# Shortcut to Harmonization with Australian Spectrum Licensing

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## ABSTRACT

Governments may facilitate the introduction of new types of wireless communication services through use of a self-regulated spectrum management system known as spectrum licensing. Spectrum licensing is able to break the nexus between the equipment standardization process and obtaining regulatory approval to access spectrum, avoiding delays and effectively harmonizing spectrum use. There are similar trends at play in several countries, and spectrum licensing can have different levels of implementation of the technical framework, even within a single country, depending on the objectives sought and the manner in which those objectives are designed to be achieved within a particular frequency band. Just as the circumstances that seem to block us in our everyday life depend on our framework of assumptions, the possibilities of spectrum licensing also depend on the chosen technical framework. When a framework is fully implemented, the important underlying objectives are to maximize *flexibility* and *certainty* for the operation of equipment while *minimizing negotiation* for the management of interference. Flexibility facilitates the management of change, and certainty creates a stable basis for that change. And, with minimal negotiation, change is faster and cheaper. The Australian case is taken as an example. The 3.4 GHz band has just been auctioned with license conditions that, for the first time, have been designed to allow equitable spectrum access for both point-to-point and mobile-like services.


## INTRODUCTION

The Radiocommunications Act of 1992 formally introduced the concept of spectrum licensing into Australia. Its introduction was seen to be necessary primarily as a means of ensuring that the allocation of radio frequency spectrum kept pace with change in technology. Spectrum licensing was finally implemented in 1997 with the sale of 500 MHz band spectrum lots. After auction, the lots were aggregated where possible and issued as spectrum licenses.

Spectrum licensing complements the preexisting apparatus licensing regime in Australia. Both forms of licensing are now employed, often side by side. Spectrum licenses are increasingly being used and offer a form of "spectrum access right" providing considerable additional flexibility to licensees who manage their own spectrum space and deploy a variety of equipment or services in a band.

A spectrum license grants access to radio frequency spectrum space, defined in terms of a geographic area and frequency band and with conditions of access that are usually sufficiently flexible to allow any type of equipment to operate and sufficiently comprehensive to maintain the space for sole use by the licensee. Previously, under apparatus licensing, the Regulator allocated spectrum for sole use by a particular equipment standard, in effect "picking technological winners." Unfortunately, Regulators in general have never had a good track record at picking winners. Additionally, this allocation process was very slow. By introducing self-regulation (not to be confused with deregulation) of the radiocommunication spectrum through spectrum licensing, it was expected that industry, without the Regulator in the loop, could keep pace with technological change. An added bonus was that self-regulation also meant self-management, an outcome that was accepted enthusiastically by government, which saw it as consistent with its policy of outsourcing many former government activities to the private sector.

The main challenge was to create market certainty in the use of a product (spectrum space) that is, in practice, difficult to control. The objective was to design legally robust license conditions that would:

- Provide a clear description of the product to be sold in order to create certainty and encourage confidence in a spectrum auction by:
  –Protecting the purchaser (the licensee) who would know exactly to what use the product could be put

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–Protecting the seller (the government) by having a clear boundary drawn between licensee and government responsibilities
–Protecting incumbent (apparatus) licensees for a short reallocation period after spectrum sale so that they might either trade their right to operate during the reallocation period with spectrum licensees for the cost of relocation or use it while they found alternative spectrum or other means of maintaining their operations
–Protecting existing adjacent apparatus licensees that may wish to continue to operate just outside both the geographic and frequency boundaries of a spectrum license
–Having clearly defined and consistent spectrum access rights over the full term of the license in order to enable a bidder to establish the correct price for spectrum, including ensuring that subsequent adjacent apparatus licensed services do not encroach on the spectrum
–Selecting a license term that provides certainty for licensees but allows government to then re-auction the spectrum after a time when its value may have changed dramatically (thus providing recurrent revenue from the rent of a valuable natural resource)

- Manage interference between devices operated under adjacent spectrum licenses with minimum requirement for costly negotiation between licensees
- Maximize flexibility by allowing all types of equipment and systems to operate (rather than biasing the license conditions by requiring relatively more space for certain types of services) and enabling the real value of the spectrum space to be based on the most economically efficient use available
- Provide for trading or sharing of all or part of the spectrum to allow efficient license shapes and sizes to evolve over time to support the operation of anything from narrowband short-range to wideband long-range services

The important underlying objectives are to maximize *flexibility* and *certainty* for the operation of equipment while *minimizing negotiation* for the management of interference. Flexibility facilitates change, and certainty creates a stable basis for that change. And, with minimal negotiation, change is faster and cheaper.

