Spectrum Management Part 1:
Introduction

Interference and Efficiency

There are two types of efficiency which regulators have to take into account when considering spectrum management.

First, technical efficiency, which principally refers to the requirement that different users and different uses of radio frequencies should not interfere with each other.

It also refers to the need to tackle a host of related problems, such as the use of faulty or non-standard equipment, the unauthorized or illegal use of frequencies, spillover signals effects from neighbouring jurisdictions administrations, the use of inappropriate levels of power, finding the optimum location for antennae, and so on, all of which can effect affect the attenuation, successful transmission and reception of signals, the problems of cross-talk and the general problem of channel radio interference.

These problems are what economists call ‘negative externalities’ which means that the use of one channel can have an adverse impact on those that are external to it. Achieving technical efficiency is really the work of the engineers inside the regulatory body.

The second type of efficiency is economic efficiency. This is a much wider regulatory issue because it involves a judgement regarding the allocation of relatively scarce spectrum among alternative uses to provide different, in some cases competing, types of services.

How is the regulator to allocate spectrum? On a first-come-first-served basis? Using purely administrative criteria? Using some form of spectrum pricing, possibly an auction, so the market will influence the choice?

Markets will change over time, and so will the prices consumers are willing to pay for different categories of services delivered by radio, and therefore so will the value a service provider places upon the spectrum they use. If the economic value of spectrum is to be included in the allocation decision, then it follows that there should also be some mechanism to allow spectrum to be reallocated as market valuations change over time.

Because both types of efficiency are required of a modern telecommunications regulator there needs to be good coordination between the engineering and the policy wings of the regulator’s office.

Usually the policy wing will take its lead from the policy-making bureau of government and translate those policy objectives into regulatory instruments. In practice the regulator, as a consequence of her/his expertise and depth of knowledge of the industry, will be the primary advisor to the government policy-making bureau. This is certainly the case in Hong Kong, where the regulator, the Telecommunications Authority (TA), provides key input into policy formulation.

The Hong Kong Government and the TA are also influenced by events outside Hong Kong. The most important influence is the work of the International Telecommunications Union (ITU)[1] World Radio Conference (WRC)[2] which convenes every two to three years to make worldwide recommendations on the allocation of spectrum for various of radio services.

Other influential bodies include the World Trade Organization (WTO) and the Asia Pacific Economic CooperationCouncil (APEC), who act to facilitate the direction and pace of liberalization of telecommunication services. The Asia Pacific Telecommunity (APT) located in Bangkok, close by the regional head offices of the ITU, is another body that plays a constructive role, especially in the area of equipment standards issues and type approval procedures.

The ITU and WRC

When a government signs the Instruments of the ITU it actually agrees to only a limited commitment. It agrees to abide by the Radio Regulations (RR) of the ITU which have been agreed by successive WARCs and WRCs, and which require Member States to abide by spectrum allocations that do not cause interference with the radio stations of other Member States.[3] Military uses of RF are excluded from this consideration.

Member States will draw up their own national frequency tables which follow closely WRC's tables, (see Part 2), but they have flexibility to vary spectrum allocations according to local circumstances. For example, WRC allocates spectrum in frequency bands that in many cases can be shared between different services, and local allocations may therefore vary considerably.

Thus, spectrum allocated to mobile services could be allocated to public cellular mobile services, to private mobile services or to paging, while mobile and fixed services may also share frequency bands. National frequency tables will also identify future allocations planned to meet forecast demand, and this process often involves the re-allocation of spectrum among existing users to free up certain bandwidths.

WRC divides the world into three regions, and Hong Kong is part of Region 3, as is the whole of China and South East Asia.

Because the world is divided into separate jurisdictions and regions, the issues of technical standards and standardization of spectrum allocation are crucially important. If the world acted as a single marketplace, it is conceivable that the economic pricing of spectrum would allow large companies with a global interest to buy spectrum internationally and harmonize its use, so that, for example, everywhere in the world used the same wavelengths for broadcasting and for cellular telephony, and that consumers could use the same television set or cellphone wherever they roamed in the world.

That is not how the world is organized, so governments and regulators have to decide how far they will go in harmonizing their allocation of spectrum with other jurisdictions and in adopting the same standards of equipment, as well as how far they will go in opening their markets to foreign service providers and equipment manufacturers.

In the past many economies in all regions chose to pursue their own spectrum allocations and standards, sometimes just because the demand was immediate and urgent, sometimes as part of a national industrial policy and strategy. Today, on both the trade front, for example the WTO, and on the industrial standards front, for example the ITU and even commercial pressures, the tendency is strongly towards global harmonization.

The most obvious recent example of this is the development towards the International Mobile Telecomunications 2000 (IMT2000), Universal Mobile Telecommunications Service (UMTS) third generation cellular mobile standard. It takes time to achieve, and the equipment manufacturers have major investment decisions to make with technologies that remain uncertain and constantly evolving.

Under these circumstances regulators have to keep abreast of events as best they can. They have to be sensitive to the technological and commercial dilemmas of the manufacturers and service operators if regulation is to reach the right balance between incentives to investment in spectrum-hungry applications, and the public's interest to have the best possible services at the most competitive prices.

The economic efficiency issue is therefore very important, but once a certain spectrum allocation has been decided the technical efficiency issues determine whether the services on offer guarantee the quality of service the public demands. The 'public interest' is not just a matter of consumer interest, it also reaches out to foreign investors who will be attracted by a well managed allocation and operation of spectrum, and in that sense spectrum management in Hong Kong also contributes to Hong Kong's role as a regional hub for telecommunications.

In fact, because Hong Kong is such a densely populated city and urban area, and so clustered with high-rise buildings, it is seen as a major challenge by equipment manufacturers and service providers to offer radio services. There is a view that says, "if it can be made to work in Hong Kong it can be made to work anywhere", and that could also apply equally to spectrum management: "if it can be managed in Hong Kong, it can be managed anywhere."

Spectrum Management Part 2:
Management of the Spectrum

Management of the Spectrum
Radio Services

In the parlance of the World Radio Conference (WRC) the uses of radio are typically divided into:

1. *radio services*,
2. the spectrum used is divided into *frequency bands*
3. administrations *allocate* frequency bands to different categories of services
4. often with a licensing process for different types of *transmission* by service providers who use the frequencies *assigned* to them by the administration.

Public and private service requirements are two distinct areas. The spectrum required for government and public services, for example the emergency services, national defence, public service, broadcasting, and so forth, has traditionally been determined by administrative means, which raises some problems.

On the one hand, it is necessary to reserve spectrum for these services because a market mechanism would almost certainly result in the relevant spectrum being used for other, more commercial purposes. On the other hand, political and security concerns may well result in an over-allocation of spectrum to these services, and the use of the spectrum by public service operators may become very wasteful if there is no mechanism to enforce the most efficient use of frequencies.

Spectrum allocated to private services, and frequencies assigned to private service providers, may confer either property rights or rights of usage, which can raise difficult questions of whether spectrum should be tradable, of the dangers of monopoly, and what, if any, regulations or obligations should be imposed upon the assignment of frequencies.

A further question concerns the re-assignment of frequencies that may become necessary, and whether the holders of the frequencies are under an obligation to return them before the expiry of their licences. And in the absence of strict regulations governing the use and non-use of frequencies, private operators may be tempted to ‘bank’ licences, being motivated by the prospect of a future sale, or simply by the desire to keep the frequency out of the hands of a competitor.

For all these reasons the allocation of spectrum and the assignment of frequencies needs close co-ordination between the technical, engineering side of the regulator’s office to monitor the efficient use of spectrum, and the economic, policy side to monitor the market and possible abuses of market power.

Frequency Bands

Nothing illustrates better the explosive growth in the demand for radio spectrum than the upper limits of the ITU's frequency tables.

- Pre-1947 = 200 MHz
- 1947 = 10.5 GHz
- 1959 = 40 GHz
- 1971 = 275 GHz

By the time of WRC 1997 most of the bands below 25GHz were in use, and although the higher bands have less utilization, additional applications, such as fixed wireless, have encroached above 25 GHz. A growing interest in space exploration and in broadcasting satellite services have also created a demand for the higher end of the spectrum. The frequency bands are shown below.

