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

In the Matter of:

Commission Seeks Public Comment on Spectrum Policy Task Force Report	ET Docket No. 02-135

COMMENTS OF FUTUREPACE SOLUTIONS

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January 3, 2003

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1.0 About FuturePace Solutions

Spectrum Management International Pty Limited, trading as FuturePace Solutions, is a private company that has operated since 1997. It is headquartered in Canberra, Australia. Michael Whittaker who was principally responsible for designing the Australian 500MHz, 800MHz, 1.8GHz, 3.4GHz and 28/31 GHz spectrum licensing technical frameworks, joined the company as a director in 1998. Barbara Phi, the founding director of the company, has a background in policy development analysis and evaluation.

FuturePace specializes in the certification of RF regulatory compliance for the major Australian telecommunications carriers, following the out-sourcing by the Australian regulator of much of their operational capacity as well as the liability for their certification function. FuturePace also offers an integrated and complete radiocommunications site management service including on-line management of EMR human exposure risk and site optimization.

FuturePace believes in technical openness. We find it is more efficient to deal with an informed client. Related publications are listed in Attachment A. We have contributed significantly to the UK Cave spectrum review and the Radiocommunications Agency consultation on spectrum trading. We see benefits in technical collaboration for the common good especially to ensure that necessary change does not come more quickly than its understanding. This has not always been the case in the Australian system.

While the Australian regulatory environment differs from that applying in the USA, and no country can automatically replicate another country's reforms, we feel qualified to profitably comment on those aspects of spectrum management in the USA dealing with the ubiquitous laws of physics and less qualified to comment on USA's industrial, social, political and economic topography. Michael Powell, FCC Chairman, said he is "prepared to talk to anyone" and in this we certainly qualify.

2.0 The Spectrum Policy Task Force Report

One of the Spectrum Policy Task Force Report recommendations is to maximize flexibility while retaining certainty for both exclusive and non-exclusive spectrum access.

At present, the USA situation does not easily lend itself to speedy introduction of new services but perhaps more importantly, the rights and responsibilities of licensees are not clearly defined. Lack of clear property rights reduces business activity. FuturePace believes this lack of clarity is the result of using traditional spectrum management approaches for the operation of multiple standards in the same band. In the case of a single standard the coordination procedures tend to be superficially simple because of its inherent spectrum management functions. This can lead to the belief that coordination is quite simple when operating with multiple standards. This belief is erroneous.

2.1 Operating with Multiple Standards – Mutual Competition is Not Supported by Mutual Interference Susceptibility

Equipment standards have in-built spectrum management functions, but only for a particular standard. When a regulator allows different standards to be operated in the same band, the in-built spectrum management functions do not cater for the other standards. While coordination for a single standard can be very simple, coordination for multiple standards can be quite complex. Hence, <u>flexibility requires an increase in the complexity</u> of interference management, simple coordination rules are no longer adequate.

Similarly, a single standard provides the user with in-built defined grades of service when the equipment is used in specific configurations. However, in a multiple standard environment those rights start to overlap and in a non-reciprocal manner. Hence, <u>certainty requires grades of service to be explicitly</u>

defined, it is no longer adequate to have a grade of service concealed within the workings of a standard.

Flexibility and certainty require:

- An increase in interference management complexity; and
- Explicit grades of service (acceptable levels of interference).

Because one standard never makes allowance for the spectrum requirements of another standard, those previously hidden workings of a standard must be brought within regulatory purview in order to compare the spectrum requirements of one standard against another. While the Commission has established simple emission limits and left the design of coordination rules to the TIA, the premise on which the Commission has acted might not have achieved the spectrum management outcomes sought. Until now the Commission has believed that there is an equal amount of 'give and take' in interference management and that mutual competition would allow interference to be settled in a mutually beneficial manner through industry negotiation. However, in practice, **mutual competition is not supported by mutual interference susceptibility.**

It has never been appropriate to let operators of different standards negotiate among themselves for interference management to the level the Commission has envisaged. PCS spectrum is currently managed using TIA/EIA TSB-84A (eight standards) and that document clearly explains the problems encountered by licensees. At present, interference management depends, perhaps a tad too much, on negotiation[1]. In addition, there is no benchmark for the beginnings of negotiations and the non-reciprocity of interference can leave licensees at the mercy of their competitors. FuturePace agrees with the Commission in leaving industry to do what they do best. Unfortunately, industry has not been given a frame of reference of sufficient clarity to enable efficient negotiation.

The traditional simple method of interference management seems to have come unstuck in the brave new world of multiple standards. FuturePace recommends the spectrum product be correctly packaged for sale, fully defined and consistent with its advertised use. Uncertainty discourages market place confidence and activity. Furthermore, our vision is for flexibility with certainty to be provided in a cost efficient manner.

Apart from a clear and exhaustive definition of spectrum rights and responsibilities, retaining certainty normally means also minimizing the amount of negotiation, required after license issue, for interference management, because the outcome of negotiation is often uncertain. This means that, for market based spectrum management, up-front definition of spectrum rights and responsibilities is both time, and cost, efficient.

2.2 Removing Artificial Technical Barriers to Spectrum Access

Spectrum management based on central control tends to create dependency for equipment selection. This dependency limits possibilities and stifles creativity in providing communication services. Expenditure on competition achieves better investment returns when the competition is played out in the market rather than in spectrum allocation debates at the ITU or elsewhere.

While a global market might be attractive to equipment manufacturers,:

- How many units <u>are</u> required to create economies of scale?
- How costly <u>is</u> it to provide frequency agility?
- What percentage of subscribers <u>do</u> require global roaming?
- Why <u>are</u> there dissonant remarks about spectrum harmonization now being heard in Europe?

[1] The cost of these negotiations reduces economic efficiency.

FuturePace believes the beginning of the answers to these questions lies in the removal of artificial barriers to spectrum access, especially technical barriers which assume conventional technical solutions, and provision of an essentially self-managed licensing framework for industry. The benefits of self-management are borne out of the rapid technical innovation and growth that has brought equipment to unlicensed spectrum because of relatively few regulatory impediments.

