True Technology Neutral Spectrum Licences

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FUTUREPACE SOLUTIONS*, AUSTRALIA

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AUTHORS:

MICHAEL WHITTAKER AND BARBARA PHI

FuturePace Solutions
PO Box 451
Mitchell ACT 2912
Australia

* FuturePace Solutions is the trading name of Spectrum Management International Pty Limited, a specialist consultancy in radiofrequency regulatory compliance and rooftop management.

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1.0 Introduction

When Australian spectrum licences were first auctioned in 1996 the Government encouraged industry to embrace a new system of spectrum management which would provide 15 years of operational certainty against clearly defined licence conditions for the deployment of any type of radiocommunications equipment. Fine print revealed that such deployments had to meet the conditions of the licence.

Until the recent auction of 3G licences at 2 GHz for a total of $1.17 billion, licence design techniques had been progressively augmenting an appropriate balance of flexibility and certainty, as both industry and government slowly came to grips with the science of spectrum licensing. The 3G auction marked a retrograde step. Following a design technique more attuned to traditional apparatus licensing, these licences were deliberately biased towards the use of a particular equipment standard, WCDMA. They were also partially defined, opening the door to costly and uncertain negotiation with adjacent licensees for interference management when other equipment is operated.

The Marketing Plan released prior to the 3G auction did not clearly state the likely impact of the failure to define certain aspects of the technical rules and many licensees may still be unaware of the full implications for future network deployment. Licensees assuming policy continuity would be well advised to closely examine their licences.

2.0 What does a spectrum licence offer?

A spectrum licence provides a means of authorising the use of radiocommunications devices within a defined spectrum space. The space is defined not only in terms of geographic area, bandwidth and time (the core conditions), but also through all the other licence conditions that limit access to the spectrum space for devices (the access conditions).

The access conditions incorporate levels of receiver protection from interference caused by neighbouring transmitters in either a direct or indirect manner and generally ensure equitable spectrum access on both sides of the area and frequency boundaries. Access conditions significantly affect the level of utility of the spectrum. If access conditions are biased towards a particular type of equipment it often means that it is more difficult to operate other types. This subsequently reduces the value of the spectrum for those other types.

The combination of core and access conditions does not directly manage interference, rather it creates a basis for the design of coordination rules by the licensee for the self-management of interference. The licensee coordinates with existing devices that are just outside the area and frequency boundaries of a licence and registered in the ACA's national on-line centralised data base. Registration of receivers grants priority for their continued operation when interference occurs. Australia leads the world in the development and maintenance of its national publicly available data base.

3.0 What is interference?

There are two main types of interference that must be managed by spectrum licensees:

- In-band interference; and
- Out-of-band interference.

3.1 In-band Interference

In-band interference can be caused over large distances by co-channel (same frequency) emissions from transmitters operated under area-adjacent apparatus or spectrum licences. Licensees manage this interference, by knowing, because it is specified in the licence conditions, the maximum level allowed to be radiated from any specified site in an adjacent area. Licensees then determine on a risk assessment basis, how far their receivers must be set back from the area boundary in order to cope with that allowed maximum level.

In-band interference may also be caused over short distances by the out-of-band emissions (emissions outside the nominal channel width) which are incidental to the use of a frequency adjacent spectrum or apparatus licence. A properly designed and fully specified spectrum licence will usually state the limits for the allowed levels of these radiated emissions. Spectrum licensees then manage this interference by determining the isolation requirements for their receivers with regard to the limits and the likelihood of the presence of transmitters operated under frequency-adjacent licences. Interference of this type, which is steady and continuous, can reduce the useable range of received signal levels, which in turn, for example, affects 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 and re-transmission of data.

3.2 Out-of-band Interference

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. This interference is not directly caused by co-channel emissions, but by having the energy of emissions at other frequencies transferred to co-channel frequencies through a number of special mechanisms[1]. As can be imagined, the management of out-of-band interference presents the major difficulty in designing licence conditions.

[1] ***out-of-band interference*** means interference:
(a) relating to selectivity, blocking, intermodulation immunity and spurious response immunity; and

4.0 How access conditions are biased

Spectrum licences are most often sold in a paired configuration consisting of upper and lower frequency bands separated by a large gap. This follows traditional spectrum planning methods, the intention, in the case of a mobile system, being for one band to be used by base transmitters and mobile receivers and the other by mobile transmitters and base receivers in what is called a two-frequency duplex system (FDD), with both signal paths able to communicate simultaneously. By using two very separate bands the base transmitters may be sufficiently isolated from co-located base receivers utilising frequency separation. This reduces the likelihood of out-of-band interference to acceptable levels. Spectrum licence access conditions have sought to mimic this type of use with transmitter deployment and radiated power constraints that are different in the upper and lower bands. These constraints tend to bias the access conditions towards a 'likely use' configuration.

