Interference Mitigation - the Impact for New Mobile Broadband Wireless Access (MBWA) Systems

David Brunnen
Director
ABFL Groupe Intellex
david.brunnen@groupe-intellex.com

Donald Pearce
Associate
ABFL Groupe Intellex
donald@pearce.uk.com

Abstract

As competition increases for spectrum suitable for mobile broadband systems the challenges of making effective use of relatively narrow spectrum bands highlight issues of adjacent channel Interference Mitigation for protection of (and from) existing mobile services. Some guard bands have been reviewed and found to be unnecessary. In other cases the Interference Mitigation conditions imposed by regulators may compromise the potential utility of spectrum. This paper uses recent examples to explore how novel MBWA systems and fresh approaches to Interference Mitigation assessments can bring additional spectrum into effective use.

1. Introduction

The general long term evolution of wireless systems illustrates how global communications capacity measured in terms of concurrent conversations or sessions has multiplied as result of improved understanding of RF propagation, advances in Frequency Division and Time Division techniques but, above all, by virtue of Spatial Division; i.e. localised reuse of spectrum as typified by cellular mobile systems. [1]

The design requirements for Mobile Broadband Wireless Access (MBWA) systems demand a balance between throughput, coverage and mobility. Where wide-area full mobility is defined as embracing both indoor penetration and physical transport speeds up to 120km/h, the issues around the particularly desirable spectrum in the region of 1.6GHz – 2.3GHz become extremely challenging.

The traditional precautionary approach to mitigation of adjacent channel interference was represented by the adoption of guard bands and it is a reflection of competitive demand for spectrum that the requirements for these have come under intense scrutiny and in some cases have been released for alternative use, for example the DECT guardbands.

The pressure for additional spectrum for mobility applications focuses even greater attention on issues of interference mitigation especially where physical co-location of different systems is required to satisfy the planning requirements for the built environment.

In addition to these challenges it has become increasingly apparent that there are wide differences in regulatory guidance that partly reflect (a) the limitations of generalised propagation theory, (b) empirical results that may be influenced by a wide range of localised conditions, (c) the possibility of commercially-led arguments around issues of incumbent market protection and (d) the determination of regulators to sustain ‘technology neutral’ spectrum management policies.

This paper reviews current guidance, the differences between theoretical studies and actual deployments, and examples of the impacts of fresh design approaches on interference mitigation.

2. Current Guidance

The current design guidance on interference mitigation for the adjacent co-existence of different mobile platforms has focused on the general distinctions between FDD and TDD cellular systems.

ITU-R Working Party 8F undertook some studies in 2003/4 and issued two reports. The first report, ITU-R M.2030, looked at UMTS-FDD v. UMTS-TDD operating in adjacent bands in the 2.5 GHz range. That report essentially said that there were coexistence issues between adjacent band TDD and FDD systems. WP8F then developed a report, M.2045, that showed that there were a number of techniques operators could use (with some costs) to address those coexistence problems.

Work has now continued in WP8F looking at adjacent band coexistence of IMT-2000 (actually UMTS-TDD and UMTS-FDD) with (a) Fixed/Nomadic BWA systems and (b) with Mobile BWA systems. In working on those reports, the validity of the propagation models (those used in M.2030 and consequentially in M.2045) has been questioned.

Further examination now suggests that the propagation models used in M.2030 and M.2045 are seriously flawed and understate the path loss between the adjacent band systems by as much as 15dB. This means that the coexistence problem has been grossly overstated. In some deployments the old propagation model may have imposed a requirement for coordination where none need exist.

Corrections to the work are currently underway to confirm the appropriate propagation models for coexistence studies of this nature and WP8F is considering the need to revise and/or withdraw reports M.2030 and M.2045.. This development may, in part, explain why empirical observations produce results that are so much better than anticipated from analytical studies using the earlier models.