Frequency band	Band number	Symbol
3 – 30 kHz	4	VLF – Very Low Frequency
30 – 300 kHz	5	LF – Low Frequency
300 – 3000	6	MF – Medium Frequency

kHz		
3 – 30 MHz	7	HF – High Frequency
30 – 300 MHz	8	VHF – Very High Frequency
300 – 3000 MHz	9	UHF – Ultra High Frequency
3 – 30 GHz	10	SHF – Super High Frequency
30 – 300 GHz	11	EHF – Extremely High Frequency

Note: The upper limit of the ITU's frequency tables was lifted from 200 MHz to 10.5 GHz in 1947, to 40 GHz in 1959, and to 275 GHz in 1971. Micowave and millimeter wave frequencies have no specific definition, but often refer to frequencies 1 – 20 GHz and above 10 GHz.

WARC and subsequent WRC recommendations have given the guidelines to the allocation of these frequency bands by national administrations.

WRC Regional Frequency Allocations

As far as possible the ITU tries to achieve harmonization of frequency allocations intra-regionally and inter-regionally. In some cases frequency allocations are specific to a particular service; in other cases a group of services can share a band and it is left up to the local administration to assign frequencies according to local requirements.

For example, in some areas the demand for cellular mobile telecommunications services will be far greater than in others. Climatic variations and signal propagation characteristics may also be important considerations.

Sharing frequency bands obviously raises problems of potential interference and regulators have to consider safeguards such as constraints on usage, for example restrictions on power levels, on the direction of antenna, on day time or night time transmission, on the use of guardbands, and so on.

Interference may be impossible to eliminate altogether, in which case acceptable levels have to be imposed.

a. *Primary and Secondary Allocations*

The mechanisms for doing this vary from the carefully calibrated use of algorithms to simple trial and error, but in the allocation of frequency bands the ITU recommendations include primary and secondary allocations. Primary allocations are indicated by upper case in frequency tables, such as FIXED or MOBILE, whereas only the first letter is capitalized in secondary allocations, for example Fixed or Amateur. In the event of interference, operators with secondary assignments are required to accommodate the requirements of those with primary assignments.

b. *Frequency Table*

The WRC frequency tables contain over thirty footnotes (treated as paragraphs in the ITU's Radio Regulations or RR) which specify a variety of addenda, such as primary and secondary allocations, jurisdictions where exceptions apply, and so on. They also cover the allocation of radio bands for technical, scientific and medical equipment and apparatus which use radio frequency (RF) and from which there is a danger of radiation which could prove either hazardous or an interference.

Service category	Service type

Fixed service (FS)	Radio links between stations at specified terrestrial locations
	Fixed satellite services (FSS) provide satellite links between stations at specified terrestrial locations.
	FSS also includes satellite feeder links between other services provided by terrestrially-located stations, such as mobile-satellite and broadcast-satellite.
Broadcasting service (BS)	Terrestrial transmitters and their emissions for direct reception by the general public
	Broadcasting satellite service (BSS) emissions for distribution for general public reception.
Mobile service (MS)	Radio stations on land vehicles, aircraft, ships or handheld, stations at fixed locations that communicate directly with them, and the radio links used between any of them.

	Mobile satellite service (MSS) links with mobile radio stations or the stations at fixed locations that communicate directly with them.
	Maritime mobile service (MMS) and Maritime mobile-satellite service (MMSS) – two special categories are port operations service and ship movement service. Aeronautical mobile service (AMS) and 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 service (LMS) and Land mobile-satellite service (LMSS) All separately identified for frequency band allocation.
Amateur service (AmS)	Amateur service (AmS) and Amateur-satellite service (AmSS)
Technical and Scientific services	Space research service (SR), Earth exploration-satellite service (EES), Meteorological-satellite service (MetS), Meteorological aids service (MetA), Radio astronomy service (RAS), the Standard frequency and time signal service (TFS), the Standard frequency and time signal-satellite service (TFSS), and the Space operation service (SO) for telemetry purposes.

	Radiodetermination service (RDS), Radiodetermination satellite service (RDSS) – radio waves are used for measuring the distance or location or relative movement of objects or other physcial characteristics – includes Radionavigation service (RNS) for ship and aircraft navigation, which is subdivided into the Maritime radionavigation service (MRNS) and the Aeronautical radionavigation service (ARNS), and the Radiolocation service (RLS) for other RDS systems. The RDSS is similarly sub-divided into the MRNSS, ARNSS, and the RLSS.
Inter-satellite service (ISS)	Direct links between satellites where the frequency bands allocated in most cases can be used regardless of the service.
Note: International frequency tables normally specify the satellite uplink and downlink frequency bands and direction of transmission.	

Source: David Withers, 1999, *Radio Spectrum Management: Management of the spectrum and regulation of radio services*, 2nd edition, The Institute Institution of Electrical Engineers, Stevenage, UK. Note: no standard terminology exists but the above is widely used.

Spectrum Management Part 3:
Frequency Allocation

Radio Regulations

The ITU's Radio Regulations (RR) are the primary reference point for all regulators of spectrum management, and are derived from the recommendations of the World Radio Conference (WRC) and the Regional Radiocommunication Conferences (RRCs). Part 2 examined the division of the spectrum into frequency bands and the use of spectrum among different radio services. Part 3 examines the allocation of frequencies among radio services.

Fixed Service frequency allocations

FS frequency allocations are extensive, but are all shared. Between 30 – 1000 MHz allocations to FS with primary status accounts for 90 per cent of spectrum in Region 3, and around 45 per cent in Regions 1 and 2.

In Region 3 FS is mostly shared with MS and BS, along with other services. Above 1 GHz around 55 – 60 per cent of all spectrum is allocated to FS with primary status, but shared with BS, BSS, FSS, MS, MSS, RLS, SR and ISS. The ability to re-use frequencies varies according to service types, for example, FSS may be highly directional leaving space for simultaneous terrestrial FS use.

Broadcasting Service frequency allocations

WARC allocations of HF spectrum up to the year 2007 provides for 3715 kHz of exclusive bandwidth distributed between the 5950 kHz – 21850 kHz bands, although country variations allow for some sharing with low-powered FS. Both FS and MS services had to shifted to clear these bands.

For wide-area continuous sound and television broadcasting much greater bandwidth is required, up to 80 MHz per TV programme and 2 MHz per audio radio broadcast. In the VHF and UHF bands about 60 per cent of all the spectrum below 960 MHz is allocated to BS, a total of 674 MHz of bandwidth in Region 3 where BS is shared equally with FS and MS.

Above 1 GHz various world and regional allocations have been made. In Region 3 11.7 – 12.5 GHz was allocated to BS on a primary shared basis. BSS allocations have been made near the 12 GHz band and the 40.5 – 42.5 GHz and 84-86 GHz bands.

Digital television and audio broadcasting

The introduction of digital television is subject to the ITU-R *Digital television terrestrial broadcasting* 1997 Recommendation (BT.798-1) guidelines which propose digital systems should fit into one of the existing 6, 7 or 8 MHz analogue channels.

As the migration towards digital television gathers pace, and that depends upon television industry standards and the pace of technological development and the rate of take-up of digital TV sets by the general public, so more channels will become available for broadcast. But also bandwidth may be freed up from BS for other uses. Digital broadcasts may also migrate to cable systems, or to BSS systems, which would free up yet more sprectrum in the VHF and UHF bands.

In the case of Hong Kong, although digital television broadcasts are expected to commence sometime around 2002, there will be no predetermined cut-off date for analogue broadcasts as the rate of take-up of digital broadcast reception by the public is unknown. When around 50 per cent of households are thought to be receiving television by digital transmission or when the simultaneous transmission of analogue and digital TV signals has commenced for 5 years the situation is to be reviewed.

Sound radio broadcasts using frequency modulation (FM) almost invariably use the VHF band around 100 MHz (87 MHz – 108 MHz in Region 3) which provides better quality than amplitude modulation (AM) at lower MF frequencies for receivers at domestic fixed locations, although FM fades more quickly and is less reliable for moving vehicles.

Digital audio broadcasting systems would offer improvements in quality of reception and will use less transmission power, but it will be some time before digital radio receivers become low cost enough for the general public to accept a switch-over. So unlike the shift to digital television, which has been time-tabled in many countries even though a cut-off date for analogue broadcasts may not always have been determined, for example in the case of Hong Kong, it is unlikely that regulations will mandate digital radio for any time soon.