A comprehensive set of technical spectrum access conditions is provided with each bidder information pack. The conditions fully specify a benchmark spectrum utility that is essentially independent of any ability or cost to negotiate with adjacent licensees about the management of interference. It is then possible to establish the value of the spectrum based on this benchmark utility in relation to specific equipment for a business plan, given that the cost of spectrum is an important aspect of business viability.

While the benchmark spectrum utility is always available, the Australian framework also provides for both the sharing of spectrum and varied compatibility requirements through agreements with adjacent licensees. This facility provides licensees with the choice of either managing their spectrum in accordance with the benchmark utility or, where adjacent licensees are satisfied with alternative levels of flexibility and certainty achieved through negotiation, designing other, possibly simplified, methods of spectrum management.

## Spectrum Licensing in Australia

A commonly heard view from overseas observers is that it is easy for Australia to implement spectrum licensing because the country is so large and cities so well separated. These observers often argue that the system would not work as well in situations where national boundaries impinge on allowable radio transmissions. In practice, however, in Australia there are a full range of situations requiring the license conditions to handle both small geographic areas and very narrow frequency bands. The form of boundary conditions adopted in Australia would be suited to adoption as a means of controlling radio emissions across national boundaries.

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The vision and methodology for spectrum licensing in Australia has been described previously [1, 2]. The Australian vision has quite a few important differences with some other implementations of spectrum licensing elsewhere in the world:

- Out-of-band emission limits are specified in radiated power that are independent of the shape of the emission of a particular transmitter.
- There are deployment constraints[1] that act to manage out-of-band interference by keeping transmitters away from base receivers when they may operate close in frequency.
- Equipment standards are not mandated, thus maximizing competition between equipment vendors from anywhere in the world.
- There have not been any buildout requirements in Australia.
- There is no direct compensation paid to preexisting incumbent licensees who are, instead, granted a short reallocation period before their licence expires.
- There are no filing notices before operating devices.
- Licensees use a national centralized data base of radiocommunication devices via the Internet for the self-management of out-of-band interference and compliance certification.
- Spectrum can be shared by agreement for third-party operation.

## Harmonization of Spectrum Use

The ITU has long been the chief battleground for technical competition processes involving various industry groups. The usual outcome was a single equipment standard enforced through rules for access to a specified frequency band. The European concept of "harmonization" is similar. European harmonization is about working to obtain and restrict spectrum access to what is now a number of equipment standards. It is possible for a standards process in countries such as Australia and the United States to have a different focus because of the more flexible licensing systems in those countries.

While European administrations often deal

[1] *Where the size of the space of a license is large, guardspace can be provided to work around deployment constraints.*

While equipment standards are not used, the objectives of an equipment standard have been transferred to the boundary conditions of the spectrum license. These conditions act as a generic equipment standard.

with the allocation, by auction or beauty contest, of "licenses" for the operation of specified equipment, Australia allocates "spectrum," where licensees may operate whatever equipment they wish within a box of spectrum space in accordance with specified boundary conditions. Under spectrum licensing, standardization is able to become an industry responsibility. And since, increasingly in the future, the spectrum in question will already be sold, an industry standardization process may consider, but will no longer be dependent on, obtaining permission from a Regulator to access spectrum. Breaking the nexus between spectrum access and equipment standardization can result in a quick regulatory response to equipment evolution. For example, the type of response required for the operation of software-defined radios, able to be programmed easily to operate over a broad range of frequencies, bandwidths, and transmission standards, may be provided without the continued involvement of the Regulator. Under spectrum licensing, independence of standards or spectrum "harmonization" can occur at the time of license issue, the Regulator then taking a back seat to industry for the evolution of standards. This alternative management method has played a part in the International Telecommunication Union (ITU), now supporting the provision of 3G services worldwide within a number of additional frequency bands.

