



Telecoms Infotech Forum

Briefing paper

# Radio spectrum issues in Hong Kong

*Plus*

## Avoiding another cable blackout?

February 2007

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# Telecoms InfoTechnology Forum

The TIF is an industrial forum run on a regular basis by the Telecommunications Research Project (TRP) at the University of Hong Kong. Dr John Ure, associate professor and director of the TRP, and Dr Peter Lovelock, deputy director of the TRP, are also the directors of TIF.

In 2006 the TRP Corp (<http://www.trp.hku.hk/profiles.html>.) The TRP provides background briefing papers for each TIF and posts these together with presentations and proceedings papers on the website.

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<sup>1</sup> The TRP also provides consulting, research and training services.

## Briefing Paper I: Radio Spectrum Policy in Hong Kong

1. Shannon's radio production function:  $I = B \log(1 + S/N)$  btps

I = capacity offered to user

B = bandwidth available

S = receiver power (in watts)

N = noise level: (i) natural, (ii) man-made, (iii) interference

'this negative externality has provided the most convincing arguments for public management of frequencies, and against market mechanisms' (Jens C. Arnbak 'Managing the Radio Spectrum in the New Environment'<sup>2</sup>)

2. Incredibly, these fish can adjust the frequency of the electrical pulses to avoid interference problems. (Fish tank, *London Zoo Aquarium*, visited 2002)

### The Discovery of Frequencies and the Invention of Radio

In 1866 an American dentist and amateur inventor Mahlon Loomis gave the first demonstration of radio telegraphy or telegraphy without wires. Scottish physicist James Clerk Maxwell in the 1860s had predicted the existence of radio waves, and in 1886 the German physicist Heinrich Hertz was the first to demonstrate them – rather than just their effects – by passing an electric current through a wire antenna and measuring the waveform of electro-magnetic emissions. The measurement of frequencies or oscillations per second has been measured in Hertz. (Hz) – radio waves in megahertz (MHz) – ever since in honour of his name. But it was the Italian inventor Guglielmo Marconi who in 1895 first succeeded in sending a radio telegram any real distance, across the Atlantic Ocean in 1901, although according to a US Supreme Court ruling, Marconi was not the first to patent radio transmitting technology. That honour was awarded to Nikola Tesla, son of a Serbian Orthodox clergyman, who also invented fluorescent lighting.

Among the many inventors working around radio waves was Lee DeForest who in 1907 patented the 'audion' using a three-electrode (triode) vacuum tube to boost the volume of the radio waves, making possible what became called 'wireless telephony' that allowed voice, music, or any broadcast signal to be clearly heard. In other words, he invented amplitude-modulated or AM radio that allowed for the first time a multitude of radio stations. Central to all efforts to provide spectrum to meet demand is the need to avoid interference, and amplifying a signal while keeping its frequency constant is one way to do this. Frequency modulation (FM) does the opposite.<sup>3</sup> Edwin Howard Armstrong in 1935 invented the FM technique. In modern wireless telecommunication systems, alongside frequency division multiple access (FDMA) other modulating systems in use include time division multiple access (TDMA) and code division multiple access (CDMA), time division synchronous cdma being developed by China (TD-SCDMA),

<sup>2</sup> See <http://lirne.net/live/content/view/7/42>

<sup>3</sup> See [http://en.wikipedia.org/wiki/Image:Amfm\\_klein.gif](http://en.wikipedia.org/wiki/Image:Amfm_klein.gif) for a nice animated diagram to illustrate the difference.

dynamic assignment multiple access used by satellites (DAMA), and next generation technologies that include artificial intelligence built into smart antennae such as switched beam and adaptive array antennas, software defined radio (SDR) such as 'cognitive radio, orthogonal frequency division multiple access (OFDMA), spread spectrum techniques, dynamic random access code assignment (DRACA), the use of mesh networks which utilize all active terminal devices as transceivers to grow the network organically, and so on.

### Spectrum as a Scarce Resource

During the early years of radio communications spectrum was generally unregulated. The sinking of the *Titanic* on 14<sup>th</sup> April 1912 revealed that radio distress signals were not picked up by a nearby ship because the ship has turned off the radio for the night. The subsequent Radio Act of 1912 in the US started the process of bringing spectrum usage under licensed control, requiring licence holders to restrict themselves to certain frequencies to avoid interference and to prioritize distress signals. The Frequency Radio Commission (FRC) was created by the Radio Act 1927 to manage spectrum as a national asset.

Avoidance of signal interference remains the greatest challenge as the demand for certain frequencies grows ever stronger. For example, in countries like India where the military and government agencies control large swathes of the spectrum, a shortage of spectrum is beginning to cause severe quality of service problems for urban cellphone users. In Hong Kong's 2006 consultation exercise on the issuing of frequencies for broadband wireless access (BWA) several existing commercial users, notably satellite networks, complained about potential interference problems. Modern spectrum management is about allocating spectrum –including re-allocation or 'refarming' – to new *uses* and then assigning spectrum to new *users* in a way that (a) avoids undue interference problems, (b) reserves sufficient spectrum for public (non-commercial) services deemed to be essential, and (c) increasingly sees the need for spectrum to be used in the most productive ways. Licensed spectrum applies to areas in which these problems are likely to arise, while unlicensed spectrum is good for non-contested frequencies, e.g. use of microwave ovens, or 'commons' usage, including many near field communications (NFC), e.g. wireless unlocking devices for automobiles and doors, low-powered indoor WiFi networks, Bluetooth, etc.