Removing artificial technical barriers means placing less emphasis on equipment standards for regulation. In saying this FuturePace in no way recommends that the Commission jettison the combined interference management functions of equipment standards and frequency channel plans. However, we do recommend transferring the concealed interference management functions of those standards to the direct visible action of license conditions, making them more tangible in the regulatory arena.

2.3 Creating a Sound Technical Foundation for Self-Management of Interference by Industry

We are mindful that one of the Commission's major tasks is to ensure that interference does not degrade the overall utility of the radiofrequency spectrum. FuturePace sees the Commission's objective being readily achieved in a more cost effective manner through the provision of a complete frame of reference that will allow industry to efficiently self-manage interference in a multiple standard environment. FuturePace proposes that the Commission restructure license conditions in a manner that shifts from the current emphasis on device characteristics to deal directly with the real objective of equipment standards and obviously, the real objective of the Commission; interference management or in general terms spectrum space management.

The one common element for the operation of all standards is spectrum space. After all, a spectrum auction is just that – an auction of spectrum rather than authorisation to operate specific equipment. There should also be a public policy objective of ensuring that the product being sold at auction is suitable for the purpose for which it is sold. There cannot be a disjunction between the auctioned spectrum product and its utility, or the rules for its use. In our view, more efficient management means taking the next logical step. Instead of representing the access rules as a list of disjointed laboratory bench test performance parameters, the access rules need to be represented coherently in terms of the spectrum space required to operate that equipment. Also, it isn't solely an equipment manufacturer issue, it's a licensee issue. The aim is to allow the licensee to access the widest possible range of equipment available, not lock the licensee, and the spectrum into today's equipment. After all, 10 years, the usual term of a spectrum license, is an eternity when compared to the present rate of change.

When a particular standard is viewed in terms of the spectrum space it consumes, rather than its laboratory bench performance, the perspective from which policy issues are developed changes, and it becomes quite easy to manage the different requirements of various standards. The Commission would then be able to manage interference by establishing a single set of access rules for any equipment in any band in any area.

To some this may seem like wishful thinking. FuturePace submits that it simply requires revised thinking. Thinking in terms of spectrum space rather than equipment characteristics.

2.3.1 Introducing the Generic Equipment Standard

The solution begins with creating a sound technical foundation by defining a ***generic equipment standard*** to provide a basis for:

- Design of fundamental license conditions that directly quantify the spectrum space requirements of the generic standard; and
- Creating a benchmark for the assessment of the spectrum space required by actual standards, which may require more or less space than the generic standard.

2.3.2 The 'Size' of Spectrum Space

Under our proposal license conditions take on a more general function of defining the 'size' of the available spectrum space, which the licensee may access and subsequently, which a licensee requires to operate their chosen equipment.

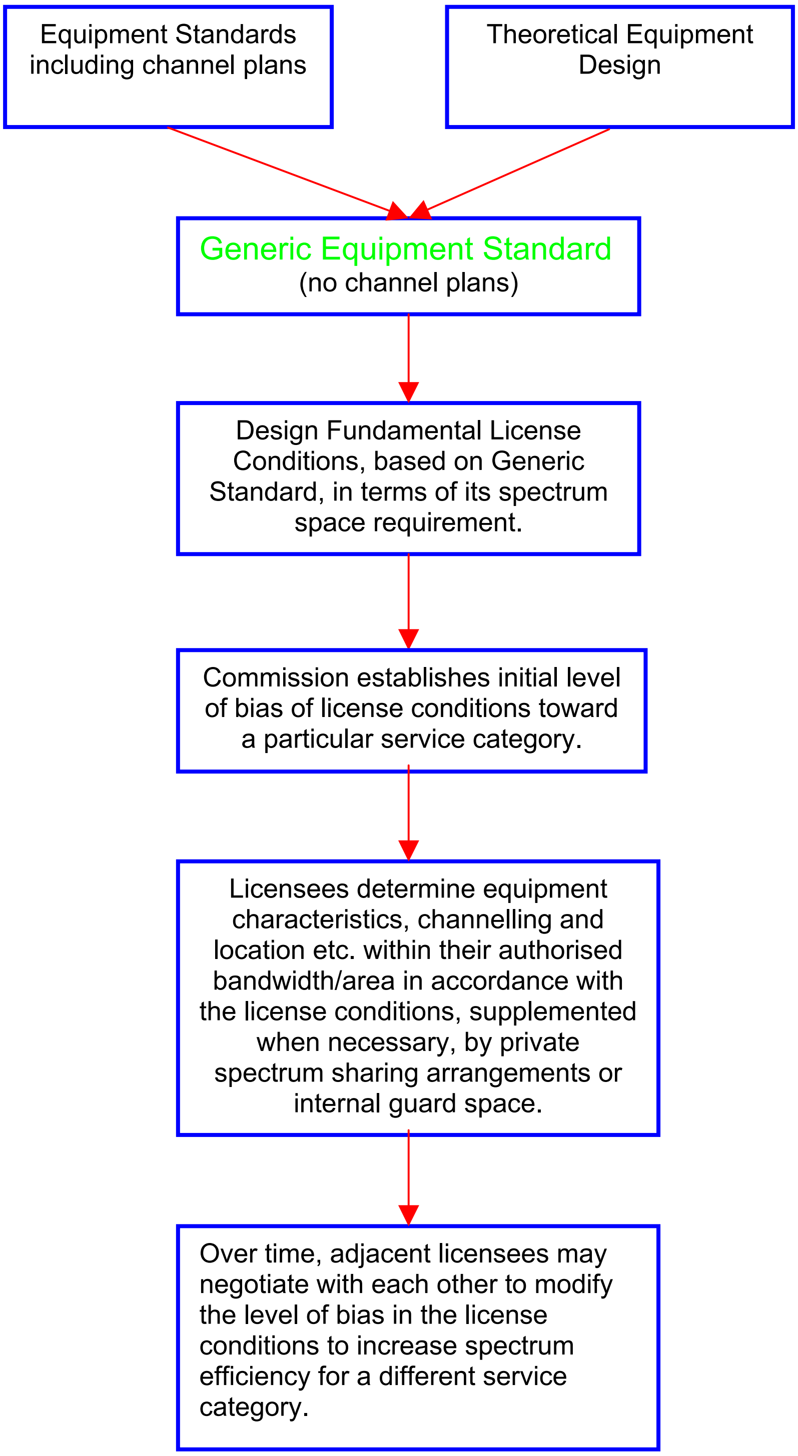
The true 'size' of spectrum space is determined by the equipment that may be operated within it. Therefore, the 'size' of a license depends as much on the associated emission limits and any coordination requirements as on the geographic area and the accompanying frequency band (for more details see reference [18]). The generic equipment standard is used to construct fundamental license conditions, which define the 'size' of the authorised spectrum space in relation to the generic standard. The fundamental license conditions take into account the level of protection from interference from outside the space and maintain the size of the authorised space essentially free of external interference for the full license term. Since interference is probabilistic, the license conditions are not exact but are designed in probabilistic terms, providing a workable solution in not all, but the majority of cases. The licensee, rather than the Commission, takes this into account in operating equipment under the conditions. This approach also reduces costs for the regulator because there is less involvement.