While equipment standards are not used, the objectives of an equipment standard (to limit emission levels for the management of interference) have been transferred to the boundary conditions of the spectrum license. These conditions act as a generic equipment standard. In Australia, licensees register[2] devices in a centralized national database, through persons who are accredited by the Regulator to certify that a device operates in accordance with the license conditions. Although not the primary objective (devices are mainly registered to facilitate the management of out-of-band interference through coordination procedures), the device registration process creates a simplified equipment type approval process. Once the device is registered it is authorized to operate and there are no additional authorization processes, such as filing notices, required. Equipment certification is performed with respect to the spectrum space each device uses and in relation to the size of the license rather than its laboratory test performance.

Although existing equipment standards are taken into account to create the emission limits of the generic standard relating to out-of-band and out-of-area emissions, the spectrum lots and later issue of spectrum licenses may or may not align with either the channel plans or out-of-band emission limits of those standards. The inherent flexibility of a spectrum license is left for the bidder/licensee to extract, and sensibly that flexibility will be based on a careful technical and commercial assessment *before* the auction. The spectrum lots and subsequently issued licenses are usually not predesigned by the Regulator to accommodate any particular standard. However, they may accommodate the operation of a particular standard (or even nonstandard equipment) at a particular location and frequency, depending on the size and shape of the license a bidder has acquired.

Spectrum licensing can facilitate harmonization of technical regulation in both standards setting and equipment compliance at the radio interface. The liberalization of the Asia-Pacific telecommunications market is currently being pursued by a harmonization of equipment certification and conformity assessment to facilitate trade under a mutual recognition arrangement (MRA).

The two basic principles for establishing an MRA are:

- Minimum technical regulation and administrative procedures
- Mutual recognition of conformity assessment

The objective of the first principle is to reduce trade barriers; that of the second is to reduce the costs and time for conformity assessment.

Two conditions are required to develop the MRA:

- Economies should subscribe to APEC guidelines for equipment certification to ensure a level playing field.
- Economies should adopt APEC conformity assessment procedures.

Up to this point the MRA is a voluntary arrangement focused on the regulation of telecommunications terminal equipment and common conformity assessment processes. While APEC is very much interested in trade liberalization, greater competition, and self-regulation, very little has happened to date in terms of moving centralized regulatory powers and standards setting out of the hands of government.

Spectrum licensing can provide a single-step process for achieving harmonization of spectrum use (or an MRA at the radio interface) but requires a shift in emphasis on central regulation to distributed regulation by industry. With more individual freedom a spectrum licensee can conduct affairs according to its corporate perception of economic efficiencies, allowing a communications services' market to evolve that is full of possibilities. Central control of spectrum through the imposition of an equipment standard is inferior to organizational methods that focus on freedom of choice and unleashing individual creativity in spectrum management. Although this may sound like unleashing chaos, in fact the desire of licensees to make a profit is a strong force for regulatory order and market and engineering performance improvement. Flexible and certain license conditions support creative and stable business plans, and governments are freed by shifting a major level of spectrum management responsibility to the licensee.

Spectrum licensing:

- Reduces trade barriers by allowing the importation and operation of "nonstandard" equipment without any previous certification in order to improve market access for suppliers
- Takes account of any available international standards to introduce harmonized spectrum use (resulting in a *single* conformity assessment procedure) using primarily the size and shape of the spectrum space to determine which of any equipment may be operated

[2] *Care is needed when comparing the licensing systems of different countries. For example, in New Zealand the term* management right *refers to a spectrum license, and* spectrum license *refers to the registration of a device.*

- Leads to transparency with minimal regulatory involvement and discrimination because a licensee decides the amount of spectrum to purchase and therefore which equipment may be operated
- Reduces the costs associated with compliance by requiring a licensee to measure power spectral density and a few steady-state and spurious characteristics (typically less than AUD$1000 for an equipment type — not each device)
- Dramatically reduces time to operate by locating the certification process with the spectrum licensee just before operation of equipment
- Uses a certification process based on self-management, with the radiated power of each device being certified in relation to the size, shape, and other boundary conditions of the spectrum license
- Uses device registration as part of the certification process, and because registration is already required to facilitate the management of out-of-band interference, and is performed via the Internet, creating relatively insignificant additional transaction costs

Some countries with large manufacturing industry bases tend to promote the use of equipment standards in connection with their spectrum auctions to further their economic growth and exports. Unfortunately, specification of standards tends to limit the effectiveness of spectrum licensing. Certainly, any efficiency to be gained from competition between different types of equipment is lost together with creativity and possible economy in spectrum usage.