### The ITU and the Supply of Spectrum

The supply of spectrum is generally governed by the recommendations of the ITU's World Radio Conferences (WRC) held every 2-3 years. The last one was 2003 and the next October-November 2007. The ITU's three regions are

- Region 1 = Europe and Africa
- Region 2 = Asia (Oceania)
- Region 3 = Americas

Each region tends to coordinate allocations to similar uses, but is not bound to other than by self-interest and economics. The first step is to identify bands of spectrum that should

be ‘allocated’ to different uses, which may be multiple. In some cases exclusivity is recommended, in other cases ‘shared’ use by different classes of service in which ‘primary’ which takes preference over ‘secondary’ and in other cases no priorities are recommended. Exclusivity usually applies to the more mission critical areas of usage or to sensitive public policy areas such as broadcasting. Various categories and sub-categories of usage are identified: fixed, mobile, broadcast, amateur, inter-satellite, technical and scientific. See slides at the end of the paper for details.

National regulators first construct their own frequency management plans,<sup>4</sup> then decide about how to make the frequencies available to users. Important frequencies are ‘assigned’ through a licensing process and selected by several methods: first-come-first serve in cases where there is no shortage of spectrum, the beauty-contest where choice between bids is an administrative and sometimes a political process, auctions, and so forth. Where frequencies are used for international communications and could cause interference problems, they are usually entered into the Master International Frequency Register (MIFR) run by the Radiocommunications Bureau of the ITU.

### Spectrum Markets?

The important point in all this is that the supply of spectrum in the most sought after bands is constrained through the acceptance by regulators of the recommendations of the WRC. This fact alone limits the degree to which the use of spectrum can be market driven, far less market determined. However, two factors are rebalancing the scales. First, there is a growing acceptance that market-type reforms are the best way to achieve a more efficient use of spectrum, and second, that advances in micro-electronics are allowing commercial users to come up with ‘intelligent technologies’ that, like the fish at the London Zoo Aquarium, internalize the harmful ‘externalities’ of interference.

Spectrum as a scarce resource is traditionally regarded as a public good in the sense that its use does not diminish its availability to others. For example, people who receive radio or TV over the airwaves do not deny others from doing likewise. But once it becomes fully utilized it is no longer available for other *uses* and interference diminishes its value to *users*. Techniques to search for the next available channel, to re-use and re-assign spectrum on demand are making big strides to overcome these limitations, but not all spectrum can be allocated on a ‘commons’ basis. Market values then enter the picture. and that is where the analogies with land come in.

#### *The Land Analogy*

Like land, the supply of spectrum is limited but its availability can be increased. The re-use and reallocation of spectrum is like land zoning changes and changes of usage. In the case of Hong Kong, change of usage requires the payment of premiums and this could also apply to spectrum if the CITB choose this option, which looks unlikely according to the CITB’s *Consultation Paper on Proposed Spectrum Policy Framework* where it suggests Hong Kong should defer liberalization and ‘monitor its developments in other jurisdictions’ (paras 14, 69).<sup>5</sup> Digital compression techniques are like the building of

<sup>4</sup> For OFTA’s allocations, see <http://www.ofta.gov.hk/en/freq-spec/main.html>

<sup>5</sup> See [www.citb.gov.hk/ctb/eng/paper/index.htm](http://www.citb.gov.hk/ctb/eng/paper/index.htm)

taller and higher density buildings, while spread spectrum techniques and directional antennae may be analogous to a ‘flexible office’ to save floor space and to tele-working, and so on. Even frequency interference can be likened to noise and atmospheric pollution from nearby land sites. And like land, companies that can accumulate it may end up reaping monopoly rents, which is the universal concern about allowing market forces replace spectrum management policy. There are other concerns as well.

Among other concerns is spectrum hoarding to deny entry to new competitors. The introduction of ‘administered incentive pricing’ (AIP) for spectrum which looks to place an ‘opportunity cost’ on the use of spectrum – an alternative method looks to estimate the discounted flow of future expected earnings – may not be sufficient to deal with this problem. Opportunity cost can only be estimated and there are different ways to do this, for example OFCOM in the UK uses the least cost alternative, but a company set upon hoarding to create a barrier to entry will offset the gains from its market strategy against this opportunity cost however it is calculated. Therefore other regulatory powers are required to protect consumers against predatory behaviour, such as spectrum ownership caps which need to be stated early in the process, *ex ante* regulatory approvals for trades, M&A powers and competition laws and policies.

#### *The Economics of Spectrum Pricing and Secondary Markets*

The arguments in favour of spectrum pricing, spectrum trading and spectrum liberalization in terms of technology neutrality and more radically service neutrality are pretty clear cut, at least in terms of abstract economic principles. But in practice there are many issues to confront.

#### *Allocation:*

1. **WRC** recommendations restrict supply – but WRC recommendations over time include re-farming in response to changes in markets and technologies
2. **Liberalization** at national levels would introduce flexibility of usage, allowing markets to decide on how spectrum is used and for which class of services – certain bands will be exempted on the grounds of national security, public interest, government policy, etc.
3. **Harmonization** could be lost if liberalization of usage takes place – services of high value in one country may capture spectrum that is used for other services in other countries, hindering international roaming and economies of scale in equipment production and standards.