The generic standard does not contain prescribed channel plans. However, it certainly contains, within it, the basis for the design of channel plans by industry for actual equipment.

2.3.3 One Size Does Not Fit All - Biasing the Fundamental License Conditions

The fundamental license conditions may be biased towards a particular service category, for example, two-frequency mobile operation, in order to improve spectrum efficiency. One size does not fit all. However, this is not a permanent operational constraint because full definition of the generic standard creates a framework for both device operation outside any imposed bias as well as change of any bias at a later date through licensee negotiation (see Figure 1). In a market driven allocation environment, this flexibility allows the more important overall objective, economic efficiency, to be achieved rather than only one of its elements, spectrum efficiency.

Figure 1. Developing License Conditions that Maximize Flexibility while Retaining Certainty of Spectrum Access



While the bias may be changed, the generic equipment standard is the reference point for the full flexibility that is made potentially available immediately at the beginning of the license term. No future change to the essential nature (the reference point) of the license is required. Thus, there is a range of flexibility immediately available to industry to support the operation of new equipment and services without the long delays often caused by the micromanagement of a regulator.

Researchers are able to assess the spectrum space requirements of experimental equipment designs in relation to the generic equipment standard and then “lease” (including time-share) or purchase that space in a secondary market. (We are assuming here that the Commission will seek to encourage general spectrum trading in the secondary market). There is no need for the generic standard to be updated because its application allows for a full range of device quality. Obviously, the generic standard is initially chosen to reduce the need for negotiation for the operation of as many standards (technical options) as possible.

We understand that the solution we offer may be forward-looking and represent a significant liberalization of current spectrum management procedures. Accepting the challenge of change can be confronting for industry. However, presenting a total reform package, rather than reform by accretion, allows industry to benefit from the economies and creative potential offered by a genuinely simpler approach to management, especially when it is combined with licensing and regulatory certainty and reduced litigation and negotiation costs.

3.0 Creating Flexibility with Certainty using a Generic Equipment Standard

The generic standard may be selected with reference to existing as well as any proposed standards. It can also be designed entirely from theoretical considerations. Regardless of its basis, the single generic standard ensures that all licensee rights are clearly delineated, whatever type of equipment they operate. This minimizes disputes by providing a clear common framework. The elegance of the system is that it provides for self-management by the licensee, making it ideal for the management of rapidly evolving wireless innovations. The performance characteristics of equipment are now becoming more software based than hardware based a trend that will continue and lead to even more rapid deployment of new systems.

Because there is only one generic equipment standard it removes the non-reciprocal result that often occurs when coordinating devices using actual equipment standards (as previously discussed see TIA/EIA TSB-84A for further information). In these cases, licensees are often left wondering exactly how much spectrum space they have been authorized to access, and exactly where that spectrum space is. Under TIA/EIA TSB-84A, spectrum space is effectively, over time, shifted in a non-reciprocal manner between licensees and without effective control by the licensees.

In creating license conditions that will manage interference in a completely unstructured environment, that is, without standards and prescribed channel plans, the combined operation of channel plans and equipment standards must be simulated by license conditions. We note that during the recent NTIA spectrum summit there was disagreement on how flexibility with certainty was to be achieved. FuturePace recommends that the Commission consider the following practical implementation of a comprehensive interference management system for the ether. It is not an ether-solution in that it has been operating very successfully since 1997 supported by a web based on-line frequency authorization system from 1998.

3.1 A Practical Example of a Generic Standard and Associated License Conditions

As the Task Force noted, interference language needs to be "harmonised both in FCC rules and affected international rules". To assist in communicating our comments it is necessary for us to take a few steps back and define terms of interference management. We will endeavor to keep our comments from falling into technical jargon so that the lay reader can also access our submission. As we move through the definitions of interference we will also provide suggestions for related components of a practical generic equipment standard and their manner of application in license conditions.

It is important to see all the technical elements of our proposal as a whole, working to manage interference. No one element should be discounted without first understanding its inter-relationship within the complete management system. In addition, the practical implementation described is chosen to minimize the cost of achieving flexibility while retaining certainty. While variations on the implementation are possible they generally do not achieve cost efficiency.

4.0 Types of Interference

Broadly speaking in a licensing context, there are two main types of interference that result from two types of emissions:

- Emissions that are in-band – in-band interference; and
- Emissions that are out-of-band – out-of-band interference.

The term "band" refers to that frequency bandwidth to which a licensee has authorised access. It may be the width of a channel or the bandwidth of a spectrum license.