Just as the three most important contributions to the value of real estate are half-jokingly stated as position, position, and position, the three most important contributions to the value of spectrum have, in the past, been considered to be frequency, frequency, and frequency, in relation to performance of off-the-shelf equipment. In some cases, the standards setting process has appeared to create segments of spectrum that are in high demand. Cheap equipment seems to create expensive spectrum. However, this may be too narrow a view. There are now eight different types of equipment available for operation in the very expensive personal communications services (PCS) spectrum in the United States. Spectrum licensing opens up use of the spectrum and allows the market to balance the cost of spectrum with cost of equipment. Certainly, equipment cost does not appear to be the dominant consideration.

Standardization is effectively a long-term contract for the use of spectrum. Long-term contracts often stifle the creative use of valuable national and community resources. For example, an outcome of the ITU standardization process was that equipment was not often designed to be frequency agile. With the release of spectrum in the United States, Australia, and elsewhere, creativity and resultant competition is occurring. And equipment is being designed to be frequency agile. A good example is the general availability of LMDS equipment working from approximately 20 to 40 GHz. And for 3G services, subscriber equipment using multiple modes and multiple bands will be the norm. The generic standard of a spectrum license well suits the future 3G generic radio by providing the necessary optimization flexibility at the radio interface.

## Managing In-Band and Out-of-Band Interference

In Australia, the national database of radiocommunications licenses is an essential part of spectrum license management. The database is available to licensees who may use it to manage their spectrum at a detailed level to extract maximum utility from their licenses. The database is useful for the efficient management of out-of-band interference across frequency boundaries. Out-of-band interference means interference relating to selectivity, blocking, intermodulation immunity, and spurious response immunity caused by emissions at frequencies outside the frequency band of the spectrum license in the space the receiver operates. This definition of out-of-band interference should not be confused with *out-of-band emission*, an ITU term used to refer to emissions at frequencies outside a channel. Out-of-band interference, unlike linear forms of interference such as in-band (co-channel) interference occurring across geographic boundaries, cannot be managed by emission limits alone but, for efficiency reasons, requires a coordination process. Certainty is introduced into this coordination process by applying an interference settlement policy that gives preference to devices that were first registered in the database.

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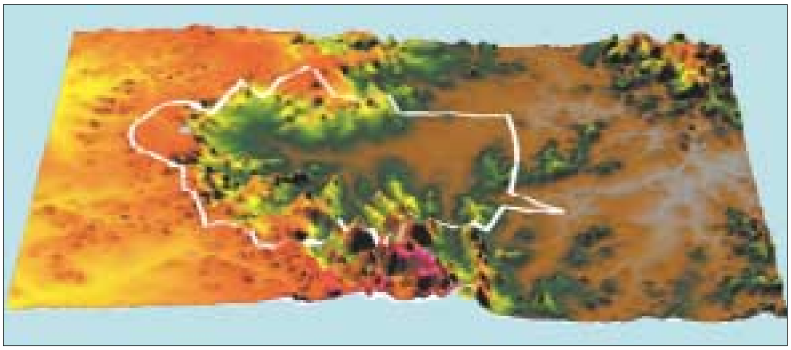
In contrast, the settlement of in-band interference does not give preference to devices first registered in the data base, and devices may have emission levels set by the license conditions at any time and at any geographic location within the license during the full term of the license. In-band interference to a receiver means those levels of emissions from a transmitter that are permitted under the conditions of the license under which it operates and at frequencies that are within the frequency band of the spectrum license in which space the receiver operates. Note that under spectrum licensing, in-band interference may be caused by the out-of-band emissions of a transmitter.