#### *Assignment:*

1. **Auctions** are increasingly the preferred method to reflect the value of the services to be provided – but we should note that as the future value of new services is unknown, the winners of auctions will tend to be those with higher than average expectations and when they get too high they give rise to the ‘winner’s curse’ despite appearing consistent with static efficiency.<sup>6</sup>

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<sup>6</sup> In their report to the CITB, Ovum remark that collecting 3G royalties has proved problematic due to the use of network turnover rather than gross turnover, making it subject to the different business models used by the operators. (see p.53 and p.92)

2. **Trading** could resolve this problem so that spectrum going to the wrong places due to miscalculations can be redistributed to those with sounder commercial judgment producing dynamic efficiency – if trading is to be encouraged spectrum may need to be broken into tradable units of some sort, and ground rules established covering outright sales, short and long leasing, buy-back arrangements, spectrum aggregation or sub-division, and the role of spectrum managers, traders and spectrum exchanges.
3. **Liberalization** allowing the buyer of spectrum in secondary markets to change its use if commercially justified will also serve dynamic efficiency – but see the ‘harmonization’ point above.
4. **Spectrum Pricing** is mostly calculated on the basis of the cost of administration of spectrum management in the form of spectrum utilization fees (SUF) but a more market-driven approach would introduce opportunity cost-based administered incentive pricing (AIP).<sup>7</sup>

#### ITU-BDT Fee Charging Formulae

Fee charging:  $F = D_i$  or  $F = f(D_i, L_i I)$

F = fee charged;

$D_i$  = direct administrative cost of processing licences;

$L_i$  = licence’s proportion of indirect administrative cost;

I = total indirect administrative costs

Revenue-based:  $F = f(a, R)$

F = fee charged;

a = proportionate fee established by regulator;

R = user revenues.

Incentive or Opportunity Cost fees:  $F = f(B, G, L, E, T)$

B = bandwidth;

G = geographical area;

L = location;

E = exclusivity of use;

T = target revenues.

Incentive: T is set arbitrarily by administration

Opportunity Cost: T approximates to market value of spectrum

### The European Approach

To meet the requirements of the Lisbon Agenda,<sup>8</sup> a spectrum policy project, known as WAPECS (Wireless Access Policy for Electronic Communications Services) was initiated and in 2004 was reviewed by the Radio Spectrum Policy Group (RSPG) of the

<sup>7</sup> This shifts from cost to price narrows the gap between the prices of spectrum (the return to the owner) and the value of spectrum (the return to the user) and would capture part of any economic rent that may arise.

<sup>8</sup> A policy strategy for promoting productivity and competitiveness across the EU by 2010, agreed in 2000 in Lisbon, Portugal.

European Commission. WAPECS delineated various spectrum bands under the generic headings: broadcasting, fixed below 6 GHz, mobile, and short range devices.

