build, while simple IF limiting receivers proved economical to manufacture in quantity. Low equipment cost, rather than any superiority of characteristics, caused FM to be preferred to other systems of modulation, nevertheless in its early form FM offered technical advantages also.

In the original realisation, using 100 kHz channels with FM modulated to a deviation ratio of 8, the FM transmissions showed strong capture effect and consequently required low protection ratios, typically 2 - 4 dB. Subsequently, to counter congestion, the channels were repeatedly halved down to 25 kHz width, and in some administrations, to 12.5 kHz. With the decrease of modulation index dictated by reduction of the channel width, the technical advantage for FM has, progressively, been lost. It was for this reason that, historically, the decrease of channel width from 25 to 12.5 kHz was strenously resisted[2] and is, even yet, not universally accepted. Without a radical change of modulation scheme there is no prospect of a further channel halving, which would predictably lead to intolerable air- interface parameters when using analogue FM modulation.

One successful way of packing more users into the existing channels is through the adoption of automatic trunking, by means of which the utilisation of radio channels is kept high even though individual users may only generate traffic at irregular intervals. However although trunking gives a real and valuable gain in utilisation, and all future PMR systems will need to be compatible with suitable trunking standards and protocols, the continuing growth in radio use has meant that it has not provided more than a temporary solution to the growing problem of

As the ultimate limitations of analogue FM, even with trunking, have grown more apparent there has also been an ever-clearer realisation that the future in PMR, as in other areas of radio technology, would be with digital transmission both of data and of digitally encoded speech.

At the same time another important change has been the evolution of microelectronics, which changes the factors determining equipment cost. As a result it is no longer the case that systems more sophisticated than analogue FM must necessarily be excluded on grounds of equipment cost, size or power consumption. Consequently there is now considerable interest in new radio air-interfaces for PMR. Although a wide range of possibilities have been proposed, only two classes of system seem to be attracting significant attention just now.

One group of developments is based upon the view that to reduce the width of the present 25 kHz or 12.5 kHz channels would present difficult problems in RF engineering, and has therefore concentrated on "splitting" the present RF channels by having several distinct digital base-band channels combined, using Time Division Multiplexing, the multiplexed group then being modulated onto a single RF carrier in a more or less conventional way. TDM systems of this type have been successfully demonstrated and are just becoming commercially available. Their great merit is that they require little or no change to RF practice, however they suffer from certain disadvantages, the most obvious of which is that channels are only available in numbers that are integral multiples of the number in a TDM group. Whilst this may be unimportant to very large users, it is a critical problem for users only requiring a few channels yet not wishing to subcontract the provision of their radio services to others.

The alternative approach proposes the use of single channels of only 5 kHz width using different modulation techniques. Whilst accepting that the RF engineering problems of a further channel width reduction were considerable, proponents of this technology nevertheless found that they were capable of solution. Research on the narrow band approach began some twenty years ago (at Stanford University in the USA[3] and the University of Bath in England[4], as well as in the laboratories of the Philips organisation[5] and of Motorola, among others), and it now has a solid scientific foundation. In the early stages analogue SSB voice transmission was envisaged, but contemporary systems aim at a fully transparent channel, able to carry either an analogue or digital signal with equal facility provided only that its spectrum components lie within an appropriately defined base band.

To achieve the required stringent limits on the transmitted radio spectrum, all of these systems have in common the generation of a well-behaved signal spectrum at base-band, where powerful digital signal processing techniques are now available, and its subsequent linear translation upward in frequency to the assigned channel within the desired radio band. At the same time there is also an up translation in power level. Because of this feature of linear translation in power and frequency of a well-behaved base-band signal, radio systems of this kind are now usually referred to as Linear Modulation or LM systems. Use of the term "single sideband" to describe the current LM systems is discouraged, since it could lead to confusion with the completely different analogue SSB technique long used in the HF band for intercontinental sky-wave radio.

The principal UK centre for research in LM radio technology has for some years been the University of Bristol[6], which from 1988 has advised the Securicor Group in its development of a range of commercial LM equipment for use in 5 kHz channels in the PMR bands.

This equipment has been designed to meet MPT 1376, the UK co-existence specification for UHF and VHF PMR systems operating in 5kHz channels. It is capable of superior performance carrying either analogue voice, or digital data at rates of 9.6 kilo bits per second and beyond.

The equipment architecture provides for the introduction of a range of trunking schemes, and the same frequency is 2D. Thus the ratio of wanted to unwanted transmitter ranges is 2:1 and hence, assuming an inverse fourth power law of propagation, the ratio of the signals is 12 dB. (For this purpose, in view of the fourth power law, to a first approximation the interference from other co-channel transmitters than the most proximate may be neglected.)