The different interference settlement policies applied to in-band and out-of-band interference seek to provide the spectrum licensee with certainty with regard to spectrum access rights, and reflect the different volumes of spectrum space affected by each type of interference. Frequency-adjacent services are affected over a small distance by out-of-band interference compared to the large distances over which area-adjacent services may be affected by in-band interference.

## Spectrum Licensing in Practice

Spectrum licenses have been issued in the 500 MHz [3], 800 MHz, 1.8 GHz, 28 GHz, 31 GHz, and 3.4 GHz [4] bands. This range of bands has in practice allowed spectrum licensing to provide for a full range of services.

When Australian spectrum licensing is fully implemented it contains the following essential



■ **Figure 1.** *An example of a device boundary for a transmitter.*

elements:
- A maximum radiated power within a reference measurement bandwidth (maximum power spectral density) together with a requirement that the necessary geographic area of a device based on its power spectral density, its "device boundary," stays within the geographic area of the license
- Deployment constraints for transmitters operating in certain bands that protect frequency-adjacent receivers at high sites and the provision of either internal guard space within a license, or spectrum sharing agreements, to work around deployment constraints
- Fixed steady state and transient radiated emission limits outside the frequency band of the license that are independent of the shape of a particular emission
- A defined generic receiver performance including selectivity curves together with a compatibility requirement on which to base coordination procedures that manage out-of-band interference between devices operated under frequency-adjacent spectrum licenses
- Technologically neutral compatibility requirements that manage interference to devices operating under apparatus licenses near the area and frequency boundaries of spectrum licenses

## The Device Boundary

The concept of a device boundary [1, 2], where a calculated area represents the deemed space used by in-band emissions from a device, has been used by Australia to provide surety of access to spectrum for licensees in addition to managing levels of in-band emission spilling into adjacent licenses. An example of a three-dimensional device boundary is shown in Fig. 1. A device boundary is a good means of setting emission limits because:
- It specifies an exact and direct procedure to determine the maximum radiated power of a transmitter (based on the effective antenna height and distance from the boundary) that cannot be challenged by an adjacent licensee.
- The direct nature of the limit means that licensees can work closer to the geographic boundary of the license than otherwise because no reliability margins are required to ensure a specified field strength.
- Licensees can accurately plan for transmitters operated by adjacent spectrum licensees across the area boundary at any time in the future.
- It may or may not be based on actual propagation models depending on the outcome required, but is usually designed to keep base stations sufficiently back from the area boundary such that subscriber transmitters also stay within the boundary.
- It often allows licensees to take advantage of terrain shielding to contain emissions within their license.
- It provides a simple facility for establishing agreements between licensees for sharing spectrum space across area boundaries by varying a single parameter to expand or contract the device boundary to provide more or less in-band protection, respectively.

## Device Boundary Criterion for 800 MHz

The device boundary criterion for 800 MHz spectrum licenses was based on a Digital Advanced Mobile Phone Service (D-AMPS) air interface system model. The system model is chosen simply for modeling purposes and does not imply any particular bias to that system. The resulting criterion allows use of isolated macro, micro, and picocells, accommodating code-division multiple access (CDMA) and trunked land mobile services. The necessary size of the device boundary is found when:

$$RP - Lb - LOP \leq 0$$

where:
- RP = the maximum power spectral density (measured in dBm eirp/30 kHz)
- Lb is a specified propagation loss
- LOP is a receiver level of protection

For 800 MHz the LOP is defined as maintaining a 17 dB protection ratio for a minimum mobile wanted level (–97 dBm) for 95 percent of the time. Using Rayleigh fading and a log-normal shadowing model with a variance of 6 dB, the 95 percent time requirement is provided by a reliability margin of 16 dB. Therefore, the LOP is (–97 –17 –16) or –130 dBm/30 kHz. The system model, consisting of a typical RP, LOP, antenna height, cell radius, and reuse distance, is fitted to the propagation model to create the device boundary criterion.