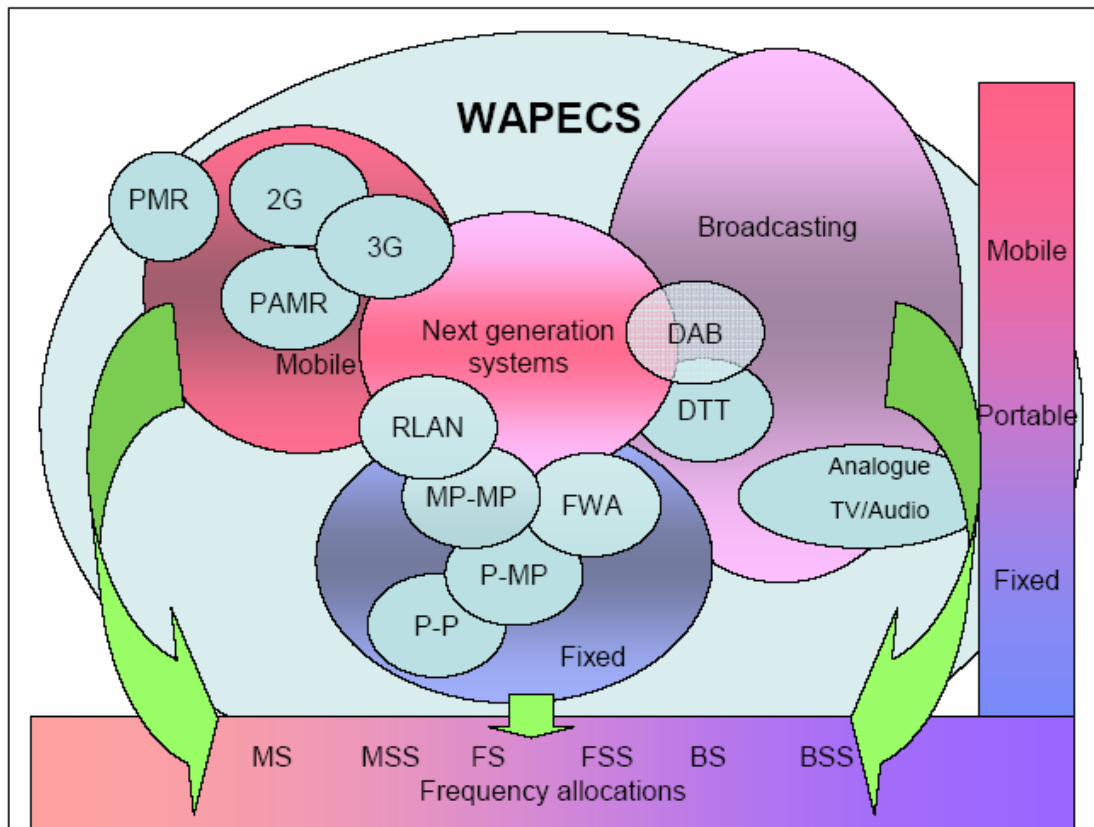


Figure 1. WAPECS Concept

Abbreviations in Figure 1			
2G	Second generation mobile	MP-MP	Multipoint to Multipoint fixed links
3G	Third generation mobile	MS	Mobile Service
BS	Broadcasting Service	MSS	Mobile Satellite Service
BSS	Broadcasting Satellite Service	P-MP	Point to Multipoint fixed links
DAB	Digital Audio Broadcasting	P-P	Point to Point fixed links
DTT	Digital Terrestrial Television	PAMR	Public Access Mobile Radio
FS	Fixed Service	PMR	Professional (Private) Mobile Radio
FSS	Fixed Satellite Service	WAPECS	Wireless Access Policy for Electronic Communications Services
FWA	Fixed Wireless Access	RLAN	Radio Local Area Networks

The term WAPECS is used to signal a move away from too narrowly specified allocations and applications, for which specific spectrum is designated. Under this definition of WAPECS, digital technologies are stimulated to deliver all electronic communications services within their capabilities, making use of any frequency band and networks. However, this is subject to technical coexistence

requirements which are tailored to each specific band. (RSPG Opinion on WAPECS, Final - November 23, 2005)<sup>9</sup>

Among the long term policy goals spelt out by the RSPG is service neutral regulation. ‘No frequency band should be reserved for the exclusive use of a particular ECS. This is without prejudice to any obligation to provide some specific service in a specific band or sub-band, e.g., broadcasting or emergency services. In effect, RSPG is foreshadowing convergence of technologies and the services they can deliver, a development that seriously questions the longer term relevance of the traditional approach to both spectrum allocation and assignment.

The table [6] comes from a report by Analysys et al. in 2004 identifying frequency bands particularly suited to trading and liberalization. It is cited along with table [7] which summarizes the frequency bands identified by WAPEC from an ITU report in 2006 on the future regulation of mobile multimedia services.<sup>10</sup>

**Table 6: Frequency bands particularly suited to trading and liberalisation**

<b>Introduce trading and liberalisation throughout Europe in frequency bands currently allocated to the following services</b>	<b>Introduce trading (liberalisation optional) throughout Europe in frequency bands currently allocated to the following services</b>
<i>Broadcasting – satellite</i> – for space-to-Earth links if and where a recognised spectrum access environment is deemed appropriate	Broadcasting – terrestrial (with a review of the case for liberalisation following the 2005 ITU Regional Radiocommunications Conference)
<i>Fixed links</i> (where usage rights are assigned exclusively to individual users)	Land mobile – private mobile radio (where usage rights are shared between users and the Spectrum Management Agency (SMA) undertakes co-ordination of individual users)
<i>Fixed wireless access</i>	Fixed links (where spectrum rights are shared between users and the SMA undertakes coordination of individual users)
<i>Land mobile – private mobile radio</i> (where usage rights are assigned exclusively to individual users)	
<i>Land mobile – public mobile networks</i>	
<i>Satellite (fixed and mobile)</i> – for space-to Earth fixed links if and where a recognised spectrum access environment is deemed appropriate; for mobile, subject to assessment of current co-ordination practices	
<i>Special user groups</i> (military, public safety, public transport), subject to ensuring that essential services are not disrupted	

Source: Analysys et al (2004): Summary of report no. 78.

<sup>9</sup> See <http://www.ilr.etat.lu/freq/docs/RSPG05-102.html>

<sup>10</sup> Analysys, et al. (2004) *Study on conditions and options in introducing secondary trading of radio spectrum in the European Community*; [http://www.analysys.com/pdfs/ofcom\\_report/final\\_report230.pdf](http://www.analysys.com/pdfs/ofcom_report/final_report230.pdf); ITU (2006) *Towards More Flexible Spectrum Regulation and its Relevance for the German Market* [http://www.itu.int/osg/spu/ni/multimobile/papers/MMS\\_flexiblespectrumstudy\\_060606.pdf](http://www.itu.int/osg/spu/ni/multimobile/papers/MMS_flexiblespectrumstudy_060606.pdf)

**Table 7: Frequency bands identified for WAPECS**

Broadcasting bands	174–230 MHz 470–862 MHz 1452–1479.5 MHz	
Fixed links/point to point (P2P)	5925–6425 MHz, 3600–4200 MHz, 1375–1400 MHz, 1492–1517 MHz, 1427–1452 MHz and 1350–1375 MHz	
Point to multipoint (P2MP)	(without MWS) 3400–3800 MHz, 24.5–26.5 GHz (with MWS) 24.5 GHz–26.5 GHz	
Mobile services	380–400 MHz 410–430 MHz 450–470 MHz 870–876 MHz 880–921 MHz 925–960 MHz	1710–1785 MHz 1805–1880 MHz 1900–1980 MHz 2010–2025 MHz 2110–2170 MHz
Unlicensed bands	1880–1900 MHz (DECT) 2400–2483.5 MHz (RLANs) 5150–5350 MHz (RLANs) 5470–5725 MHz (RLANs)	