While broadband noise from a number of transmitters at, for example, communal radiocommunication sites can accumulate to a level where many services can be degraded (and it is obviously in the site manager's commercial interest to prevent this from happening), it is more common for interference to be caused by specific transmitters.

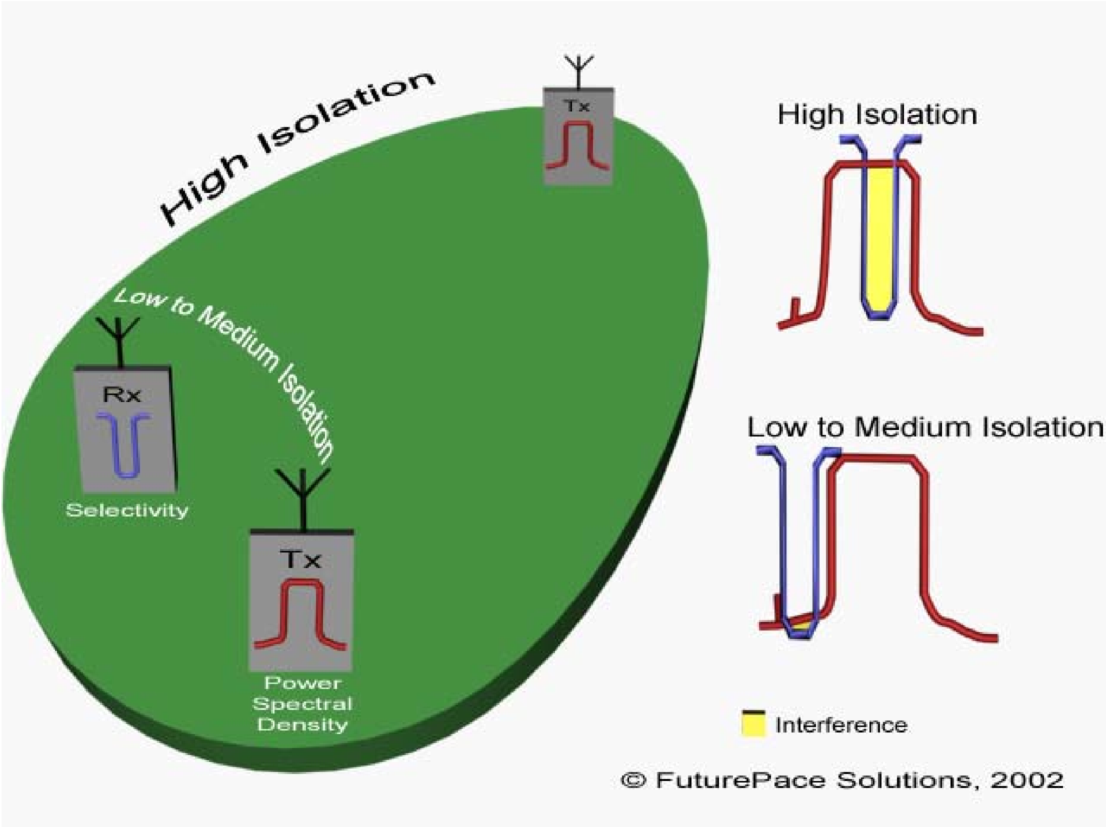
4.1 In-band Interference

In-band interference may be caused over large distances by emissions at frequencies that are within the authorised band and from transmitters that are operated in adjacent geographic areas by other authorised licensees. However, it may also be caused over short distances by the **out-of-band emissions** of frequency adjacent transmitters operated in the same geographic area (see Figure 2). Out-of-band emissions are transmitter emissions, at frequencies outside the authorised band that are superfluous to communication. It is very important to note that, in our comments, out-of-band interference is not synonymous with out-of-band emission.

Therefore there are two situations where in-band interference may occur, receivers in the presence of:

- Long range area adjacent in-band transmitters; and/or
- Short range frequency adjacent transmitters.

Figure 2. Sources of In-Band Interference when Using Multiple Standards



4.2 Out-of-Band Interference

In a licensing context, out-of-band interference is not caused by in-band emissions, but by a receiver responding to the energy of emissions at other frequencies, outside the authorised band, through a number of special interference mechanisms[2]. Out-of-band interference is caused by design imperfections within the receiver. And therefore, the level of interference depends on the design quality of the receiver. In general, the management of out-of-band interference presents the major difficulty in managing interference.