But satellite digital audio broadcasting (S-DAB) for reception by vehicles and mobile handsets is finding a market. The 1452 – 1492 MHz band has been allocated for BSS for S-DAB outside the USA and one or two other countries, but it is shared with FS and other services. The ITU has also proposed reserving part of the corresponding frequencies of the BS band for terrestrial digital audio broadcasting (T-DAB).

Mobile Services frequency allocations

Mobile services cover land, sea and air. Below 30 MHz maritime and aeronautical mobile services, including satellite, have primary and often exclusive status. In the case of Hong Kong maritime mobile services have exclusivity ranging between 14 and 70 kHz and aeronautical mobile services exclusivity in different bands ranging between 2850 kHz and 137 MHz.

Above 30 MHz, in the VHF and UHF bands, many land mobile service (LMS) devices, such as cordless telephones, remote controllers and security alarms are permitted unlicensed usage of frequency bands a few hundred kHz wide, subject to low power output which will travel only short distances. This allows widespread geographical re-use of these channels. LMS all have secondary and shared status. Citizen Band (CB) is also found in these frequencies.

Although WRC recommendations allow for MS and LMS below 30 MHz, which include primary status in some frequency allocations, they are all shared, and in Hong Kong there are none.

Above 30 MHz both public mobile radio service (PMRS) and private mobile radio services (PMR) are common, but many are secondary and mostly shared with FS, which is often primary. However, there is growing trend along the 30 to 960 MHz spectrum and upwards towards 3 GHz for MS and LMS to replace FS where the latter moves off-air and online.

Private mobile systems are widely used by different industries, typically using a band 20 to 40 MHz wide, divided into uplink and downlink bands, each sub-divided into 12.5 to 25 kHz channels. Users, such as trucking companies, will purchase transmitter/receiving equipment, mostly FM and increasingly digital, tuned to the pair of frequencies assigned to them.

a. Private Mobile Services

The demand for PMR is usually very high, and grows in parallel with commercial development as transportation companies enlarge their fleets to cater for growth in freight and passenger traffic. Withers (1999)[4] outlines four approaches open to regulators to minimize channel interference:

1. Same channel-pair assignment may be possible if the base stations are sufficiently far apart, given the frequencies used, height of antennas and nature of terrain.
2. Ensuring the use of narrow bandwidth equipment, which can be encouraged by pricing the use of spectrum.
3. Channel sharing can be possible using selective calling devices which can detect when neighbouring networks are not utilizing channels, which happens if different networks have markedly different utilization rates, or use their systems at different times of the day.
4. Sharing channels can work even during periods of heavy traffic on neigbouring networks if a *trunking* system is used, which allows any group to seize any channels available on the networks involved.

Trunking systems are generally more expensive than simple PMR systems, but make much more efficient use of spectrum. They can work either off a centralized base station system that assigns channels to a group according to immediately availability, or without a base station as mobile-to-mobile. The typical range of transmission is up to 10 km operating at around 900 MHz.

b. Public Mobile Radio Services

The public mobile radio system (PMRS) is virtually an extension of the PSTN. First generation (1G) mobile was an analogue system, introduced into Hong Kong in 1985. Second generation (2G) mobile came to Hong Kong during the 1990s, and by 1995 there were three 2G operators who replaced the AMPS 800, TACS 900, and TDMA ETACS networks with D-AMPS, CDMA , D-TDMA and and GSM systems. The D-AMPS system has since been replaced by a narrowband CDMA network.

In 1996 six Personal Communications Network (PCN) licences were issued for GSM 1800, bringing the total of networks to eleven, operated by six companies. Three of these operators are able to offer seamless handover between their GSM or CDMA territory-wide coverage and their PCN pico-cell coverage of the busiest commercial districts.

These operators are preparing for 2.5G packet-switched networking, and at the time of writing are awaiting the outcome of the regulator's decision on the issuing of third generation (3G) mobile UMTS licences. 140 MHz of spectrum is to be allocated during 2001, with the possibility of a further 160 MHz becoming available after three to four years, following the WRC recommendation in May 2000.

Other common MS services include paging, typically operating around 172 MHz or 280 MHz using assignments of 25 kHz, and cordless telephone and office systems linking work stations operating in frequency bands from around 2 MHz to 2 GHz.

The key difference here is between licensed and non-licensed uses of frequency, where unlicensed usage is regulated through equipment approval procedures to ensure the devices conform to regulations governing power levels and operating frequencies. Licensed services, on the other hand, are, in the case of Hong Kong, a major source of revenue to fund the work of the regulator's office, the Office of the Telecommunications Authority (OFTA). This is examined in Part 6.

c. Fixed Satellite Services

Fixed satellite services 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 GeosStationary Oorbit (GSO) satellite networks services, non-GSO satellite networks services, BBS and MSS feeder links, among others. The higher frequency bands are listed below.

Code	Nominal Frequency range (GHz)
L	1-2
S	2-3
C	4-6 3-8
Ku	10-15
Ka	17-31

Worldwide allocations for FSS are for uplinks, 13.75 to 14.5 GHz, and for downlinks, 10.95 to 11.2 GHz and 11.45 to 11.7 GHz, plus 12.2 to 12.75 GHz for Region 3, mostly using bandwidths of 500 MHz.

The uplinking bands tend to be exclusive, and downlinking bands not used for terrestrial services, although in Region 3 BSS shares with over 12.2 to 12.75 GHz.

FSS shares the 13.75 to 14.5 GHz band with RLS and RN services which are primary.

To avoid undue interference, satellites are expected to be operational within a tolerance of $\pm 2^{\circ}$ of their nominal orbital position, and preferably $\pm 5^{\circ}$.

WARC Orb-88 aimed to meet the concerns of developing countries by giving all ITU Member States 800 MHz transmission bandwidth for GSO satellites, using 4500 to 4800 MHz (downlinks) and 6750 to 7025 MHz (uplinks) in the C-band and 10.7 to 10.95 GHz and 11.2 to 11.45 GHz (downlinks) and 12.75 to 13.25 GHz (uplinks) in the Ku-band.

The nature of satellite transmission, especially for small countries, involves the possibilities of cross-border over-spill between Member States of the ITU, and it is a condition of ITU membership that this should be avoided if it involves interference. Four factors pose problems for regulators in this area.

1. The electrical characteristics of transponders, antennas and emissions need to be taken into account when assigning frequency allocations.
2. Many satellites are uplinked in one jursidiction but downlinked in others.
3. Uplink and downlink frequencies are almost always closely related which needs to be taken into account when assigning frequencies.
4. The tuning ranges of the earth station receivers and transmitters may not be as wide as those of the satellite.

Broadcasting Satellite Services frequency allocations

Broadcasting satellite service (BSS) is sometimes known as direct broadcasting satellite (DBS) and 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 have been more likely to allow DTH broadcasting as it can be required to confine service to the domestic market, whereas DBS by its nature tends to be cross-border, for example, regional in its footprint.

Only one allocation has been internationally agreed for BSS, around 12 GHz, with feeder links at 14 GHz and 17 GHz, and although BSS is primary it is shared with BS, FS and MS which are also primary.

By 2007 additional spectrum around 17 to 22 GHz should be available. 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 frequency allocations

There are six groups of spectrum allocations for MSS, plus some FSS feeder links to MSS, and in recent years direct links between Medium and Low Earth Orbiting satellites (MEOs and LEOs) to connect subscribers across regions and to connect with 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 GSOs, embracing MSS, MMSS, AMSS and LMSS, using bands from UHF and above.
2. Government, including military, networks, using bands from UHF and above.
3. Non-GSO systems below 1 GHz using narrow bands, mainly so-called ‘Little LEOs’.
4. Non-GSO systems using major band systems below 3 GHz in UHF, mostly for global mobile personal communications by satellite (GMPCS), including GSOs, 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.
7. MSS feeder links from stationary earth stations to satellite are assigned as part of FSS.

In recent years the idea of global satellite-based mobile and Internet services has received much publicity, although the commercial viability of some of these projects remains uncertain.[5] Regulators have to be able to accommodate the demand for such innovative services, and at the same time remain aware of how far the market is developing because the spectrum will always have alternative uses and alternative claims made upon it.