Source: RSPG

## World Trend in Spectrum Trading

<b>Spectrum - Secondary trading</b>		
<b>Countries</b>	<b>Secondary Trading is allowed</b>	<b>Change of Spectrum Use Permitted on Transfer</b>
El Salvador	v	
Australia	v	v
Bulgaria	v	
France	v	
Hungary	v	
Ireland	v	
Poland	v	v
Slovenia	v	
Spain	v	
Sweden	v	
United Kingdom	v	v

Source: ITU World Telecommunication Regulatory Database 2005

Source: <http://www.ictregulationtoolkit.org/en/Section.2094.html>

### *Trading within Bands*

The argument for trading is that it promotes dynamic efficiency over static efficiency,<sup>11</sup> and by providing a mode of exit it facilitates new entry and market competition. Trading in cases where the use of the spectrum is fixed – which usually implies a form of apparatus licensing, such as 3G licensing – only implies changes of ownership or rights of usage where the spectrum may be aggregated or sub-divided by time and/or space.

### *In-band Migration/Service Liberalization*

In-band migration is service liberalization within an allocated band. ‘Jurisdictions in the Americas and Asia have used this policy with the introduction of IMT-200 systems, allowing existing mobile operators to provide third generation (3G) networks in their assigned frequencies.’ [ICT Regulation Toolkit, *infoDev*.<sup>12</sup>] In other words, holders of non-3G licences can offer 3G-type services. Full service liberalization would allow traded bandwidth to be used to provide services associated with other band allocations. Besides the danger of interference – this problem could be handled by granting ‘receiving rights’ as well restrictions on geography, frequencies and transmission power – unregulated liberalization raises the risk of undermining international harmonization of band usage.

### *Australia and New Zealand*

**Australia** allows spectrum trading by private arrangements, trading exchanges or band managers, within bands but subject to an ‘interference management framework’ governing each set of auctions. Standard Trading Units (STUs) are defined by geography and bandwidth boundaries for up to 15 years without guarantee of renewal, and trades must be registered. In cases of interference disputes the first to register is given priority. There is flexibility on spectrum use for new services, such as citywide wireless access in 2.3GHz and 3.5GHz.

**New Zealand** auctions exclusive spectrum management rights for up to 20 years which allows the owners to assign tradable spectrum licences. The low level of trades has been attributed to the large supply of spectrum for management rights. Spectrum caps and competition laws are guards against the threat of concentration and hoarding.

### *El Salvador and Guatemala*<sup>13</sup>

**Guatemala** since 1996 has granted TUFs (‘title to usufructory frequency’ rights) on renewable 15-year leases with specified technical limitations governing the power transmission and emission. There are no limitations on either the technologies used or the services provided. ‘The result is perhaps the most liberal spectrum regulatory policy in the world.’ (Hazlett and Ibarguen, p.6) Over 40% of TUFs have been traded.

<sup>11</sup> ‘The volume of trades is unlikely to be large initially unless current assignments are highly inefficient.’ Ovum, et al. (2006) *Spectrum Policy Review: Final Report to CITB*, p.100.

<sup>12</sup> <http://www.ictregulationtoolkit.org/en/Section.2094.html>

<sup>13</sup> See Thomas Hazlett and Giancarlo Ibarguen, ‘Property Rights to Radio Spectrum in Guatemala and El Salvador: An Experiment in Liberalization’ March 2006, George Mason University *Law and Economics Research Paper Series* [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=889409](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=889409)

**El Salvador** followed Guatemala in 1997, assigning property rights ('usufructory' rights) to 20-year concessions which are free to transfer or subdivide the spectrum rights in frequency, geographic or time dimensions, with freedom to choose technologies and services. In contrast to Guatemala, such concessions must pay an annual usage fee but there is no spectrum registry. El Salvador has granted 1,311 concessions (152 by auction), 80 authorizations and 56 licenses.

#### *Europe/UK*

**EU** allows trading within its Framework Directive and trading was recommended in 2004 by a European Commission commissioned report – see WAPECS and the RSPG above. **UK** has been widening the scope of trading available across a wider range of bands since 2004, allowing existing licences to be converted into tradable licences valid for 5-year rolling (renewable) periods. The regulator OFCOM differentiates between transmission rights and interference rights. 'Spectrum masks' define the geographical and frequency boundaries of the former. Competition law and fair trading laws are guards against anti-competitive behaviour.

#### *USA and Canada*

**USA** has permitted trading for many years, with encouragement given by the 1996 Telecommunications Act to increase the efficient use of spectrum. Trading is guided by regulations governing partitioning and disaggregation rules with regard to geography and frequencies, but trades have been minimal, possibly due to relatively high transactions costs, and '[p]artitioning and disaggregation are an imperfect substitute for spectrum leasing and have not worked well.'<sup>14</sup> Under leasing arrangements the licence owner either retains legal and operational control (*de jure*) or retains the legal and a third party has operational control (*de facto*). New service licences are auctioned on a 10 year lease, and anti-competitive issues are handled on a case-by-case basis. Interference issues are left to private negotiation or civil action.

**Canada** has introduced 10 year exclusive transferable licences but both parties to the trade must seek regulatory approval. No apparatus-specific licences are yet tradable and trading has been minimal in the permitted bands 2 GHz, 2.5GHz, 2.3/3.5GHz, 24/38GHz.