As an example of current practice, the interference mitigation requirements for the coordinated licensing of the band 1785-1805MHz in the Republic of Ireland and Northern Ireland (part of the UK) is illustrated in Figure 1. [2]

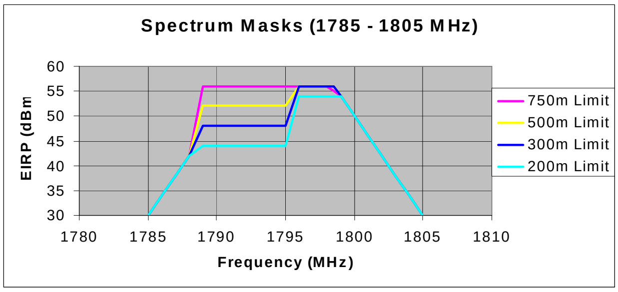

Figure 1. Spectrum mask

The spectral context for this specific set of requirements is given in Figure 2 which shows the location of GSM operations above and below the band.

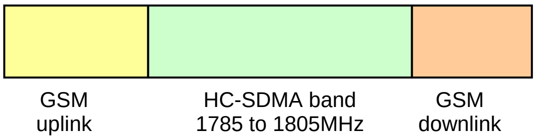

Figure 2. Extent of the band

It can be seen in Figure 1 that the impact of these requirements allows only a 7MHz central band to be available at full power. Potential licensees had therefore to give very careful consideration to the type of system that might be deployed and the economic impact of these usage restrictions.

Sensibly the full burden of these mitigation requirements is not intended to apply in environments where the new system base stations are fully coordinated with the adjacent pre-existing GSM locations. The example does however illustrate the deployment difficulties for systems such as IEEE802.16e (requiring a minimum band of 21MHz) even if these were to be manufactured outside of the current standard for the attractive frequencies below 2.3GHz.

3. Theory vs. practice

In practice, things are seldom this constrained. A new operator who has to ease himself in amongst a set of incumbents is likely to be just as a much a victim as a cause of interference, so it is not in his interests to deploy his equipment in such a way as to be potentially harmful.

There are plenty of weapons in the mitigation arsenal one can deploy, each of which can win upwards of 10dB of isolation.

Hide them

A first obvious one is to make use of building structures to block the line of sight to the neighbour. This might be something as trivial as a rooftop equipment room, but it may well be enough to save a potentially troublesome situation.

Stack them

Where it is not possible to achieve this and the two systems must be close to each other, as much as 30dB of additional isolation can be achieved by tower sharing. Antennas located above each other couple very poorly and the interference level will be far lower than would have been the case if they were on, say, adjacent rooftops. This is a solution that is well received by both planning authorities and the environmentally concerned.

Stagger them

Then there is the opportunity to deploy at different heights. In a dense metropolitan environment it may well be that the mobile phone network is not deployed on rooftops, but for operational reasons is further down the buildings; picocell isolation may demand this. In these circumstances, a system that can deploy larger cells may move higher up the buildings, and make use of the vertical off-axis response of the antennas to achieve isolation.

Don't let them talk

Newer technologies also play their part. Where the latest designs of adaptive DSP radio systems (also, but perhaps misleadingly, called adaptive antennas) are used, they will actively prevent interference from reaching their neighbours. For example, the HC-SDMA system will see a neighbouring GSM system as a source of interference, and in defining its receiving profile from a mobile user, will seek to minimise the pickup of signal from the GSM. This will put the GSM system in an effective radio null from the HC-SDMA system. Now, when the HC-SDMA base station transmits, using an inversion of that profile, the GSM base station will again be in the same null and will be spared the full force of the possible interference.

So if we summarise the possibilities for interference mitigation, which can be applied individually or (in some cases) together we see:

Prevention of line-of-sight	>10dB
Tower sharing	>30dB
Height difference	>15dB
Adaptive antennas	>20dB

So by combining, say, height difference and adaptive antennas, 35dB of added interference mitigation can be expected. If this is applied to the co-ordination mask in Figure 1, it is clear that even minor attention to detail in deployment can render the co-ordination question almost trivial – certainly most sub-200 metre deployments for the example in Figure 1 could follow the co-ordination requirements for systems beyond 750 metres. This does depend, of course, on active co-operation between incumbents and newcomers, a process that may in some instances require the mediation of the regulator.