Spectrum Management Part 4:
Licensing of Spectrum Use

The Issues

Spectrum management is first and foremost about tackling the problems of interference between different users of the spectrum. When Member States sign up to the ITU they agree to abide by the Radio Regulations which stipulate they should manage their national spectrum in ways which prevent cross-border interference. Interference issues that arise solely within national boundaries are matters for individual Administrations and their respective regulators.

Three key issues concern regulators of spectrum:

1. interference issues
2. potential radiation hazards on health and safety issues
3. efficiency issues

In addition, the regulator must study the following:

1. WRC recommendations and other ITU spectrum allocation issues
2. other international agreements, such as come under the WTO, including the Basic Agreement on Telecommunications (BAT) Reference Paper on transparent regulatory procedures, the International Technology Agreement (ITA) commitment to remove tariffs on equipment imports, APEC's Mutual Recognition Agreement (MRA) for mutual equipment type approval procedures, and so on.
3. recent developments in technologies
4. market developments
5. developments in regulatory practices world wide
6. And finally the regulator is guided by the policies of the government. In the case of Hong Kong the overall policy objectives are set out as follows:

    - That the widest range of quality telecommunications services should be available to the community at reasonable cost;
    - That telecommunications services should be provided in the most economically efficient manner possible; and
    - That Hong Kong should serve as the pre-eminent communications hub for the region.

This means the regulator's job extends far beyond the purely technical and engineering skills required for spectrum management.

The regulator must be able to relate all the policy issues mentioned above to the job of spectrum management, for example, in the case of Hong Kong the emphasis is upon making and keeping the economy as open and competitive as possible. This means a minimum level of regulation wherever possible, and a technology-neutral approach to the equipment standards adopted by licensed operators.

Insofar as equipment is used for purely private purposes, licensing is either not required in Hong Kong, or it is simplified to reduce the time it takes to obtain a licence, the documentation required to obtain a licence, and the cost of obtaining a licence.

The costs of licensing are covered in Part 6 where it is shown that licence fees, while very light, generate sufficient income to make OFTA self-funding and financially independent of the Treasury. By creating a wide funding base across the industry, OFTA is also seen and widely regarded as being independent of any industry influences, an important consideration if the regulator is to command the respect and trust of all the parties involved.

Spectrum Planning

OFTA employs around 120 staff in spectrum management, out of a total of 300 staff, such is the importance of spectrum planning, frequency allocation, assignment and licensing in the regulator's work.

Logically, the first job of the regulator is to draw up a national spectrum plan based upon the ITU's regional allocations.

The national plans are usually far more detailed than the ITU's because there will be many different types of service under each major radio service heading. For example, there are many mobile services, both private and public, everything ranging from car security locking devices, to shared trunked radio systems used by transportation companies, to public service cellular mobile systems.

A second reason is that many frequency bands are allocated to different radio services which share the bands, some of which are given primary status and other secondary status.

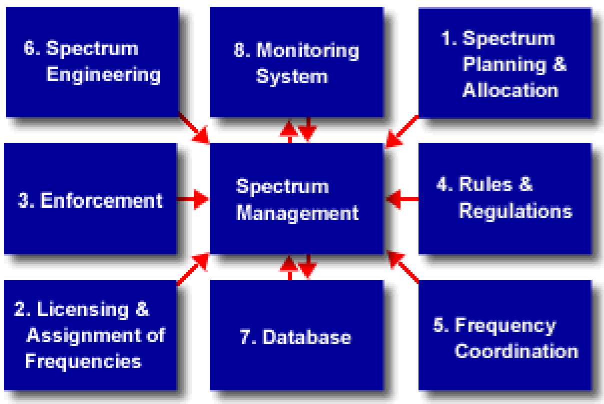
In each Member State the sharing arrangements can differ, and as long as the national frequency allocations do not interfere with the allocations of other Member States, variations will reflect the local demand for and supply of spectrum.

Hong Kong's *Table of Frequency Allocations* is published by the Office of the Telecommunications Authority and available on the OFTA website. The *Table of Frequency Allocations* details in one column the ITU's Radio Regulations spectrum allocations for Region 3, and in the adjoining column Hong Kong's allocations, and in a third column a detailed breakdown of actual frequency utilization. A summary chart is provided as an appendix to this Part**.**

The procedure OFTA adopts in spectrum management is as follows (see also diagram below):

1. Spectrum planning and allocation, following the guidelines of the ITU's Radio Regulations, but with local variation. (See above).
2. Assignment and licensing of frequencies to users for different radio services.
3. Regulation and rule-making to take into account changing circumstances and emerging international recommendations and guidelines.
4. Frequency coordination with adjacent administrations, for example mobile systems with Guangdong province, or satellite networks with Philippines.

5. Spectrum engineering, where OFTA uses a computer-run mathematical model of radio propagation patterns in Hong Kong to compute electromagnetic emissions and the likelihood of interference or health and safety hazards.
6. Database of existing frequency utilization records for the computer-run model.
7. Monitoring system, run by the Radio Monitoring Unit (RMU) to detect the illegal or wrongful use of frequencies or equipment.
8. Enforcement of regulations and licence conditions, principally to stop interference from the wrongful or illegal use of frequencies or equipment.



Procedures and Consultation for Frequency Assignment

Frequency assignments logically follow on from the allocation of spectrum bands to radio services, but the devil is always in the detail.

In Hong Kong's case several critical challenges arise. Hong Kong is a small, densely populated and mostly urban area with large clusters of high rise commercial and residential buildings, and a hilly terrain. Line-of-sight radio communications are therefore difficult to come by, and new building development can easily obstruct what was previously an open view.

Because of the relative shortage of land, property prices are inevitably high and so are commercial rates for suitable base station and cell sites. Sites tend to become very crowded unless a sharing arrangement can be worked out, and this sometimes requires regulatory involvement. A sub-tropical climate, with heavy monsoons and occasional typhoons adds to the challenges, making radio propagation at the higher frequencies unreliable.

Hong Kong is also the principal gateway to mainland China for air, sea and land freight and passenger traffic, so there is enormous demand for private mobile radio systems from the transportation sector.

Further, in Hong Kong's highly competitive public telecommunications sector there are already eleven second generation (2G) mobile networks, and several third generation (3G) networks to come. In addition, the broadcasting market has been liberalized and BSS frequencies have been allocated. OFTA has encouraged many fixed services to move away from RF and into cables and fibre, thereby freeing up frequencies for new assignment.

Consultation and Advisory Committees

OFTA therefore has to engage in at least two broad types of consultation with the industry.

First, general advice on how best to allocate frequencies between radio services which share the same bands of spectrum, and ancillary advice on equipment standards, power levels, sharing of sites, deployment of antenna, health and safety measures, and so forth. For this purpose OFTA has two Advisory Committees, the Radio Spectrum Advisory Committee and the Telecommunications Standards Advisory Committee.

Second, OFTA has direct consultation with potential users over their applications for a licence and the frequency of the channels that are to be assigned to them.

For the most part, these procedures are completely standard and administrative. They involve, for example, a search of the database for current frequency utilization and the alternative spare frequency channels.

Until the early 1980s, when demand was still not so great, the regulator, at that time the Postmaster General of the Hong Kong Post Office department, assigned frequencies more or less on a first-come-first-served basis. If spectrum was available, it was assigned. This policy was inadequate to cope with the explosion in demand for radiocommunications, especially for mobile communications from the mid-1980s, and so the current modern methods of spectrum management were introduced.

Exemption Order, Type Approval, and Enforcement

There are numerous devices that produce low levels of electromagnetic emissions, such as security and alarm systems, cordless telephones, industrial and scientific equipment, which do not represent any serious danger of radio interference or health and safety hazard as long as they conform to approved standards of design, power, frequency usage, and so on.

Equipment meeting internationally recognized and approved standards for such devices are included by OFTA in the Exemption Order that permits their unlicensed use in Hong Kong within specified bands of spectrum. For example, on the advice of the newly formed Radio Spectrum Advisory Committee (RSAC) in October 1995 OFTA amended the Exemption Order to include wireless microphones and certain spread spectrum devices.

Two difficulties arise in Hong Kong. First, the use of low-energy devices which do not conform to local regulations, for example cordless phones operating at 800 MHz rather than 1.7MHz or 47 MHz. Second, the illegal use of private mobile radio transmitters and receivers, a problem that is exacerbated by the very large number of transportation vehicles passing through Hong Kong to and from mainland China.