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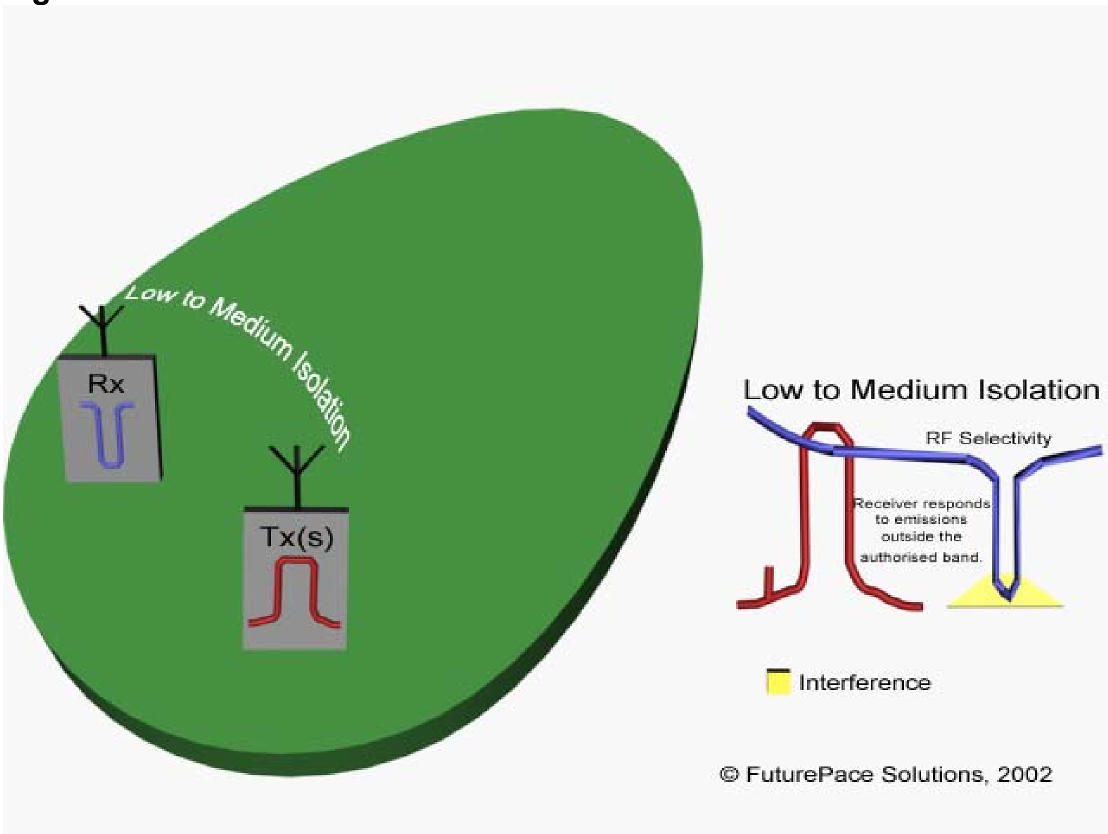
[2] ***out-of-band interference*** means interference:

(a) relating to selectivity, blocking, intermodulation immunity and spurious response immunity; and

(b) caused by authorised transmitter emissions at frequencies outside the authorised band of a receiver's license;

This is where the property analogy to spectrum rights breaks down. Property rights enshrine the view that the owner can do whatever it wants with its property. The truth is not as clear-cut as that due to the interconnected nature of some property. The interconnected behaviour of spectrum is best illustrated by out-of-band interference, which can cause interference between non-adjacent spectrum licences.

Figure 3. Sources of Out-of-Band Interference



This definition of out-of-band interference relates to specific interference mechanisms and should not be confused with 'out-of-band emission', a term normally used to refer to transmitter emissions at frequencies outside its authorized band.

5.0 Managing Interference

Interference has been traditionally managed by setting maximum limits for in-band and out-of-band transmitter power. This has the effect of indirectly setting the acceptable levels of:

- in-band interference for both area-adjacent and frequency-adjacent receivers; and
- to a degree, out-of-band interference for frequency-adjacent receivers.

An indirect method of setting acceptable levels of interference is often chosen because of the complexity of defining and in practice measuring, the very low signal levels that can cause interference to a receiver.

5.1 Managing In-Band Interference by Indirect Methods

FuturePace believes that in-band interference may continue[3] to be efficiently managed indirectly by:

- in the case of long-range area-adjacent in-band transmitters, specifying the maximum radiated power spectral density as a function of effective antenna height and distance; and
- in the case of short-range frequency-adjacent transmitters, specifying both the maximum steady-state and transient, radiated power spectral density as a function of frequency offset from the authorised bandwidth.

5.1.1 Setting Limits in Radiated Power

Radiated power emission limits are preferable when managing in-band interference because they provide additional flexibility to the licensee and are more accurate than specifying the power of the transmitter alone. In addition, the same radiated limits may also be used to manage the generation of

[3] This approach is common. The FCC already uses it and the UK has foreshadowed its use in the government response to the Cave review.

passive spurious emissions that are created outside a transmitter within antenna systems.

While a power spectral density limit does not necessarily limit the maximum transmitter power, limits for passive spurious emissions as well as out-of-band emissions place an indirect cap on the maximum transmitter power that is possible.

5.1.2 Taking Account of Discrete and Broadband Out-of-Band Emissions

In the case of limits for power spectral density as a function of frequency offset (out-of-band emission limits), it is possible to have different limits for spurious and non-spurious types of emissions. Non-spurious emissions have broadband characteristics[4]. Also, owing to the random nature of the frequency of discrete spurious emissions, their levels may be higher than broadband non-spurious emissions because they have a lower interference probability. Since there is no reason why the two emission types should have different interference probabilities, the spurious emission limit may be increased by a probability margin.

5.1.3 Taking Account of Antenna Directivity

It is possible to have different spurious and non-spurious limits for non-directional and directional antennas to take account of the large difference in their antenna gain. Directional antennas generally[5] concentrate their interference power into a self-managed area, and result in a lower interference probability to other areas. Hence, directional antennas may also radiate higher levels or spurious and non-spurious emission according to the relevant probability margin.

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[4] It is more practical to define out-of-band emissions by their type rather than the ad hoc ±200% of frequency method which is sometimes used.

Examples of very flexible, legally robust, definitions for radiated power are provided in Attachment B. These have been specially designed to take account of all forms of modulation. Acceptable estimation errors are also required to support these definitions.

5.1.4 Practical Long Range In-band Interference Management

In the case of in-band interference caused by area-adjacent in-band transmitters, it is possible to provide certainty in a very cost effective manner by specifying the radiated power with a single, unanimously accepted mathematical formula for radiated power rather than specifying a field strength, received level or acceptable interference level. Each licensee then knows, according to the single mathematical formula, the maximum power spectral density that may be radiated from any specific site as a function of effective antenna height and distance. Using power spectral density also ensures that all service categories, including the high gain antennas of point to point services, may be managed under a single formula.

Licensees then determine, on a risk assessment basis, how far their receivers must be set back from that particular location in order to cope with the allowed maximum radiated level. Note that in the case of managing long range in-band interference for spectrum licensing, it is not necessary to know whether or not a transmitter is actually operating at a particular location in an adjacent area. Where utility of a spectrum license is to be reserved for the term of the license, transmitters may be operated, without in-band coordination, at any time in the future during the license term. An adjacent licensee would assess the utility of their spectrum with regard to in-band interference from outside their geographic area using not only the mathematical formula but also the

[5] Noting that elevated ducts can significantly extend the interference range of point to point services in certain cases and that the ITU model for point to point fading, previously used as a basis for link design, is <u>currently</u> being corrected.

topography and the likelihood of future operation of transmitters at particular locations by adjacent licensees.