#### **Hong Kong**

Traditionally Hong Kong takes the view that as a small open economy it should *follow* world best practice. In most other jurisdictions the step-by-step approach is adopted since the outcomes are indeterminate, but caution is also a reflection of the legacy issues. For example, there was a clear statement by OFTA that additional spectrum for 3G-type services could be made available, but how easy will that be in practice? OFTA's attempts to reform the 800 MHz frequencies used by CDMA showed that the 'use it or lose it' maxim is to all intents and purposes inoperable, at least until licences expire. The CITB's proposal to depart from 'technology neutral' in favour of CDMA 2000 and TD-SCDMA ('apparatus licensing') sits uneasily with moves towards liberalization (under which both technologies could be used if the commercial case was sufficiently strong). These issues show that the Consultation Paper is not yet clear on the way forward.

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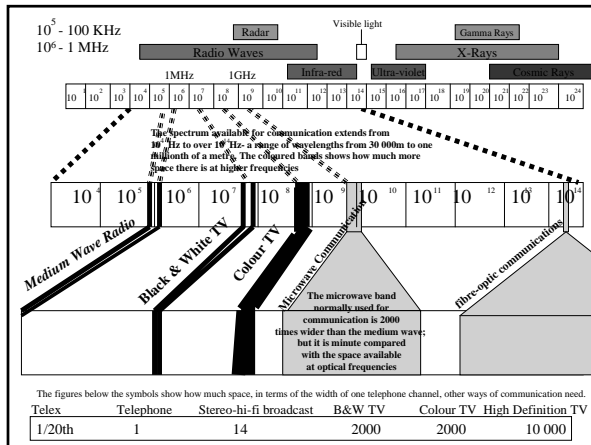
<sup>14</sup> Ovum, et al. (2006) *Spectrum Policy Review: Final Report to CITB*, p.149

## Spectrum Management

- ITU Allocations - Radio Regulations decided at the World Radio Conferences (WRC) and the Regional Radio Conferences (RRC)
- ITU Regions
  - Region 1 = Europe and Africa
  - Region 2 = Asia (Oceania)
  - Region 3 = Americas

## Common Spectrum Terminology

Frequency Band	Band Number	Symbol
3-30k kHz	4	VLF
30-300 kHz	5	LF
300 - 3000 kHz	6	MF
3 - 30 MHz	7	HF
30 - 300 MHz	8	VHF
300 - 3000 MHz	9	UHF
3 - 30 GHz	10	SHF
30 - 300 GHz	11	EHF



## Satellite Spectrum Terminology

Frequency Band	Band Code
1-2 GHz	L
2-3 GHz	S
4-6 GHz	C
10-15 GHz	Ku
17-31 GHz	Ka

NB. Microwave usually implies above 1 GHz; millimetre wave can mean anything above 10 GHz or above 40 GHz!

## Broadcasting Spectrum Terminology

Frequency Band	Band Code
1-2 GHz	I
2-3 GHz	II
4-6 GHz	III
10-15 GHz	IV
17-31 GHz	V

## Spectrum Classifications

- Fixed Services (FS) + Fixed Satellite Services (FSS)
- Mobile Services (MS) + Mobile Satellite Services (MSS)
  - maritime mobile + maritime mobile satellite
  - land mobile + land mobile satellite
  - aeronautical mobile (AMS) + aeronautical mobile satellite (AMSS) - [(R) = route/civilian; (OR) = off-route/non-civilian]

## Spectrum Classifications

- Broadcasting Services (BS) + Broadcasting Satellite Services (BSS)
- Amateur Services (AmS) + Amateur Satellite Services (AmSS)
- Inter-Satellite Services (ISS)
- Technical and scientific services of various kinds
  - SR = Space; RAS = radio astronomy service
  - EES = Earth-exploration satellite service; MetS = meteorological-satellite service; etc., etc.

## Spectrum Allocation, Assignment and Status

- ITU Radio Regulations “*allocate*” frequencies between uses agreed by WRC recommendations
  - Member states usually follow these allocations
  - Member states “*assign*” frequencies within these allocations to users, e.g. by issuing licences
- Status of Usage
  - **Exclusive** = highest status
  - Shared: (a) **primary**, or (b) **secondary** - Member states must not allow interference **across borders** of (a) by (b)  
*NB. no specified agreements covering interference of (b) by (b).*

## Frequency Assignment Procedures

1. Dialogue between applicant(s) and Administration
2. Search for short list (if applicable) of potential assignments
3. Co-ordination with foreign frequency assignments, where applicable, eg. involving international spillover or roaming
4. Assignment of frequencies and issuing of licences
5. International registration of frequency assignments, where applicable (e.g. involving international communications or possibility of causing ‘harmful interference’) = **Master International Frequency Register (MIFR)**
6. Action after assignment and monitoring - eg. use of guard bands, moderating transmission power, measuring radiation, etc.