The first of these problems arises because it is not possible to require overseas equipment suppliers to manufacturer to Hong Kong’s specifications, nor to prevent people buying from overseas and bringing these devices back to Hong Kong. Banning such devices and prosecuting users would be a harsh reaction in cases where the potential for interference was very low, yet OFTA cannot allow such devices to be used by placing them on the Exemption Order because they can cause interference in some situations.

Where the potential for interference is greater, for example, the use of a wireless LAN high power transmitter, a way forward under consideration is to apply more rigorous type approval requirements. OFTA follows the recommendations of the CISRP, an international commission tasked with regulating radio interference.

CISRP CISPR issues guidelines for any device that emits electromagnetic signals, such as an internal combustion engine of an automobile, and OFTA uses these guidelines, but does not necessarily ban a device that fails to conform. OFTA's criteria are: (a) does the equipment cause interference, and (b) does it exceed CISRP CISPR's radiation limits?

a. Type Approval

A type approval process can become a significant cost factor facing equipment importers and network operators wishing to adopt a new technology. Various bodies, such as the Regional ITU and the Asia-Pacific Telecommunity, both based in Bangkok, have worked hard to simplify and streamline the procedures adopted by various administrations, and APEC has responded with the Mutual Recognition Agreement to which Hong Kong is a signatory.

Under the MRA signatories agree to accept type approval granted by any one APEC member, thereby cutting down on the need for an equipment supplier or importer to seek type approval for the same equipment from every administration in turn.

OFTA has two procedures for type approval, one a documentary procedure, and the other involving laboratory testing. OFTA recently introduced a flat-rate fee system for type approval requests. (See TSAC paper 15/98). OFTA also recognizes all type approvals given by member states of the European Union and North America, however, because Japanese frequency allocations are significantly different from those in Hong Kong some types of Japanese equipment are not approved for use in Hong Kong.

b. Radio Monitoring Unit

In the second case, the case of the illegal use of private mobile radio stations, the problems of interference can be serious. For example even the police were forced to move their frequencies to obtain clean channels, and prosecutions in a magistrate's court do take place, although the maximum fine of HK$50,000 is rarely used.

The difficulties tracking down the users of illegal private *mobile* radio phones are obvious. One way is to set up roadblocks, which is done maybe ten times a month. OFTA employs around 60 staff in a Radio Monitoring Unit (RMU) who work closely with the police by day and by night, but too many roadblocks would cause disruption to traffic so this tactic is limited.

The RMU is divided into six outdoor teams, each with their own vehicle and direction finding equipment, and indoor staff who monitor feedback from monitoring equipment located in the hill stations around Hong Kong. The indoor staff try to detect possible illegal or improper use[6], and the outdoor teams then try to locate the users.

The authority of OFTA to carry out this surveillance, to seize equipment, and to enter premises with a warrant from the judiciary, derive from the Telecommunications Ordinance, 2000. Previously these powers were only spelt out in the conditions attached to each licence, so the legal basis for OFTA's powers has been strengthened through the legislature and made more transparent.

Under the Telecommunications Ordinance, only the decisions of the Telecommunications Authority (TA) concerning anti-competitive behaviour may be appealed at the Telecommunications (Competitive Provisions) Appeal Board, but for all other issues there is recourse to judicial review based upon Common Law precedents.

Monitoring is a very important aspect of spectrum management enforcement because without it the database used for frequency allocations and assignments becomes useless. At the heart of the system is a computer that works off the database and can give instant readouts of the licences issued and the frequencies assigned. (See Part 5).

Cross-Border Coordination

Eliminating cross-border interference of radio waves is the primary commitment of signatories to the ITU in the area of spectrum management.

On 1st July 1997 Hong Kong became a Special Administrative Region (SAR) of the People's Republic of China when sovereignty reverted from Britain to China, but under the agreement of the Joint Liasion Group (JLG) Hong Kong retains direct representation at the meetings of the ITU as a member of China's delegation.

As a Special Administrative Region of China, cooperation and coordination between Hong Kong and the neighbouring province of Guangdong to the north remains important for interference-free broadcasting, aeronautical and marine navigation, and the use of cellular mobile phones, private mobile radio equipment, and pagers.

Frequency Coordination

A Frequency Coordination Agreement was originally endorsed in 1992 by OFTA and the Office of Guangdong Wireless Management Committee. As stated by OFTA in a press release on 6 November 2000 announcing the signature of a new frequency coordination agreement between the HKSAR Government and Guangdong province:

> It covered land mobile, fixed and broadcasting services for frequencies below 1GHz. The Agreement laid down the procedures and standards for the coordination of the use of frequencies to avoid mutual harmful interference. Although the 1992 Agreement expired on 30 June 1997, both sides have agreed to extend the validity period of the Agreement to beyond 1 July 1997 to give more time to work on a new frequency coordination agreement.
>
> The new Frequency Coordination Agreement signed in Shenzhen today covers the procedures and standards for coordinating terrestrial radiocommunication services including land mobile, fixed, maritime and broadcasting services in the frequency band from 30 MHz to 40 GHz. The Agreement also includes new procedures for

handling cases of radio interference and a mechanism for both parties to meet annually to revise the content of the Agreement in light of changes in technologies and demand of the telecommunications industry.

The 1992 Agreement divided spectrum into three categories: “Hong Kong priority”, “Guangdong priority” and “shared-use” blocks, where the “shared-use” block was divided on a first-come-first-serve basis.For example, the 400 MHz spectrum was used by government users police on both sides of the border.

Where interference arises in areas such as mobile cellular or broadcasting, each side will agree to reduce the power of transmission or tilt the antenna close to the border. For the most part these details are worked out by phone calls or facsimile, with face-to-face meetings only where more complex issues are involved.

The new 2000 Agreement which has extended the range of the 1992 Agreement, has instituted an opportunity for an annual review, and has recognised that new technologies, for example third generation (3G) mobile telecommunications, will create new demand for spectrum allocation and frequency assignments in the future.

Satellite

The other major area calling for coordination is satellites. If a Hong Kong based company, or a neighbouring economy plans to launch new satellites, then the issue of positioning often requires negotiation. For example, during 1999-2000 satellite coordination meetings were held with India, Indonesia and Vietnam.

Issues can involve nudging the orbital position a few degrees, or splitting frequencies, or lowering the power of the satellite.

Negotiations may also be necessary with the UK which, for historical reasons, shares orbital slots with Hong Kong. AsiaSat has satellites in these slots.

In October 1998 Hong Kong also took over the coordination for the five orbital assignments for the APT Satellite Company from mainland China’s Ministry of Information Industries (MII).

OFTA monitors the Telemetry, Tracking, Control and Monitoring (TTC&M) of all these satellites.

Spectrum Management Part 3:
Spectrum Management and EMC

Spectrum Management and EMC

OFTA, or rather its predecessor unit within the Post Office, did not start serious spectrum management and planning until the early 1980s. Until then frequencies were issued on a first-come-first-served basis within the spectrum band allocations. For example, there was considerable demand for frequency assignments for the paging industry.

Public Mobile Radio Services

The turning point was the advent of public mobile radio services. The first three analogue cellular mobile services began in 1985, and interference between pagers and mobile phones was a serious problem. A senior OFTA official describes the situation in those days as follows:

> Before OFTA instituted a proper frequency planning system, there was only a simple frequency registration process. Radio assignment was done in a very simple way. If there was a vacant channel, you simply put the operator in it. You didn't look at the technical aspects of a particular transmitter. You didn't look for problems of mutual interference caused by a combination of transmitters. You didn't look at the location of paging transmitters in relation to mobile transmitters.
>
> The situation in Hong Kong was particularly bad because you had so many tranmsmitters in a densely packed populated area. Operators preferred the same locations, high-rise buildings. They liked to put all their transmitters all together on the rooftops of taller buildings.

In the 1990s a new interference problem arose from the introduction of GSM and PCN cellphone networks. Transmitters even 2-4 km apart can still interfere if "they see each other."

To widen the level of industry representation and advice which OFTA can draw upon, and to encourage cross-industry cooperation and discussion of the problems, OFTA has established two advisory committees in this area: the Radio Spectrum Advisory Committee (RSAC) and the Technical Standards Advisory Committee (TSAC). All the major issues of spectrum management and allocation and procedures for assignment are aired at the meetings of these advisory committees and in the papers presented at the meetings.