It follows that for the optimal three-frequency layout to be possible the radio system adopted must require a protection ratio of 12 dB or less. In most administrations 12 dB is therefore specified (for example, in UK specification MPT 1326) as the maximum acceptable protection ratio for the analogue FM systems at present widespread in PMR service. In extensive trials, carried out independently by the Radiocommunications Agency of the UK Department of Trade and Industry, the LM system has demonstrated a consistent worst case protection ratio requirement of 10 dB for co-channel interference from a similar signal and therefore can accept a three-frequency layout pattern with a margin in hand, valuable in real systems where the terrain is not ideally flat and interference levels may be higher than the theoretical value. A three-frequency plan will, however, require 75 kHz of spectrum in the case of 25 kHz FM systems, but only 15 kHz for LM, yielding a valuable improvement in spectrum utilisation.

In the real world problems of frequency assignment are greatly complicated by the topology of the terrain to be covered and such issues as national frontiers, so that general theoretical treatments are impossible. What is evident is that optimal frequency assignments will not be achieved with protection ratios worse than 12 dB and that in those cases where the propagation of interfering signals is better than assumed in the simple flat plane model, for example because of the existence of a line of sight path, a substantially better protection ratio will be required. In this respect the LM system tested has a characteristic which can usefully be exploited. When channels are off-set by 2.5 kHz the protection ratio falls to 1 dB, so in particular cases where interference is experienced in actual systems the possibility of exploiting half-channel offset to achieve a very favourable protection ratio can greatly ease system design problems. Nothing comparable is possible with FM or FM/TDM.

To summarise, in terms of economy of spectrum use, a factor of 5 improvement in LM relative to 25 kHz FM is secured by channel width reduction alone. If the possibility of a half-channel offset is fully exploited a further improvement in protection ratio is obtained giving potentially a substantial additional improvement in spectrum utilisation.

2.2 Signal impairments and how they are countered

The land mobile environment is characterised by near-earth propagation at wavelengths short compared with many surface features such as buildings. There is almost never a line-of-sight propagation path between transmitting and receiving antennas, so that propagation is by scattering[12,13]. As a consequence the signal is highly variable and capable only of statistical description. All received phases are equiprobable and the amplitude is Rayleigh distributed about a mean power which falls as the inverse fourth power of range from the transmitter. The received signal characteristics are further complicated by the effects of doppler shifts at a mobile receiver.

Attempts to counter the amplitude variation by receiver AGC are complicated by the very fast rate of fade and the narrow coherence bandwidth[14]. However FM or FM/TDM systems, aided by the use of limiting or its equivalent in the receiver IF stages, are relatively insensitive to variations of amplitude (provided that it does not fall below the threshold), which has been seen as an advantage. The key to successful LM systems is that both the phase and amplitude variations of the received signal are substantially removed by using a transmitted pilot tone as a reference together with fast acting feed-forward signal regeneration in the receiver[15]. To secure good fade correlation between the pilot tone and the signal spectrum it is essential that the pilot be placed near the centre of the transmission band. This is achieved by breaking the base-band spectrum into two parts (upper half and lower half) in the transmitter, and then frequency translating the upper half upward by a few hundred hertz, so creating a gap in the spectrum into which the pilot may be inserted. At the receiver the pilot is extracted and used for signal regeneration, while the signal baseband spectrum is reassembled phase coherently by reversing the processing in the transmitter. A fully "transparent" transmission channel consequently results.

Field trials with analogue voice transmissions demonstrate the success of this approach. LM gives a received signal quality closely comparable to FM in high signal areas, however at the edges of the coverage area there is a divergence. Once the mean signal is low enough for it to fall below the threshold in the troughs of Rayleigh fades, the FM system is subject to annoying auditory disturbance and data loss as the receiver moves. The LM system, having no threshold, degrades more gracefully and thus for analogue voice transmission remains readable to lower SINAD ratios, and hence greater useful range, than FM. In respect of digital transmissions, LM in 5 kHz channels has already proved highly successful at data rates of 9.6 kilobits/second, in comparable transmission environments recording BER approaching one order of magnitude better than conventional FM/modem systems (which can be used only at much lower data rates). This improvement in raw error rate may be attributed to the effectiveness of the feed-forward signal regeneration. The data rate of 9.6 kb/sec means that 8 kb/sec voice codecs, now increasingly available, can readily be accommodated for digital voice transmission and voice encryption.

Ignition noise is an impairment of the land mobile radio bearer that can be significant, particularly at the lower VHF frequencies, despite the improvement in suppression of contemporary road vehicles. Because of its smaller bandwidth, less ignition noise power enters the LM receiver and the perceived effects are noticeably less intrusive. At 100 MHz an advantage over 12.5 kHz FM of 6 dB has been measured.