The choice of the propagation model for establishing the device boundary criteria is fundamental to the protection of receivers. The size of the geographic area deemed to be used by the emission from a transmitter depends on the height of receivers in adjacent licenses that need to be protected. A high-low propagation model is often used because for that model, propagation loss increases very fast with distance. This minimizes the size of the in-band emission buffer zone along the geographic boundary between spectrum licenses. A simple mathematical model of Fig. 41(c) of [5] was used in order to reduce the complexity of the device boundary criteria rather than improve its accuracy beyond useful limits. This means that receivers at high sites and close to the boundary are not protected. If a licensee wishes to operate a receiver at a high site, it must be operated either well inside the geographic area or utilize a directional antenna pointed inside the geographic area.

## Device Deployment Constraints

For bands that may be used in a paired manner for two-way two-frequency operation, either the upper or lower band will normally be subjected to transmitter deployment constraints. Deployment constraints are defined on the basis of effective antenna height (i.e., the height with reference to the average terrain within about 7 km of the device). In the lower 800 MHz band, the effective antenna height is to be kept less than 10 m, but with an allowance of 48 m for terrain height variation. The 48 m allowance effectively means that transmitters that are 10 m above ground may be used anywhere within the built-up areas of Australian capital cities irrespective of the terrain height variation. This normally allows licensees to operate receivers at high sites in the lower band without concern for out-of-band interference. Complex deployment constraints were used for 500 MHz spectrum licenses in order to manage intermodulation interference in situations where spectrum may be traded at a fine level in the frequency dimension (12.5 kHz). Simpler deployment constraints are used at 800 MHz because fine levels of trading are not supported in that band, with licensees having more options for managing intermodulation.

The deployment constraints avoid expensive or uncertain negotiation between adjacent licensees but bias the license conditions toward a preferred configuration of the upper and lower bands for either the base (or hub)-to-subscriber link or the subscriber-to-base link.

Deployment constraints operate in two ways:

- In the case of managing license frequency boundaries, keeping transmitters and receivers operating close in frequency separated by large distances to limit the likelihood of out-of-band interference
- In the case of managing license area boundaries, limiting the likelihood of in-band interference to receivers at high sites and allowing receivers at high sites in an area-adjacent license to be located close to the geographic area boundary

While deployment constraints provide ready access for equipment using the most common configuration, there are situations (e.g., PCS repeaters) in which compliance with the deployment constraint is not possible. The constraints are implemented through a prescribed process for device registration. However, Australian spectrum licensing manages this situation by allowing for the registration and operation of transmitters that do not comply with the deployment constraints. In this case, the objectives are achieved in a different manner through the use of guard space, that is, a guard band and guard area (see next section *Avoiding Deployment Constraints Using Guard Space*). While the deployment convention for 800 MHz supports nationwide land mobile and point-to-multipoint services, it does not prevent the operation of point-to-point services, and there are currently many point-to-point services operating under 800 MHz spectrum licenses.

The management of 3.4 GHz lower band uses a new design where transmitters using narrow beamwidth antennas (less than 5° half-power beamwidths) have no deployment constraints applied to them while the operation of other transmitters are restricted. The use of narrow beamwidth antennas limits the likelihood of out-of-band interference. In addition, any interference at a location to where such an antenna is directed would be the responsibility of the spectrum licensee because the responsibility for management of co-site interference is imposed on spectrum licensees as a license condition. By using this technique, the 3.4 GHz band is not biased toward any type of service in terms of the spectrum space they each require.

## Avoiding Deployment Constraints Using Guard Space

Compliance with license conditions ensures that emission buffer zones are established along the area and frequency boundaries of licenses in a manner that complements the deployment constraints. However, devices that do not comply with the deployment constraints may also be operated when larger emission buffer zones (guard area and guard band) are provided by a licensee. If a transmitter is operated at a high site when it is usually constrained to a low site, the likelihood that there will be a high-site-to-high-site interference path between the transmitter and a receiver increases. The purpose of guard area is to reduce this likelihood to that provided by the deployment constraint. And the purpose of the guard band is to allow licensees to manage out-of-band interference using filtering but without sacrificing their own spectrum space.

Guard space may be provided either internally or externally. Internal guard space is provided within a single license, and external guard space may be obtained through agreements between adjacent spectrum licensees to share their spectrum space.

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## Managing Broadband and Narrowband Unwanted Emissions

There are two types of unwanted emissions that may occur outside the frequency band of a spectrum license: broadband and narrowband unwanted emissions.