Computer-based EMC

Before assigning a frequency, OFTA now looks carefully at potential interference on

a. intermodulation problems of transmitter location,
b. co-channel systems problems of spurious emissions, and
c. interference problems between adjacent channels.

Many technical parameters need to be taken into account, including the radio propagation characteristics of the frequency, the type and nature of the equipment such as the transmitter's radiation signal characteristics and the sensitivity of the receiver, power levels, directional and positioning issues, to calculate the level of mutual interference.

Originally OFTA made these calculations manually, but in the early 1980s switched to a computer. After upgrades of specially written software, the computer now stands at the centre of OFTA's spectrum management operations. Its effectiveness depends entirely upon the quality of the database from which all calculations follow.

In making a new frequency assignment OFTA will use the computer to make electromagnetic compatibility (EMC) calculations, based upon the considerations listed above.

As explained in the fifth meeting of the RSAC, 11 July 1995, in making a new frequency assignment, the culling distance and the culling frequency could vary in accordance with the frequency band in the EMC calculation.

The culling distance and culling frequency would be at least 2 - 3 MHz and 1/2 - 1 km respectively. But the EMC calculations exclude mobile-to-base and base-to-mobile because

. the interference is transient in nature,
i . the calculation time would be unduly long, and
ii . the number of assignable frequencies would be significantly reduced.

In anticipation that the problems of mobile-to-base would worsen as more networks were licensed, OFTA has encouraged operators to informally cooperate by making known the locations of their base stations and channel frequencies at the band boundaries so that adjacent channel interference can be avoided. The possibility of using guard bands has been ruled out due to the short supply of frequencies available given the strength of demand for cellphones in Hong Kong.

Fixed Links Assignments

A user who wishes to operate a fixed link has to submit an application for frequency assignment to OFTA. OFTA then has to conduct electromagnetic compatibility calculations before approving the application, but the tendency now is to move fixed radio services off spectrum and onto cables and fibre and into leased circuits to make way for the growing demand for mobile wireless services.

This is especially true for spectrum below 13 GHz. Notable recent exceptions have been the use of 23 and 38 GHz point-to-point fixed links used by mobile operators and the issuing of five multi-directional broadband fixed wireless licences, using 24 GHz and above.

Where other microwave applications are made, OFTA follows the FCC approach in the US where microwave users themselves have to carry out the necessary frequency coordination and submit their coordination report with their applications for frequency assignments. This dramatically speeds up the frequency assignment process.

Private Radio Mobile Services

Following a recommendation in a report commissioned by OFTA from Deloitte Touche Tohmatsu (DTT) *Consultancy Study on the Introduction of Economic Mechanisms to Spectrum Management in Hong Kong*, March 1995,[7] Hong Kong adopted a standard 12.5 kHz channel spacing for the use of private radio mobile systems. OFTA advised the RSAC on 15 September 1995, that

> The Electrical and Mechanical Services Department had suggested that the equipment life was 7 years and 60% of the UHF portable radios were licensed within the past 4 years. It was therefore reasonable to start changing the equipment in 3 years' time. The assignment of existing users should remain unchanged and they had to change their equipment into 12.5 kHz channeling in 7 years. Following adoption of a migration plan, OFTA would monitor the situation and would review the type approval specification for the 12.5 kHz channeling equipment of UHF band. The main target was to narrow channel bandwidth in the UHF band.

Re-assignment of Spectrum

Re-assignment of spectrum is a task that becomes necessary as new technologies give rise to new types of devices and new radio services while making old ones redundant. Conforming to ITU guidelines is another factor.

For example, OFTA needed to reallocate the 1.9 – 2 GHz spectrum for PCN use by 1997 when it was being used extensively by fixed links. In accordance with WRC 2000, OFTA must obtain the return of spectrum in the 11 – 12 GHz frequencies being used for MMDS and television broadcasting for future use by third generation (3G) mobile networks.

The process of returning spectrum can be an awkward one unless it was written into the licence awarding the original frequency assignment. In some cases the regulator has to wait for licences to expire, in other cases to trade one set of frequencies for another, or, in the case of many fixed radio services, encourage their migration to wirelines or cables or fibre.

New Licences and Services

When new technologies give rise to new radio services, for example third generation (3G) mobile radiocommunications, OFTA follows standard procedures.

These begin with a working group set up to examine the technology and the spectrum requirements. Here reference is made to Radio Regulation spectrum allocations and the Hong Kong *Table of Frequency Allocations*.

A consultant may be hired to provide further study, and visits to overseas administrations may be involved. The process can take a year or more. The results of the working group are put before the Advisory Committees for their consideration.

The second step is drawing up a licence and its conditions, a process involving legal drafters and taking about three months to complete. Licence conditions address coverage and the rollout plan of the operator.

The final considerations are frequency assignments, approval of transmitter sites, control of interference, and so forth.

One additional consideration is that the costs of this process are more than covered by the licence and spectrum fees charged, as OFTA has been set up as a Trading Fund under the Trading Funds Ordinance. (See http://www.justice.gov.hk/Home.htm for all Hong Kong legislation) Another consideration is the methods of issuing licences are beginning to change, notably with the possible use of auctions. These two issues are examined in Part 6.

Health and Safety

No-one doubts that radiation at high levels and in high doses causes health and safety risks, the problem is knowing for sure what transmitting devices emit dangerous levels, when and under what circumstances they may do so, over what periods of time exposure reaches critical levels, and so forth. No conclusive evidence really exists as yet for many applications, for example whether cellular mobile phone and base station emissions can cause harm.

OFTA follows the guidelines of the ICNIRP and regularly monitors sites in Hong Kong for radiation levels.

OFTA has issued a "Code of Practice for Protection of Workers and Members of the Public Against Non-Ionizing Radiation Harzards from Radio Transmitting Equipment" for all radio operators to follow. They should ensure that the electromagnetic radiation emitted from their antennae does not cause exposure of occupational personnel and members of the general public in excess of the limits set by the ICNIRP. To ensure that the radio operators comply with the requirements as set out in the Code of Practice, OFTA conducts inspections on randomly selected radio site locations.

One problem is that OFTA does not have sufficient technical details about every base station site that is negotiated between, say, the owner of a building rooftop and a radio service operator, and there are many hundreds of them. The assignment of frequencies is undertaken to avoid interference, and it is therefore primarily the responsibility of the radio site operators to ensure safe installation and operation of their radio systems/sites.

To tackle this potential problem OFTA has produced a Code of Practice to be followed by the industry in line with the recommendations of CIRPA, NRPD and IEEE, to govern the placement, height and usage of radio antennae to protect the public's health and safety from any potential hazard of non-ionizing radiation.

These measures do not necessarily lessen public concern, and therefore OFTA responds to requests and concerns of the public by carrying out inspections and measurements to allay these concerns.

Spectrum Management Part 6:
Licence Fees and Spectrum Pricing

Licence Fees and Spectrum Pricing

The issue of efficiency involves both technical efficiency, in using spectrum in a way that avoids mutual interference between users, and economic efficiency, in using spectrum as a scarce resource in a way that brings the greatest social gain. For reasons spelt out in Part 1, market mechanisms may not ensure that some public goods, such as emergency services, are adequately provided with spectrum. On the other hand, charging for the use of spectrum makes it likely to be used in less wasteful ways.

Further, when new radio services come along a mechanism is required to re-allocate spectrum from less valuable to more valuable services. In some cases technology comes to the rescue, when for example many fixed services can migrate quite painlessly off wireless and into cable or fibre. In other cases an administrative approach may be necessary, for example the non-renewal of licences.

But market mechanisms which, for example, allow users to bid in an auction for spectrum, are an alternative which have the advantage of being cheap to administer and relieve the regulator of the necessity of making what can seem like arbitrary or biased decisions in the allocation of frequencies and licences.

Auctions have been used by many administrations, notably the FCC in the USA, but the auctions for third generation (3G) universal telecommunications service licences (UMTS) in Europe during the summer of 2000 probably did more than anything else to focus recent attention on this issue. On the other hand, auctions can raise problems of their own as the controversies over 3G auction prices have shown.[8]

OFTA as a Trading Fund

OFTA has the status of a Trading Fund. (All Hong Kong legislation). This means that OFTA has the legal requirement to cover its costs and make a limited return on capital after paying a dividend to the Government. The principal source of revenue is income from licence fees and the use of spectrum, which typically account for between 80 – 90 per cent of turnover.