This approach simplifies network planning since everyone knows exactly what maximum power may be radiated from a specific location and obviates any cost associated with confirming a specified received level by measurement. When a single mathematical formula is used, the onus is placed on the adjacent licensee to take those known levels into account in planning. This can sometimes mean negotiating with an adjacent licensee. But this would involve negotiating a variation to a fully and clearly defined parameter, with consequent reduction in uncertainty and the cost of negotiations.

This indirect method of management can also simplify management of in-band interference across international borders. Both countries would agree to apply the same mathematical formula on both sides of the border. It is important to understand, and accept, that the mathematical formula is a simplification or starting point, providing a workable solution in a majority of cases and that negotiation may be required for the remaining few cases. The benefit of such an approach is that the majority of cases have, in our practical experience, been very quickly and cheaply resolved.

5.1.5 Practical Short Range In-band Interference Management

In-band interference caused by frequency-adjacent transmitters located in the same area[6] is managed by licensees determining the isolation requirements for their receivers with regard to:

- the allowed out-of-band emission limits; and
- the likelihood of the presence of transmitters operated under frequency-adjacent licenses.

[6] The emissions of unintentional radiators, including receiver emissions, would be managed under an EMC regime to underpin the radiocommunications environment.

Interference of this type, which is steady and continuous, can reduce the useable range of received signal levels (referred to as the near-far effect), which in turn, for example, reduces the maximum communication distance of mobile services.

Interference of this type, which is transient in nature, can reduce the communication capacity of a system by the loss of data and the subsequent requirement for re-transmission of that data. Transient short range in-band interference needs to be considered carefully in the case of Ultra Wide Band and other similar services. This form of interference can result in an overall reduction in the capacity of a network. For a receiver, each doubling in its IF bandwidth results in a 6 dB increase in interference caused by transients. Wide bandwidth services are degraded accordingly. There is an interference relationship based on the time taken to send a packet of data and the duration and level of transients received during that time interval. If a packet is so corrupted that it must be re-sent, and the transients are consistent, then a large loss of capacity results. Interference does not need to be continuous to cause a continuous loss of data.

When the maximum steady-state and transient, radiated power spectral density as a function of frequency offset from the authorised bandwidth is defined, adjacent operators can then establish the likelihood of interference for their particular operational configurations, either negotiating revised conditions with neighbours or providing internal guard space from their authorised bandwidth when the fundamental license conditions are not compatible with their particular equipment. A cost trade off is made possible between equipment quality and the necessary size of the spectrum space it requires to operate. Obviously, the fundamental license conditions would be defined in a manner to minimize the need for such negotiation or guard space.

Importantly, the generic standard contains within it all the definitions required to either:

- Determine the amount of additional spectrum that is required; or
- Determine the necessary[7] amount of internal guard space.

5.1.6 Tightening Out-of-band Emission Limits

FuturePace concurs with the Task Force recommendation for a tightening of out-of-band emission limits rather than persisting with generous regulatory bench-performance allowances. Regulatory out-of-band emission masks are often unrealistic and, in our experience, measurements of actual equipment usually outperform these masks by a significant margin. In practice, additional high quality filtering is often employed on transmitters which also reduces the actual levels of emissions substantially. Therefore, a worst case regulatory mask selected from a number of actual standards should not be copied directly into a generic equipment standard. When it is copied[8], the need to consider that high levels of out-of-band emission are allowed can create a risk in using the other types of equipment and lead to an acceptance of less economically efficient solutions in order to build in protection margins. This limits licensee creativity and can have deleterious market place impact.

Obviously it is better to maximise spectrum utility and creativity by initially establishing low levels of out-of-band emission, striking a balance between actual performance and theoretical models as well as minimising the need for negotiation. Licensees may then increase those levels, if they so desire, biasing spectrum use through spectrum sharing arrangements, but this should be a commercial consideration, never a technical limitation of the license.

[7] Calculation of the spectrum space required is not described in this submission due to length considerations.
[8] Similarly, other standard's parameters need to be assessed in conjunction with their associated test method. Not all parameters are accurately representative of their field behaviour.

5.2 Managing Out-of-Band Interference by Direct Methods

As the Task Force study correctly reports, in the case of out-of-band interference, the indirect method of setting receiver protection leaves much to be desired. In this case a licensee's rights and responsibilities are not clearly defined because the level of interference depends very much on the quality of the receiver.

While the acceptable level of in-band interference may be set indirectly, the acceptable level of out-of-band interference must be set directly. This is due to the different characteristics of in-band and out-of-band interference. In-band interference is reasonably linear while out-of-band interference can be decidedly non-linear.

Linear interference means that for every increase in interference signal level a wanted signal would have to increase a similar amount to maintain the same receiver output quality. Non-linear interference means that for every increase in interference signal level a wanted signal would have to increase a number of times that required for linear interference. The susceptibility of a receiver to out-of-band or non-linear interference is very dependent on receiver design.

Out-of-band interference occurs when transmitters and receivers operate close together in terms of the two main variables that determine their degree of isolation from each other: distance and/or frequency separation. Out-of-band interference may be caused over short to medium distances when there is insufficient isolation, and in the case of one type of out-of-band interference, intermodulation, when the frequency separations have particular relationships.

5.2.1 The Generic Receiver

As Chairman Powell, has suggested, further definition of minimum receiver performance, or a “Generic Receiver” (this would be part of a Generic Equipment Standard), is necessary to provide a defined measure of receiver interference susceptibility. Once a generic receiver is defined, it is simple to determine whether actual receiver performance characteristics are better or worse than the generic definition.