Another form of biasing occurs when out-of-band emission limits are also chosen with regard to a 'likely use'. These levels are usually in accord with rather generous regulatory bench performance allowances. They are quite high, sometimes making it difficult to operate other equipment configurations in frequency-adjacent spectrum. Regulatory out-of-band emission masks are often not realistic and measurements of actual equipment usually outperform these masks by a significant margin. In practice, additional high quality filtering is also usually employed on transmitters which reduces the actual levels of emission substantially. Therefore, regulatory masks should <u>not</u> be copied directly into spectrum licence technical conditions. When they are copied, the need to consider that the licence conditions allow high levels of out-of-band emission militates against use of any other configuration.

(b) caused by emissions at frequencies outside the frequency band of the spectrum licence;
This definition of out-of-band interference relates to specific interference mechanisms and should not be confused with 'out-of-band emission', a term used in apparatus licensing to refer to emissions at frequencies outside a channel.

Obviously it is better to provide an initial high spectrum utility based on low levels of emission taking into account actual performance, operational practicality as well as theoretical models. Licensees may then increase those levels, if they so desire, biasing spectrum use through spectrum sharing agreements, but this should be a commercial consideration, not a technical limitation of the licence.

5.0 What is wrong with designing licence conditions around a 'likely use'?

Access conditions have been biased towards a single likely use in all previous auctions except for 1.8 GHz remote areas and 3.4 GHz. Unfortunately, use of frequency bands is often not the same around the world, European and USA spectrum allocations often differ substantially. For example, the lower band of the recently sold Australian 3G spectrum at 2 GHz is paired even lower with the 1.8 GHz band in the USA. Also, frequency bands are subject to re-planning in the longer term. Likely use today will often be unlikely tomorrow.

There are many other types of services for which biased FDD access conditions are not appropriate, for example, same-frequency operation (time-domain duplex (TDD)) where a base transmitter/mobile receiver communicate for a period and then stop while the mobile transmitter / base receiver communicate, same-frequency repeater stations and point to point services. The constraints are also often not appropriate for other band pairing arrangements.

Any bias towards one service type means that additional spectrum space will usually be required to operate other types. This creates inequities in the isolation demanded by the access conditions for different types of services. Therefore, biased access conditions lead to inefficient use of spectrum for certain equipment.

Biasing may also be viewed as simply another way in which a government can ‘pick technological winners’ even though the Australian Government have clearly stated that its policy is not to do so. It can also follow that, because of the technical complexity of the issue, some areas of government may not realise they are being led to a technically biased solution which may favour one company or technology over others. But there are implications for government which mean that a lack of such an awareness can lead to policy and cost aberrations. Owners of biased licences can sometimes lever an assumed right to limit competition from a government decision to bias licences. For example, the very high prices paid for the UK 3G UMTS licences are likely to have ramifications for policy development for 3G services in other bands in the UK well into the future. Governments can avoid these situations by providing unbiased access conditions.

There is no need for governments to take risks by biasing access conditions. Instead, spectrum licences can and should be designed upon a basic framework of true technology neutrality. After this is established, any decision to bias spectrum use, for whatever reason, may be left to industry. After the government establishes the basic neutral conditions, the decision to bias could then be taken according to industry consensus either before an auction, or spectrum sharing agreements negotiated between successful bidders after an auction. This would clearly differentiate between the basic neutral framework and added elements of technology bias and remove any in-built bias from the fundamental operation of the access conditions initially provided by government. A neutral framework reference would then assist industry in self-managing the evolution of its spectrum use over the full 15 year licence term, or permanently if perpetual licences are to be issued at some time in the future.

6.0 Achieving True Technology Neutrality

To achieve true technology neutrality, the access conditions must be designed without any bias towards an assumed likely use and therefore, be identical for both upper and lower bands. Simple access conditions and out-of-band emission limits based on mimicking a likely use would not be used. However, the conditions would still need to be capable of managing out-of-band interference for receivers and transmitters operating close in terms of both frequency and distance separation.

This can be achieved using *guard space* techniques.

Guard space methods are not new. They are commonly used to manage discontinuities in spectrum planning between different types of services such as:

- the division between CDMA base transmitters and GSM base receivers at 890 MHz;
- the division between PHS and 3G TDD systems at 1.9 GHz; and
- the division between DECT and DCS-1800 systems at 1.88 GHz.

7.0 How does guard space work?

Guard space, consisting of both guard *band* and/or guard *area*, may be created by spectrum licensees deliberately not using their own spectrum space. A guard *band* may be created by not operating transmitters on frequencies that are near the frequency boundaries of licences. The objective of creating this internal guard *band* is to allow a frequency-adjacent licensee to utilise it for the operation of the roll-off of a filter they would need to protect their receivers. The objective of creating a guard *area* is to allow an area-adjacent licensee to utilise it to help isolate their receivers that are located at high sites near their area boundary. Note that it is also possible to design access conditions that require guard space to be shared with, or even fully provided by, an adjacent licensee. Shared guard space would obviously be the most equitable solution.