Under Australian spectrum licensing, the definition of a broadband unwanted emission is based on the source of the emission rather than its frequency in relation to a transmitter carrier frequency. Broadband unwanted emission means "*an emission that is a modulation product or broadband transmitter noise or caused by a switching transient*." Narrowband emissions are all other types of unwanted emissions.

The two types of emissions are treated differently because narrowband emissions are random in frequency and have a lower likelihood of interference. Therefore, because a given decibel margin relates to a specified likelihood (when

| Maximum true mean power (dBm *eirp* per 30 kHz) | Frequency offset (MHz) from limits of spectrum license |
|---|---|
| 25 | 0–0.03 |
| 6 | 0.03–0.06 |
| –9 | 0.06–0.09 |
| –13 | 0.09–10 |
| –30 | Greater than 10 |

**Table 1.** *Emission limits outside the band at 800 MHz.*

based on a propagation loss model of known variance), the limit for narrowband emission may be made higher than broadband emission, there being no reason why the likelihood of interference from the two types of emission should differ.

## 800 MHz Broadband Unwanted Emissions

Both D-AMPS (TIA/EIA/IS-138-A) and CDMA (TIA/EIA/IS-95-A) standards and actual emission spectra were considered in establishing the limit for broadband unwanted emissions at 800 MHz. Other types of services are able to operate within the resulting limits; however, additional attenuation of unwanted emissions may be required in some circumstances. The criteria on which the limits were designed were:

- The maximum power spectral density for both D-AMPS and CDMA was normalized for a typical urban system model.
- Three CDMA carriers were to be able to operate within a 5 MHz band.
- Broadband transmitter noise was based on adjacent land mobile services, but adjusted for antenna gain.
- A 30 kHz rectangular measurement bandwidth was used because it is sufficiently narrow to resolve the rolloff rate of broadband emissions at 800 MHz, and the “rectangular” measurement requirement provided a clear legal definition

Because the out-of-band emission characteristics of D-AMPS and CDMA are so different, there were two main options: one favoring CDMA and another favoring D-AMPS. And because the emission limits are specified in units of radiated power, normalization of the limits was based on 51 dBm *eirp*/30 kHz for D-AMPS and 28.8 dBm *eirp*/30 kHz for CDMA. The limits are expressed in units of “true mean power” [1], so all types of modulation were covered by the limit. After industry consultation, the D-AMPS option was chosen. This option requires a CDMA operator to use additional transmitter output filtering if three channels were to be operated within 5 MHz. It is often better to maximize the benchmark spectrum utility by isolating spectrum space through the license conditions as much as is reasonable, and then allow licensees to reduce that isolation through spectrum sharing agreements if they so desire. The limits are shown in Table 1. “Square” limits are used, that is, the limits at two ends of a specified bandwidth are equal. This method is used because a linear varying limit is unclear when the rate of change is large compared to the measurement bandwidth of 30 kHz. In addition, a linear decreasing emission envelope is usually the practical result when needing to satisfy a “square” emission limit.

For 3.4 GHz an average of the out-of-band emissions of five different types of equipment was used as the limits for broadband unwanted emissions.

## 800 MHz Narrowband Unwanted Emissions

In establishing the limit for narrowband unwanted emissions at 800 MHz, the traditional conducted limits of –36 dBm measured in a 100 kHz bandwidth below 1 GHz and –30 dBm above 1 GHz were used. However, because the limits were to be specified in radiated power, the antenna gain needed to be added. The 0 dBi gain bandwidth for a typical panel sector antenna was found to be 500 MHz–1.65 GHz. Therefore, 14 dB (antenna gain minus feeder loss) was added to the traditional limits within this bandwidth.

## 800 MHz Transient Emissions

Spurious emissions include transient emissions, and these are managed by specifying a peak power to be measured just outside the frequency band of a spectrum license. The limit, a peak power of –4 dBm *eirp*/30 kHz measured at 120 kHz offset from the frequency limits of a spectrum license, was based on the D-AMPS standard plus antenna gain and feeder loss for a typical system in an urban area. To maintain this limit the rise time of a transmitter must be limited as a function of its carrier frequency offset within the upper or lower frequency limits of the spectrum license.