Establishing a generic receiver does not necessarily mean receivers must at least operate at that minimum performance level. In the case of a reduced level of performance, an operator may either negotiate to prevent the operation of transmitters in a guard band of adjacent spectrum, or provide guard space within their own spectrum. The amount of necessary guard space would be based on the difference between the characteristics of the generic and the actual receiver. Modification of receiver performance, for example, additional filtering, is another obvious option. However, under the proposed system a licensee is able to personally make technical and economic trade offs, usually a balance of the cost of spectrum against the cost of infrastructure. The issue is thus a commercial judgement based on known license conditions, not a matter of regulatory fiat.

Also, a receiver that does not operate at the minimum performance level does not necessarily have to forgo protection. A receiver whose characteristics are worse than the generic receiver should still receive protection up to the level defined by the interference susceptibility of the generic receiver.

For complete definition, a generic receiver must include models for:

- RF and IF selectivity;
- Blocking;
- Intermodulation immunity;
- Spurious response immunity; and
- Acceptable level of interference (sensitivity).

An example of a quantitative metric for acceptable interference for a generic receiver is:

- an output quality equivalent to a wanted to unwanted signal level ratio that is not less than 15 dB for more than 1% of the time in any 1 hour period;
- with the wanted signal never less than -111 dBm; and
- when measured as mean power within a 30 kHz rectangular bandwidth that is within the authorised band.

(Note: All levels are referenced to the antenna connector of the equipment. The minimum level of performance of an antenna system for a receiver is a gain of 10dBi in all directions and a feeder and combiner loss of 2 dB.)

A benchmark for interference like this may be used when it is necessary to negotiate with adjacent licensees, defining what is meant by 'harmful', 'permissible', 'safe' or 'unacceptable' interference during the negotiation.

5.2.2 Practical Out-of-band Interference Management

Because out-of-band interference can be non-linear, transmitter emission limits can not be used to manage it efficiently by using indirect methods. If indirect methods were to be used, limits would have to be made so low that wireless communication would not be possible. Therefore, the best first line of defence in managing out-of-band interference is, before operation, to coordinate services using fully defined predictive interference modelling. If actual interference occurs at a later date then the first step for its resolution is to perform a desk audit with the backstop being actual measurement. Measurement is a last resort because it is quite costly and difficult to measure low level interference accurately especially at communal sites where the electromagnetic environment is highly polluted.

Management of out-of-band interference may be simplified in practice by establishing deployment constraints for transmitters, based on effective antenna height, in order to reduce the range over which out-of-band interference occurs, from medium to short distances. This consequently provides protection for receivers used in the converse deployment. The distance can be designed to become sufficiently short to enable transfer of the responsibility for management of out-of-band interference to site managers or their agents. When a national device database is not available, coordination must be restricted to co-site services, with device information being supplied by a site manager. However, greater flexibility is possible for transmitter and receiver deployment when a national database of transmitters and receivers is available and utilised.

Deployment constraints bias spectrum use towards a particular service category. They often mimic current planning in the band (for example, two-frequency base transmit and base receive). In spectrum space terms, biasing spectrum creates a need for additional space for the operation of other service categories. Deployment constraints may be worked around by licensees (to support, for example, TDD systems) by supplying more spectrum space, that is, negotiating with adjacent licensees for spectrum sharing arrangements or by providing internal guard space. In these cases the objective is to maintain the simplified out-of-band interference management for other licensees by providing the same level of receiver protection that would be provided as if the deployment constraints had been followed. Again, and most importantly, there is a clearly defined “line-in-the sand” around which adjacent licensees may negotiate.

6.0 Managing Non-Exclusive Spectrum Access

While the above holds true for both exclusive and non-exclusive spectrum access, the main differences between the two forms of access is their different interference management mechanisms. While a “commons” approach may seem attractive, procedures must still be in place to avoid a “tragedy of the commons”. Non-exclusive use appears to offer operation without coordination and without license fees. However, for operation within premises, the cost of the license fee has been transferred to the cost of the necessary negotiated agreement to occupy and operate within the premises and eventually, to maintain those premises free of interference. Here the rights of the licensee essentially become the rights of the occupation agreement. This element of non-exclusive access is similar to the property right of exclusive access.

To manage interference for non-exclusive access, services are, by necessity short range, using low transmitter power and:

- In point-to-multipoint configuration, the operator achieving coverage within premises ("hot-spots") by negotiating interference-free access to the radio environment in those premises; or
- In point-to-point configuration, the maximum distance dependent upon the degree of directionality for radiated power and interference management often supported by dynamic frequency assignment and power control so that the service can automatically adapt to the interference environment.

By the very nature of its design, non-exclusive use is interference-limited in its operation. And, the level of acceptable interference is whatever is found to be acceptable in a particular environment. Instead of talking in terms of acceptable interference it is often more appropriate to rate systems by their communication distance and/or their data throughput. As distance/throughput reduces, more access points closer to mobile terminals are required. This is a cost-benefit trade off for the operator. Obviously, larger communication distances/throughput for both point to multipoint and point to point services would be possible in rural areas by virtue of the lower number of operators. However, it may not be cost effective to operate in rural areas.

It can be useful to think of non-exclusive use within premises in terms of operating a small spectrum license, the owner of the building effectively owning the spectrum space within the building and being responsible for spectrum management within that building. Occupation agreements would contain conditions similar to fully defined spectrum licenses to provide certainty with regard to management of in-band and out-of-band interference. One can also think of building rooftops as small spectrum licenses managed by the building owner or their agent with of course, the attendant issues of EMR Occupational Health and Safety also being the primary responsibility of the site owner. From an investment risk management perspective, services such as WiFi need technical assessments to ensure the efficacy of commercial decisions so that, for example, funding is provided on the basis of expected telecommunications capacity rather than the quality of the coffee and ambience of surroundings.