## Fixed Services < 30 kHz

- VLF (3-30kHz), LF (30-300kHz), MF (300-3000kHz), HF (3-30MHz)
- VLF and LF
  - ionospheric and ground wave interference problems at VLF; tropospheric interference is less for LF
  - very few FS stations operate in these bands today
- MF and HF
  - voice-frequency FM and AM discouraged, except single sideband (SSB) AM using 3 kHz channels

## Fixed Services > 30 kHz

- FS share primary allocations with many services, especially with broadcast and mobile up to 1 GHz and with broadcast, mobile, ISS, technical and scientific above 1 GHz

## Broadcast Services

- Broadcast allocations do NOT include transmissions to and from the broadcast transmitters - these are typically FS allocations.
- BS - various bands between 5.95-26.1 MHz allocated exclusively to domestic and foreign BS.
- Sound radio broadcast in LF/MF/HF and VHF established 1910s and 1950s - digital terrestrial transmission (DTT) now challenging these allocations → *multiplexing licences proposals*
- VHF/ UHF allocation for BS ≅ 60% spectrum < 960 MHz!

## Television Services & Digital Audio Broadcast (DAB)

- Almost all use Bands I, III, IV and V - Picture standards = (a) 625-lines/25 frames-per-second; (b) 525-lines/30 frames-per-second
- Frames transmitted as a video signal + chrominance information transmitted by *phase alternate line* (PAL) or *séquentiel couleur avec mémoire* (SECAM) or the *National Television Standards Committee* (NTSC).
- TV channels typically 6-8 MHz - ITU recommendation same for DTT
- DAB - S-DAB and T-DAB to use BSS & BS frequencies

## Mobile Services

- Low-powered devices (few metres) often not licenced - eg. anti-theft devices, cordless phones, microwave ovens, 'Bluetooth', 802.11???
- < 30 MHz many maritime, aeronautical and LMS allocations
- 30 - 960 MHz: since 1980s many LMS allocations from FS of non-BS frequencies, eg. vehicle portable phones, private mobile radio (PMR), pagers, mobile cellphones
- > 3 GHz not very suitable for mobile applications, but ok for wideband short-range broadcast vehicles

## Mobile Services

- Note: frequency assignments to connect base stations never registered with the MIFR, but assignments to transmitting and receiving land stations and MSCs can be registered to protect against foreign inference from other mobile stations.
- UMTS (Universal Mobile Telecommunications Service) (3G plus) allocated 1885-2025 and 2110-2200 MHz (including 1980-2010 and 2170-2200 MHz for MSS) - WARC-92

## Satellite Services 1

- **Fixed Satellite Services (FSS)** - provide satellite links between stations at specified terrestrial locations, including feeder links between other services provided by terrestrially-located stations, such as mobile-satellite and broadcast-satellite.
- **Broadcasting satellite service (BSS)** - emissions for distribution for general public reception.
- **Inter-satellite service (ISS)** - Direct links between satellites where the frequency bands allocated in most cases can be used regardless of the service.

## Satellite Services 2

- **Mobile satellite service (MSS)** - links with mobile radio stations or the stations at fixed locations that communicate directly with them
- **Maritime mobile-satellite service (MMSS)** - two special categories are port operations service and ship movement service.
- **Aeronautical mobile-satellite service (AMSS)** - includes civil air 'Route' (R) and non-civil air 'Off-Route' (OR) frequencies for traffic control AMS(R) and AMS(OR) and safety messages AMS (R)S and AMS(OR)S
- **Land mobile-satellite service (LMSS)**

## Fixed Satellite Services

- **Fixed Satellite Services (FSS)** - provide satellite links between stations at specified terrestrial locations, including feeder links between other services provided by terrestrially-located stations, such as mobile-satellite and broadcast-satellite.
- **FSS** occupy around 55 per cent of WRC allocations of spectrum between 2.5 and 31 GHz. The major services include commercial C, Ku and Ka band Geostationary Earth Orbit (GEO) satellite networks, non-GEO satellite networks, feeder links for BSS and MSS, etc

## Broadcasting Satellite Services 1

- **BSS** emissions for distribution for general public reception.
- Sometimes known as direct broadcasting satellite (**DBS**) - needs to be distinguished from direct-to-home satellite television (**DTH**) which comes under **FSS** and is probably today the dominant activity of **FSS**.
- Some countries allow **DTH** broadcasting as it can be required to confine service to the domestic market, but not **DBS**
- Only one ITU allocation around 12 GHz for **BSS**, with feeder links at 14 GHz and 17 GHz, although by 2007 additional spectrum around 17 to 22 GHz should be available.

## Broadcasting Satellite Service 2

- Compared with BS terrestrial television broadcasts using around 700 MHz bandwidth, BSS television broadcasts use around 2.5 to 2.6 GHz.
- One application of growing importance is the feed of satellite television and broadband Internet streamed video signals to the head-end of terrestrial cable and fixed wireless broadband distribution systems.
- By contrast, satellite radio digital audio broadcast (S-DAB) uses around 1.4 GHz, and this is becoming increasingly popular as a means of providing radio signals to moving vehicles.

## Mobile Satellite Services 1

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## Mobile Satellite Service 2

- 6 groups of spectrum allocations for MSS + FSS feeder links to MSS + direct links between MEOs and LEOs to connect (a) subscribers across regions; (b) terrestrial mobile switching centres or Internet eXchanges.
- Inter-satellite links (ISLs) can also be provided by Inter-satellite service (ISS) frequencies.
- The six groups are bands for:
  1. Commercial GEOs, embracing MSS, MMSS, AMSS and LMSS, using bands from UHF and above.
  2. Government, including military, networks, using bands from UHF and above.