## Managing Frequency Boundaries for Point-to-Point and Mobile Services

In some bands (e.g., 800 MHz), the emission limits outside the band of the spectrum license are based on levels that support the operation of mobile services using antenna gains less than 19 dBi (the typical urban cellular system model). However, fixed point-to-point services often use higher antenna gains and create levels of emission outside the band that are higher than allowed under the license conditions. Therefore, in seeking to register fixed services, it may be necessary to either provide guard bands, working well within the spectrum license, or filter the transmitter emissions. The conditions for 3.4 GHz provides two sets of emission limits outside the band: one for transmitters using narrow beamwidth antennas and another for all other transmitters. This design balances spectrum space requirements for both point-to-point and point-to-multipoint (mobile-like) services.

## Device-Specific Compatibility Requirements

Both frequency and geographic (and time) boundaries are created whenever a section of spectrum space is carved out of the continuum. In Australia, spectrum licenses have boundaries with space managed under apparatus licensing (an authorization to operate a certain device at a specified location). The interference across those boundaries is managed using compatibility requirements. Compatibility requirements are necessary for *incumbent* services (apparatus licensed services allowed to continue operation within the space of a spectrum license for a short reallocation period after an auction), or frequency-adjacent or area-adjacent apparatus licensed services.

## Indirect Compensation for Relocation of Incumbent and Adjacent Services

Adjacent services (or incumbent services) may cause significant loss of utility to a spectrum license over the term of the spectrum license. In these cases, the spectrum licensee may wish to negotiate to relocate the service. Under its legislation Australia does not provide direct compensation for the removal of services; however, indirect compensation may be achieved through this negotiation process. Indirect compensation may provide an apparatus licensee having many licenses with a strong overall negotiating position for assisted relocation of their services.

## Conclusion

The evolution of new wireless telecommunication services is now at a pace that is difficult to handle by traditional centralized spectrum allocation techniques. While there are similar trends in a number of countries, the Australian vision for spectrum licensing uses self-regulation to facilitate fast change by removing "government red tape" and allowing industry, which is better placed to respond in a more efficient manner, to decide how best to use spectrum and manage the associated economic and technical risk.

There is no need for import or selling restrictions for equipment operated under a spectrum license. The conditions of a spectrum license can act like a technologically neutral generic equipment standard, allowing many different equipment standards (or even nonstandard equipment) to operate under a harmonized equipment compliance regime with certification of equipment made a licensee responsibility at the device registration stage.

The Australian vision for spectrum licensing depends on having license conditions that maximize both flexibility and certainty for a licensee. Maximizing available options facilitates change, and maximizing certainty creates a stable basis for that change. Flexibility facilitates creativity in business plans by allowing equipment from anywhere in the world to be used. Certainty allows the design of business plans to accurately establish the spectrum space requirements for the equipment operating in a network. Auctions then allow the estimated value of that spectrum space to be tested against other competitive business plans. The result is efficient use of the spectrum and maximum return to the community in terms of rent for a valuable natural resource.

*the Australian vision for spectrum licensing uses self-regulation to facilitate fast change by removing "government red tape" and allowing industry to decide how best to use spectrum and manage the associated economic and technical risk.*

## References

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## Biography

Michael Whittaker (futurepace@ozemail.com.au), B Sc. (Physics), Grad. Dip. Electronics, has worked for the Australian government in spectrum management since 1984, pioneering automated frequency assignment systems and publishing widely in that field. He previously worked for 10 years as manager of a Nuclear Magnetic Resonance (the basis of MRI) research group at the Australian National University and has published in that field. He led the introduction of spectrum licensing techniques in Australia as chair of the Technical Liaison Group, a government-sponsored industry consultative forum, which established the license conditions for 800 MHz and 1.8 GHz spectrum licenses. He is now a director of FuturePace Solutions working part-time on a contractual basis with the Australian Communications Authority as a special adviser for the government's continuing rollout of spectrum through price-based reallocation processes. He also provides advice for prospective licensees anywhere in the world concerning the design of conditions for spectrum licenses to ensure the full definition of their spectrum access rights. He also designs and licenses device registration, and network and business planning software related to spectrum licensing.