According to the Telecommunication (Amendment) Ordinance, para 321, Spectrum Utilization Fee reads as follows:

1. Subject to the consultation requirement under section 32G(2), the Authority may by order designate the frequency bands in which the use of spectrum is subject to the payment of spectrum utilization fee by the users of the spectrum
2. The Secretary may by regulation prescribe the level, or the method for determining the level, of spectrum utilization fees

3. A spectrum utilization fee may be calculated on the basis of a royalty or any other basis that includes an element in excess of the simple recovery of the cost of providing a service by the Authority

In the financial year ended March 2000 turnover was HK$359,366,000 and operating costs HK$234,927,000 and profit after tax HK$144,642,000 from which a dividend of HK$30,474,000 was paid to the Hong Kong SARG.

This revenue and profit is the basis of OFTA's financial independence from the Treasury and the industry[9]. The Trading Fund is supposed to target a rate of return over fixed assets of 13.5 per cent, but because of a surge in the use of mobile cellphones, and despite a decline in paging revenues, the rate of return hit 68.8 per cent in 2000.

The accumulated fund, which stood at HK$688,102,000 in March 2000, can be used for only one of two purposes, either to delay or reduce fees paid by the industry or to fund capital and income account items. This is to ensure the money is returned to the industry and not diverted to other uses. It is a transparent system because if the Government wished to use the funds for other social expenditures it would need to do so by raising taxes or increasing the dividend payments, and this would be subject to debate and agreement by the legislature.

Table 6 at the end of Part 6 lists the licence fees payable into the Trading Fund.

Spectrum Fees

Spectrum and licence fees are supposed to cover the administrative costs of the studies and monitoring required to plan and manage the relevant part of the spectrum, and the amount of frequency that is used, because the more frequency used the greater the problems of monitoring and managing interference. In addition a variable factor is built-in to encourage the use of higher frequencies in order to reduce the crowding at lower frequencies.

The following tables illustrate the structure of spectrum fees. Early calculations by OFTA estimated the manpower costs of managing spectrum for public mobile phone use would be around $50 per kHz and this figure was fixed, but the fee for building out base stations is variable, and falls beyond 50 base stations from $1000 to $500 per base station, and falls again beyond 100 base stations to $100 per base station.

Public Radiocommunications Service Licence	Fee payable to OFTA

1-50 base stations	$1000 per base station
51- 100 base stations	$500 per base station
101 and above	$100 per base station
1-200 mobile stations used by customers	$6000
For every 100 mobile stations over 200	$3,000
For every 1 kHz of spectrum assigned	$50

The following table shows the spectrum fees for fixed links used by fixed telecommunications network service (FTNS) licence holders. Below 1 GHz the fee is $50 per kHz, but between 1 – 10.999 GHz the fee is $(50 – 4f) where f = the frequency rounded to the nearest GHz. For example, if a fixed wireline operator used a microwave link of 9.45 GHz, the fee would be $(50-9) = $41 per kHz. Using a microwave link of 9.55 GHz would incur a fee of $40 per kHz. Above 19 GHz the fee is a flat rate of $1 per kHz.

FTNS	Fee
Where f = frequency rounded to nearest GHz in the assigned band	$1000000 + $750 per 100 connections +
	a. $50 per kHz below 1GHz b. $(50 - 4f) per kHz between 1 GHz and 10.999GHz c. $(20 - f) per kHz between 11 GHZ and 18.999GHz d. $1 per kHz above 19GHz
In cases where the spectrum is shared the fee is reduced proportionally	

a. Spectrum Pricing

In September 1994 OFTA employed a consultant to report on the possibilities of introducing spectrum pricing as a means towards the more efficient use of spectrum in Hong Kong. The report, by Deloitte Touche Tohmatsu (DTT) *Consultancy Study on the Introduction of Economic Mechanisms to Spectrum Management in Hong Kong*, March 1995, was made public.

The report points out that there are many different approaches to estimating the value of spectrum, for example using discounted expected future cashflows derived from the use of a frequency, or benchmarking the relative cost of using alternative services or technologies or frequencies, but they are all likely to yield prices which more correctly reflect the economic cost (that is, the opportunity cost) of using spectrum.

A recent challenge has been the auctioning of third generation (3G) mobile licences. This is because the technology offers access to broadband mobile Internet services and Internet business models take the industry into a void of uncertainty. It is very problematic to know how to, or whether to, use traditional techniques of market valuation in the Internet environment, so there is less certainty that auction prices truly reflect the value of spectrum rather than other commercial considerations. This complicates the issue of spectrum pricing and presents a challenge for future policy making. (See Part 7)

b. Tradeable Licences

A related issue to spectrum pricing is that of tradable licences. The advantages include a market efficient means of reallocating spectrum subject to constraints upon usage set by the regulator to prevent interference or otherwise undesirable usage. It also allows licencees to exit a market for commercial reasons, and the more companies are free to exit the more likely they are to enter in the first place.

The regulator again can impose ownership constraints where the competitive structure of the market is under threat. But for licences to be tradeable they need to be issued for periods of perhaps 10 or 15 years, and confer some form of property rights for that time. Tradeability could also apply to part of the spectrum covered by the licence, so ‘surplus’ frequency can be traded.

Of course there are dangers associated with tradeability, including the incentive to ‘bank’ licences for future commercial gain rather than immediate usage. One way to tackle this problem is to introduce pre-qualification, whereby the regulator judges whether or not the applicant is serious about, and capable of, providing a radio service.

c. Licence Fees

Up to March 2000, OFTA issued over 106,000 licences. The following table lists the categories and the fees paid into the Trading Fund.

Licence	Fee payable to OFTA
1. Private telegraph (reception)	$20 per channel

2. Private telegraph (transmission)	$55 per station
3. Private telegtaphtelegraph (transmission & reception)	$22 per channel + $55 per station
4. Ship station	$150
5. Aircraft station	$150
6. Press reception (direct)	$1500
7. Radio receiving station (not sound broadcasting)	$80

8. Experimental station	$300
9. Mobile radio system –	
fixed station	$750
mobile station	$300
10. Aeronautical VHF fixed station	$1500
11. Radiophone Communication –	
fixed station	$750
mobile station	$370
12. Induction Communication	$150
13. Radio dealers (restricted)	$750 ($80 for auctioneer or

	pawnbroker)
14. Radio dealers (unrestricted)	$1500
15. Demonstration, unestrictedunrestricted	$300
16. Radiocommunications school	$300
17. Amateur station	$150
18. Model control	$55
19. Industrial, Scientific and Medical Electrical	$80
20. Radio paging system –	
fixed transmitting station	$750
receiving station	$80
21. Wide band link and relay station	$150 per MHz
22. Broadcast relay station	$360 for every 100 outlets

23. Closed circuit television	$150 per transmitter + $80 per receiver
24. Broadcast radio relay station	$750
25. Public Non-Exclusive Telecoms Service (PNETS)	See above
26. Pleasure vessel radio network station	$150
27. Radiodetermination and conveyance of commands, status and data	$80
28. Hotel television (transmission)	$150 per transmitter + $80 per receiver + $75 per MHz of occupied bandwidth for both transmitters and receivers
29. Public Radiocommunications Service (PRS)	See above
30. Satellite Master Antenna Television (SMATV)	$750 + $700 per 100 outlets
31. Fixed Telecoms Network Services (FTNS)	$1000000 + $700 per 100 connections – see separately

32. Self-Provision External Telecoms Service (ETS)	$750 + $6000 per Vsat requiring TA frequency coordination ($5000 not) + $17000 per earth station requiring TA coordination ($1100 not)
33. Public Radiocommunications Service (other than for land mobile services)	$50000 + $1000 per land station or land earth station

Spectrum Management Part 7:
Broadband and Convergence

Broadband and Convergence

The delivery of broadband services, such as digital terrestrial and satellite television, cable television and cable modem services, interactive television over telephone lines, fast Internet services over digital subscriber lines, or over fixed wireless broadband to the building, or through packet-switched mobile networks to different handheld devices, poses new challenges for regulators and spectrum management besides the obvious one of allocating frequency to different services.

Indeed, the problem of allocating new frequencies to new services and issuing new licences is nothing new at all, just an extension of the regulator's traditional tasks. What is new is the degree of attention that now must be placed upon customer access networks for the delivery of broadband services.