7.0 Acknowledgment

FuturePace Solutions acknowledges the significant contribution made to this submission by Mr Noel Higgins, from the Radiocommunications Standards Team of the Australian Communications Authority.

8.0 Conclusion

We have explained how the superficially simple coordination procedures of a single standard can not be assumed to also manage use of multiple standards. In practice, interference management through mutual competition has been found to be impractical because interference is often non-reciprocal. We have suggested that a solution lies in focussing on managing spectrum space rather than equipment details, providing a frame of reference based on a generic equipment standard for self-management of interference by industry. The generic standard is used to design license conditions that define the ‘size’ of the spectrum space which the licensee may access and subsequently, the ‘size’ of the space a licensee requires to operate their chosen equipment. We have proposed a practical example of such license conditions that maximise flexibility while retaining certainty, together with some suggestions as to policy issues, which could be developed to support such a construct. FuturePace sees benefit in collaboration and submits this spectrum management solution to the Commission for its consideration.

In our experience the technical issues can and have been solved.

However, we acknowledge that political and social interests often influence the final outcome.

FuturePace Solutions
3 January 2003

Attachment A – Related Publications

[1] Bramley R., Peppercorn A.E., Whittaker M.J. "Simultaneous Nitrogen-14 and Cobalt-59 Decoupling from Protons" Journal of Magnetic Resonance 35, 139-144(1979).

[2] Whittaker M.J. "Land Mobile Frequency Selection Strategies and Compatibility Criteria used in the Frequency Assignment Subsystem of the DOC's Spectrum Management Information System" IREECON '85 Digest of Papers 1985, pp 882-885.

[3] Whittaker M.J. "LYNX - An Automated System for the Assignment of Frequencies to Two-Frequency Single Channel Fixed Radiocommunication Services" IREECON '87 1987, Digest of Papers, pp 799-802.

[4] Whittaker M.J. "Spectrum Efficiency Considerations in the Planning for Land Mobile Services which Employ 12.5kHz Channelling" IREECON '87, 1987, Digest of Papers, pp 806-809.

[5] Whittaker M.J. "Land Mobile Receiver RF Intermodulation Immunity Measurement Using Two Signal Generators" Journal of Electrical and Electronics Engineering, Australia Vol. 5, No. 4, December 1985.

[6] Whittaker M.J. "Determining Necessary Adjacent Channel Isolation and Reuse Distance for a Radiocommunication Service" Journal of Electrical and Electronics Engineering, Australia Vol. 10, No.4, December 1990, pp 353

[7] Whittaker M. J. "Frequency Assignment Strategies in Australia" Journal of Electrical and Electronics Engineering, Australia Vol. 11, No.3, September, 1991, pp 157-163.

[8] Whittaker M.J. Yang H. "Managing Spectrum Licensing in Australia" ESRI 1997 Users Conference, Digest of Papers, San Diego, July 1997, see www:esri.com for a full copy of the paper.

[9] Whittaker M.J. "Establishing an Interference Management Framework for Spectrum Licensing in Australia" IEEE Communications Magazine, April 1998.

[10] Whittaker M. J. "Establishing Conditions for Australian Spectrum Licences in the 28 GHz and 31 GHz Bands" www.aca.gov.au/frequency/spps/0207spp.pdf (Attachment A), Spectrum Marketing Group, Australian Communications Authority, August 1998 19pgs.

[11] Whittaker M. J. "Australia's Airwaves for Sale" Mobile Asia-Pacific February/March 1999 Vol. 7 No. 1.

[12] FuturePace Solutions "Response to the UK Independent Radio Spectrum Management Review" www.spectrumreview.radio.gov.uk/responses/futurepace19Sept.pdf 19 September 2001, 16pgs.

[13] Whittaker M.J. "Short Cut to Harmonisation with Australian Spectrum Licensing" IEEE Communications Magazine, January 2002.

[14] FuturePace Solutions "True Technology Neutral Spectrum Licences" www.futurepace.com.au/TNSL.pdf February 2002, 13 pgs.

[15] FuturePace Solutions "Comment on Recommendations of the Independent Radio Spectrum Management Review" www.spectrumreview.radio.gov.uk/comments/future_pace.pdf 11 March 2002, 23pgs.

[16] FuturePace Solutions "Additional Comment on Recommendations of the Independent Radio Spectrum Management Review" www.spectrumreview.radio.gov.uk/comments/futurepace-2.pdf 8 May 2002, 8 pgs.

[17] FuturePace Solutions "Comments on 'Implementing Spectrum Trading'" www.radio.gov.uk/topics/spectrum-strat/responses/ist/futpace.pdf 6 August 2002, 9pgs.

[18] Whittaker M J "Concerning the Size of a Spectrum Licence" www.radio.gov.uk/topics/spectrum-strat/responses/ist/futpace-add.pdf November 2002, 8pgs.

Attachment B - Flexible Definitions for Radiated Power

radiated power, for a radio communications device, is specified in units of dBm and means the product of:

(a) the maximum true mean power, within the frequency band of the license authorising the operation of the device; and

(b) the maximum antenna gain relative to an isotropic antenna.

maximum true mean power means the true mean power measured in a 30 kHz rectangular bandwidth that is located within a specified frequency band (frequency band of the license) such that the true mean power is the maximum of true mean powers produced.

[NOTE: The power within a 30 kHz rectangular bandwidth is normally established by taking measurements using either an adjacent channel power meter or a spectrum analyser. The accuracy of measuring equipment, measurement procedure and any corrections to measurements necessary to take account of practical filter shape factors would normally be in accordance with good engineering practice.]

true mean power means:

(a) if an unmodulated carrier is present - the mean power measured while the unmodulated carrier is present; and

(b) if an unmodulated carrier is not present - the mean power measured while transmitted information is present.

mean power means the average power measured during an interval of time that is at least 10 times the period of the lowest modulation frequency.

peak power means the average power measured within a specified bandwidth during one radio frequency cycle at the crest of the signal envelope.