These techniques, particularly the adaptive antenna, are the shape of the future, but, given current knowledge, it is difficult for regulators to include such mitigation techniques into necessarily conservative and technology-neutral co-ordination requirements. However, as more of these systems are built and are seen to coexist without problem, it will be vital to include such mitigation techniques into co-ordination processes from the outset, and greatly ease the bureaucratic complexity of new rollouts.

4. Fresh design approaches

Mobile systems deploying adaptive antennas are to date more commonly found in Asia-Pacific and African Regions than in the USA and Europe – although deployments have recently emerged in Canada, South Dakota, The Netherlands, Denmark and Norway and have been trialled elsewhere. Figure 3 shows a city-centre roof-top in Yokohama, Japan, that accommodates three generations of multiple antenna systems – the early 2 antennas of the popular PHS system, the 8-antennas of the WLL design and the more-recent 12-antenna system codified in 2005 by ATIS/ANSI as HC-SDMA and a candidate technology for IEEE 802.20.

Figure 3. Three generations of antenna

The studies undertaken in 2006 for a deployment of HC-SDMA systems in Malaysia provide useful insights into the performance of these systems at around 1.8GHz in a dense urban environment with spectrally adjacent GSM systems.

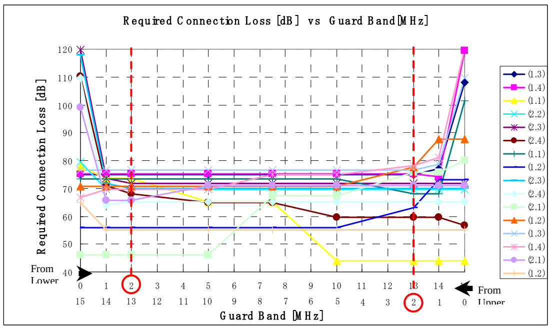

Figure 4. Guardband calculations

The view emerging from these studies, and now confirmed in practice, shows that this type of Adaptive Antenna System produces remarkably low interference levels on account of its ability to dynamically avoid cell coverage regions containing interfering sources. Similarly it is unaffected by incoming interference from GSM stations.

The result is that the guardband required for this environment is in practice no more than 2MHz as shown in Figure 4.

5. Conclusion

The economic impacts of this technological innovation are profound. Fully mobile broadband systems can now be accommodated in relatively narrow bands that cannot be utilised by older designs.

It is not simply that TDD systems (using unpaired rather than paired spectrum) provide superior coverage and capacity relative to traditional designs. The major benefit derives from the massive spectral efficiency that can be achieved when systems are designed from the outset to exploit the full potential of spatial division offered by adaptive antenna signal processing.

The scope for increased competition and customer choice becomes an important factor in regions where communications services are relatively under-developed. Under these conditions a single 20MHz band might now, from a purely technological viewpoint, be considered sufficient to accommodate two or possibly even three competing operators. This would represent a vast expansion of potential spectral capacity compared to the traditional approaches typified by the demands of some groups for additional MBWA spectrum. However, a predisposition to favour specific technologies does not sit comfortably with neutrality in regulatory policy.

Even where the encouragement of infrastructure competition is not a major regulatory objective it is possible to see the value of these designs in situations where legacy spectrum users are currently blocking more effective use of small bands.

In a climate where attention may increasingly be focused on waste and pollution of the airwaves it is expected that the issues of (and techniques for) Interference Mitigation between different MBWA design generations will require a reduction of the distance between theoretical and practical considerations.

6. References

[1] Cooper's Law. Dr. Martin Cooper http://www.arraycomm.com/serve.php?page=Cooper

[2] Co-ordinated Auction of Spectrum 1785 - 1805 MHz - Information Memorandum. Ofcom and Comreg.
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