2.3 Transmitter issues

Whilst it is relatively easy to make radio receivers having linear response for the LM system, linear RF power amplifiers for use in LM transmitters at one time presented more of a problem. In the past to secure reasonable linearity it was necessary to operate power amplifiers in Class A, with poor power efficiency compared with the Class C amplifiers used for FM or FM/TDM. However the technology of linear RF amplifiers has made great improvements over the last decade and this problem has now been solved.

Several techniques may be employed, depending on the balance of amplifier performance and cost which is thought optimal; in particular the required fractional bandwidth of the amplifier is an important parameter in this respect. The earliest approach used feedback techniques[16], and is probably still the best (using either the polar or Cartesian loop configuration) provided that the bandwidth required is not greater than 0.25% of the centre frequency. Other techniques, although more complex, lend themselves to much wider band amplifiers, up to at least 3% of centre frequency[17]. In both cases power efficiencies of up to 65% (conversion of DC to RF) are claimed.

The transmitter mean power required for LM is less than that for FM assuming the same service range, due to the narrower bandwidth of the receiver and coherent demodulation. Theoretically the advantage should be up to 9 dB, but in practice due to a number of factors (including the pilot power and non-ideal bandwidth) a lower figure is observed, typically 6 dB. This lower power requirement has three important consequences. The first is that third order inter-modulation products are reduced by 18 dB absolute (12 dB relative to signal), which eases co-siting and receiver linearity problems. The second is that in the case of battery powered equipment reduction of transmitter power by a factor of four results in substantially reduced battery drain, and hence lengthens the interval between charges. Finally any biological or chemical hazards attributable to RF emission are significantly reduced, which may be important in some circumstances of use.

2.4 Compatibility

Because the LM system differs only in the RF bearer from older PMR technology, it is fully compatible with existing PMR systems, including trunking. Measurements of co-channel interference performance against other systems[8] have shown that the required 12 dB protection ratio is bettered against co-channel CW, FM and digital audio broadcasting (DAB). There seem to be no compatibility problems yet identified.

3.0 Comparison of Multiple Access Technologies

3.1 Introduction

Evolved radio systems for almost any service require the user to be able to access one of a

The choice for PMR is generally accepted as between TDMA and FDMA, and their relative merits will now be reviewed. The question is not new: a definitive analysis of the system aspects, published by Muilwijk[18] as early as 1973 marginally favoured FDMA although confirming that any difference was slight. However much has changed since then, particularly in the ease with which complicated hardware and software functions can be implemented.

In line telecommunications practice, FDMA gave way progressively to TDMA in the thirty years following 1950. Many from a PTT background assume that the same will happen in the radio domain, but this is a false analogy, and not only because the system requirements are different. In the period 1950-80, when TDMA grew to dominate line telecommunications thinking, time domain signal processing, using (the then new) solid state active devices, was much easier and cheaper than processing in the frequency domain, which still depended on expensive LC and crystal filters. However the evolution of digital filtering techniques in the 70s and the perfection of digital signal processing in the latter part of the 80s has progressively eliminated this once important difference in the realisation cost of the two techniques.

Present multiple access radio practice is mixed. PMR is wholly FDMA for the present, although TDMA systems have been proposed and are under consideration. A trunked narrow band (5 kHz) FDMA PMR system has been the subject of extensive trials in the UK[7] which conclusively demonstrated its practicability for PMR use. The future therefore appears wide open, and although TDMA has had strong support in Europe, FDMA is in widespread use both there and elsewhere.

Sometimes it is argued that FDMA equipments require better internal clocks than TDMA, because of the need to place equipments precisely on frequency. This is only true if the TDMA systems are allowed to synchronise the[illegible] to received transmissions; as in practice they [illegible]

3.2.3 System Considerations

Another advantage for FDMA in future PMR services relates to the ease with which the existing proven standards, which apply exclusively to this mode of access, can be carried over

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[20]It is hardly surprising that the two systems of multiple access are difficult to differentiate when the time and frequency domain descriptions in the two cases are close to being Fourier transforms of each other
[21]The same argument demolishes the case, sometimes put, for retaining analogue rather than digital transmission, on the ground that analogue equipment, particularly hand-held TRs, can be made to consume less power
[22]Polar and cartesian feedback, digital predistortion and phasing or LINC techniques
[23]The comparable property of TDMA is that the spectrum does not have to be available on a time-continuous basis (as it does for FDMA) however it is vanishingly rare for this to convey any system advantage
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Appendix 2

DEPARTMENT OF TRADE AND INDUSTRY

RADIOCOMMUNICATIONS AGENCY

MPT 1376

Co-existence Standard for Transmitters and Receivers Operating in 5 kHz Channels

March 1993

CONTENTS