The amount of guard space required for a specific situation may be estimated on the basis on a fully defined minimum receiver performance (or notional receiver). This usually includes a full description of the RF and IF selectivity (receiver input filtering) together with a compatibility requirement defined as the likelihood of a maximum unwanted power spectral density at the receiver input. In the past, reasonably concrete models have been used. However, there would be no difficulty in stripping away the physical model to its simpler more mathematically abstract form. The receiver model, together with models for in-band and out-of-band interference mechanisms, are then used by a licensee to calculate the minimum guard space requirements for a particular transmitter. Similarly, the minimum necessary additional internal guard space requirements for the operation of a receiver that does not operate better than the minimum receiver performance may also be calculated when licensees wish to operate those types of receivers.

8.0 Guard Space in Practice

Minimum guard band and guard distance for the co-existence of dissimilar 2 GHz cellular systems based on managing transmitter wide band noise and receiver blocking[2] is discussed in reference [1]. Given sufficient guard band, the respective base stations can be co-located as long as vertical antenna separation is used to achieve the necessary additional isolation.

Unfortunately, many guard band studies have used inappropriate equipment models, for example, the high levels of regulatory emission masks discussed earlier, and usually propose a larger guard band than actually necessary. Other equipment models can also be inappropriate, for example, models for handset power at a cell edge, handset sensitivity and propagation in the near

[2] Intermodulation effects can also be the limiting form of interference.

field all need to be accurately modelled [2] to arrive at real guard band requirements. Guard band requirements between two adjacent CDMA operators is examined in [5].

In the case of asymmetric services with high data throughput in one direction, for example, video on demand, only one band of a FDD service would be required, hence utilising TDD in FDD spectrum could potentially double the spectrum utility. A true technology neutral spectrum licence would allow TDD operation in so-called FDD spectrum and fully define the conditions under which it would be allowed to occur. Studies [3] show that TDD and FDD base stations operating in adjacent bands can be co-located if the amount of power reaching the receiver, due to imperfections in physical implementation of the transmitter and receiver, is more than 70 dB below the total transmitter power. This power ratio is referred to as the Adjacent Channel Interference Ratio (ACIR). Reference [4] recommends an increase in ACIR above a proposed 30 dB to ensure that data capacity is not reduced through interference when competitors operate in adjacent spectrum. The full definition of the minimum receiver performance for a spectrum licence is central to the value of ACIR.

9.0 What is wrong with the Australian 3G licences?

Unfortunately, the Australian 3G access conditions do not include the necessary full definition of the minimum receiver performance. Given that the concept of a fully defined notional receiver applies in traditional apparatus licensing it is difficult to understand the reasoning behind its excision from the 3G framework, unless the rush to auction to allow the predicted $2.6 billion input to the Revenue was the catalyst. In the event both the technical rigour of the licences and the budget predictions were unmet expectations. Instead of providing 15 years of operational certainty, the 3G licences potentially allow for 15 years of negotiation. Especially if, as equipment and technology develops, a licensee wishes to deploy something other than WCDMA. And this is highly probable in a highly creative industry dedicated to the creation of new and better technical solutions.

The decision to provide biased and partially defined access conditions will inevitably create difficulties. Importantly the resolution of interference problems will now be problematical without a clear indication of exactly which carrier is at fault and which needs to act and at what cost. Now that the spectrum has been sold a solution is likely to require the agreement of all licensees. However, any 3G licensee not yet ready to use its spectrum could, by drawing out negotiations, act in the market place to deliberately impede competitors wishing to be first in the marketplace.

10.0 True Technology Neutrality in Practice

If access conditions are defined on the basis of guard space, to achieve a fully defined benchmark of true technology neutral utility, licensees could negotiate additional spectrum sharing arrangements, as they do now, to bias the access conditions taking advantage of any new overseas developments as they occur but without the complexities caused by in-built bias. A decision to bias spectrum use would then be in the hands of industry rather than government. And, any bias would also have been reversible by industry without government involvement. This would represent a change in the state of the art of licence design, and significantly add to an increasingly self-regulated communications sector.

As more and more spectrum is managed under spectrum licensing, true technology neutrality would enable a licensee to use band pairing consisting of one band from a current auction and another from a previous auction. This will be an essential requirement for industry if perpetual licences are to be issued at some time in the future.

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About FuturePace Solutions

Spectrum Management International Pty Limited, trading as FuturePace Solutions, is a privately owned company operating since 1997 and headquartered in Canberra. FuturePace has two Directors, Michael Whittaker who was principally responsible for designing the Australian 500MHz, 800MHz, 1.8GHz, 3.4GHz and 28/31 GHz spectrum licensing technical frameworks and Barbara Phi who handles business development and administration.

The company specialises in the certification of RF regulatory compliance and EMR risk hazard management following the out-sourcing by the ACA of much of their liability in relation to their certification function. FuturePace has a long-term commitment to professional research and the development of general and cost effective spectrum solutions for network, regulatory and public interest matters. They may be reached at www.futurepace.com.au or by e-mail at futurepace@bigpond.com.