## Mobile Satellite Service 3

3. Non-GEO systems below 1 GHz using narrow bands, mainly so-called 'Little LEOs'.
  4. Systems using major band systems below 3 GHz in UHF, mostly for global mobile personal communications by satellite (GMPCS), including GEOs, MEOs and 'Big LEOs'
  5. Nine bands above 40 GHz, offering 'millimetre-wave' MSS allocations, but they are not much used at present.
  6. Distress and safety communications in the VHF and UHF bands.
- Note: MSS feeder links from stationary earth stations to satellite are assigned as part of FSS.

## Satellite Services Frequencies

Code Letter	Nominal Frequency range (GHz)
L	1-2
S	2-3
C	3-8
Ku	10-15
Ka	17-31

## Briefing Paper 2: Avoiding another cable blackout?



Source: Telegeography

### The Quake

Nothing illustrates better how important the Internet has become to businesses and individuals than the quake on December 26, 2006 measuring 7.1 on the Richter scale that damaged and severed several major submarine cables off the coast of Taiwan, undersea

cables that carry about 90 per cent of East Asia's voice and Internet traffic. The results are all too well known. At the peak of the crisis PCCW said its capacity was down by 50 per cent. Two undersea cables connecting mainland China to the global communications network were functioning at just 60 per cent of capacity.

Telcos scrambled to reroute traffic along undamaged lines and repair ships were dispatched to the quake epicenter in the Luzon Strait between the Philippines and Taiwan. But deep water, with the cables out of reach of remotely controlled submersibles, and rough seas hampered repair work. The cables must be hoisted to the ocean's surface with grappling hooks and new cable fused into the gaps. Three weeks after the quake Hong Kong ISPs were operating at only 80 per cent capacity ('The Internet Trembles', *NewsWeek*, January 29, 2007). Phone service was restored faster than Internet service because voice requires less transmission capacity so traffic can be more readily rerouted.

### What Can Be Done?

Ideally, meshed networked submarine cables that provide redundancy by by-passing the affected areas, but this is unrealistic. Most of the capacity already out there is unlit because there remains a huge glut of supply and the costs of lighting are not recouped in the leasing revenues. For that reason, several major international carriers prefer to lease rather than build. The consortium cable Trans-Pacific Express (China Telecom, China Netcom, China Unicom, Chunghwa Telecom, Korea Telecom and Verizon) is due to link China directly to the US at an estimated cost of US\$500 million, whereas if it encircled the Pacific Ocean to give redundancy the estimated cost was closer to US\$1 billion. It will have 1.28 terabits lit out of a capacity of 5.12 terabits. Currently over 80 per cent of capacity on the trans-Pacific route is accounted for by just one cable, Tyco Transpacific which came online in 2002 with a designed capacity of 7.68 terabits and was bought by VSNL (India) in 2004. Only about 6 per cent of the Tyco cable is lit such is the excess supply of existing bandwidth.

This makes the announcement by Asia Netcom that it is raising upwards of US\$800 million in private equity to finance an East Asia Cable (EAC) to link the Philippines to Guam, Hawaii and California a bit mind bending. But if it happens then an alternative route is opened up, not once but twice as AT&T, Malaysia Telecom, AiTi of Brunei, Starhub of Singapore, CAT of Thailand, VNPT of Vietnam and Reach of Hong Kong have also announced a cable, the Asia-American Gateway to link South East Asia and the US following the same route as the ANC proposal at a cost of around US\$500 million. All these highly generous donations, announced before the quake, could certainly help avoid the worse consequences of another quake.

### *Land Routes or Satellite?*

An alternative is to use land routes, for example across China, Russia and Central Asia to Europe. The only problem here is that the cable may meet a real Borat in Kazakhstan or somewhere along the route where the highest speeds are determined by the weakest links in the chain. Satellites offer no realistic alternative. The traffic capacity of the world's entire fleet of satellite could be transmitted down just one optical fibre.

For the foreseeable future, the industry seems to be stuck with the current configuration of submarine cables, and the glut has retarded investment in new technologies as well as new cables. It is an irony that Internet Protocol was designed to beat a track around outages, and yet it is the Internet traffic that was most severely affected.

### Strategies

Obviously, companies heavily dependent upon international communications should not rely on a single service provider but have at least two service providers, as some are able to resume operations faster than others. But one consequence may be that Internet fees go up as telecom companies try to come up with better contingency plans and cover the increase in operation costs – and the cost of new cables.

According to the Hong Kong Telecom Users Group, IPLCs and private networks which are less dependent upon the Internet were not so badly affected or recovered more quickly. SLAs may have played a part here, so the lesson is plan secure routings for redundancy for mission critical operations. HKTUG also suggested thinking strategically about a Hong Kong-Shanghai overland cable via North Asia to the US.

In Hong Kong OFTA is holding discussions with telcos about faster rerouting procedures in the event of future cable failures, and pushing for greater cooperation and dialogue in the industry to improve the reporting mechanism. And HKBN, never short on ideas, has made a couple of suggestions: (1) centralize ISP bandwidth in times of crisis and distribute it to all users; (2) extend the Universal Service Obligation to include broadband Internet access and overseas telecommunications.

### The Politics of Routing

If national states can invest billions of dollars in national information infrastructures, then maybe the APEC agenda of building an Asia Pacific Information SuperHighway needs revival and revision. But the question always remains, which routes are politically sensitive. It is noticeable that the Trans-Pacific Express due to link China directly to the US by-passes Japan. The politics of routing includes, of course, the Luzon Straits, or better be called the Dire Straits.