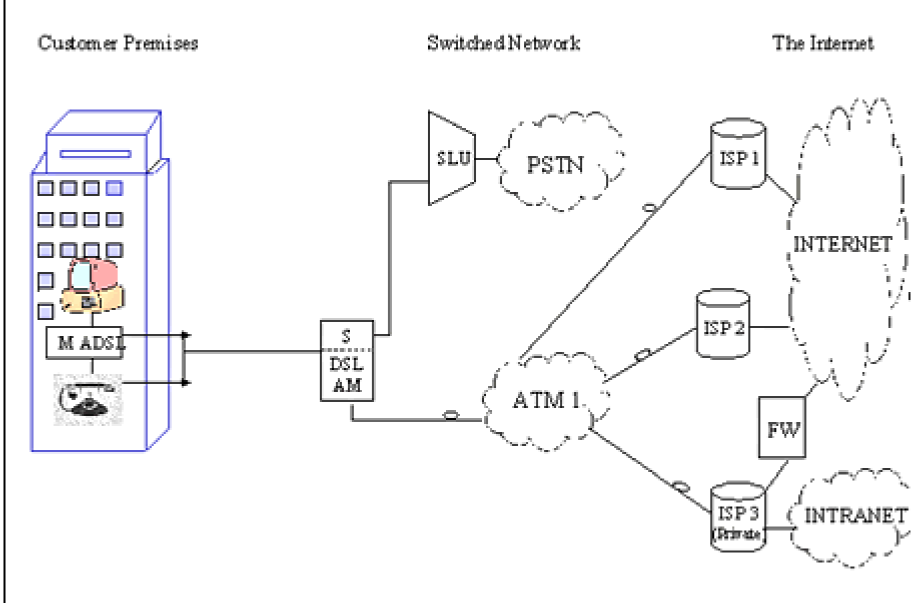
Customer access networks are often bottlenecks in the delivery chain, either because of a lack of capacity or because of interference problems when many users, for example in a residential building, wish to access different delivery channels.

The policy of the Hong Kong Government is that consumers should enjoy the widest possible choice at reasonable prices, and it is the regulator's job to ensure that comes about. Difficulties arise because the technologies used to deliver broadband content are still evolving, and standards have yet to be established between manufacturers, network operators and service providers, for example set-top box standards and cable modems.

For an OFTA discussion of the latter, see TSAC paper 14/2000 *Technical Standards of Cable Modems for connection to In-building Coaxial Cable Distribution Systems* Additionally, the problems of interference that may arise in the local access network or in the traditional in-building wiring systems from high speed transmissions of data remain unknown.

Diagram 1 illustrates access by the ITU standard G 992.2, otherwise known as G-Lite or Discrete MultiTone (DMT). A splitter in the exchange seperates PSTN traffic from broadband traffic which is routed to the ATM through fibre and then onwards towards the Internet and a Web-based environment. The characteristic of G-Lite is the delivery of up to 1.5 Mbps over a twisted copper wire pair at the customer access end. The question is how much interference from cross-talk may arise between neighbouring pairs serving different customers? If this proves a problem, it becomes initially an issue of spectrum management for the network operator and customer access provider, but what implications may this have for regulatory issues such as interconnection and unbundling of the local loop? Incumbents often resist interconnect, and offer virtual co-location rather than physical co-location, and physical co-location rather than local loop unbundling, in that order of preference. If spectrum management proves to be a serious issue for broadband transmissions in the local loop, then regulators may find themselves having to take a cautious approach.

Diagram 1



ITU G.992.2 (G.Lite) 'Splitterless' ADSL/DMT Broadband Access

In-building Coaxial Cable Distribution Systems

In-building Coaxial Cable Distribution Systems (IBCCDSs) are the block wiring systems inside multi-storey buildings that provide connectivity for a variety of broadcast and multimedia networks. Cable television is one system which is distributed through a hybrid fibre coaxial network to the building basement and channels are then relayed through the IBCCDS to individual subscribers.

There are a number of free satellite television signals that are relayed by Satellite Master Antenna Television (SMATV) systems using receiver dishes on rooftops and signals are fed down through IBCCDS. Two free-to-air broadcasters use Communal Aerial Broadcast Distribution (CABD) systems that make use of the IBCCDS, as do Closed Circuit Television (CCTV) systems.

The four terrestrial television channels in Hong Kong are transmitted in the frequency band 470 – 790 MHz and they are commonly distributed through the CABD system at the same frequency, although there are variations around the territory. For this reason these has been no territory-wide frequency plan for the distribution of terrestrial television programmes in the CABD.

Similarly, because CCTV systems, which use one of the channels in the same band and are mainly used to provide building security, are exempt from licensing there is no central record of them. SMATV systems do require licences, but use different television formats, PAL or NTSC, and occupy bandwidths of either 6 MHz or 8 MHz.

Satellite television services which carry only a few programmes use non-adjacent channels in the IBCCDS, whereas systems that carry many programmes use filters so that adjacent channels can be used.

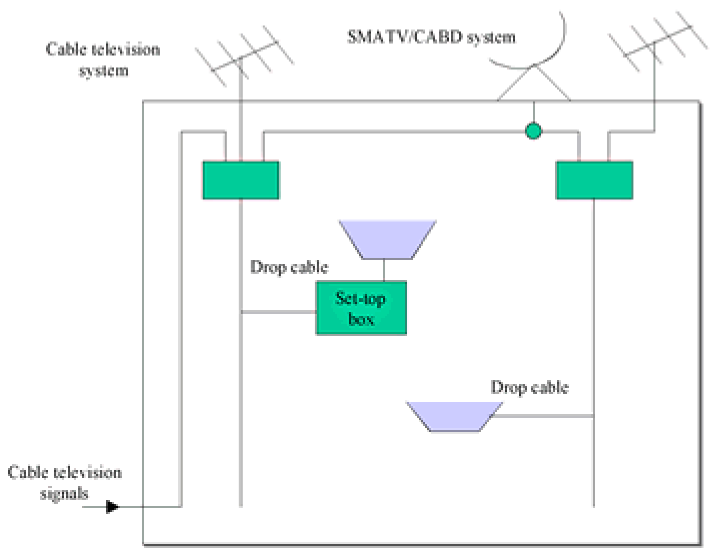
The cable television network has a capacity to offer 31 channels, transmits in VHF and uses adjacent channels with filters at the headend. It also offers 20 channels over MMDS, but the MMDS frequency is to be returned by May 2001.

Only HKT's interactive television and Video-on-Demand service is offered over twisted pairs to the customer, but Hutchison Telecom/Global Crossing also offer broadband services to some business and residential districts, while New T&T will be offering telecommunications services over Hong Kong Cable Television Limited's cable network. Hong Kong has also licenced four BSS services, each capable of transmitting up to 40 channels, and more BSS frequency could become available.

Diagram 2 illustrates the issue of inbuilding or block wiring. The ultimate bottleneck here is the last horizontal cable drop into the residential premises.

Diagram 2

Typical Configuration of the In-building Coaxial Distribution System



The challenge is to squeeze more channels into the IBCCDS for the delivery of a growing number of broadband services. In March 1999 OFTA issued a Consultation Paper '[Frequency Layout Plan of In-Building Coaxial Cable Distribution Systems]' which discusses these issues in detail. In June 1999 OFTA published the [results of the public consultation] and in July 1999, OFTA published [a summary of the industry's views and OFTA's initial response] which lays the groundwork for the next step. Among the issues that arose were the following:

1. If consumers in a building decide they want to buy new services then the providers of these new services shall be required to use digital compression in a ratio of at least 6:1 and use 8 MHz channelling even when 6 MHz NTSC signals are being distributed. This will gradually increase the level of harmonics across Hong Kong.
2. The cost of upgrading the IBCCDS will be left to commercial arrangement, and will not apply where new services are not being supplied. A central database of all new systems will be maintained and will be published.

3. A timetable for the digitalization of all IBCCDS will be reviewed when terrestrial digital broadcasting begins, probably in 2002 2003.
4. The allocation of frequency for IBCCDS, spanning VHF and UHF (54 – 470 750 MHz) is to be increased up to 862 MHz, and adjacent channels will be used to increase capacity when required. Some adjacent channels will be reserved for telecommunications.
5. Set-top boxes are the means of conditional access consumers have to many of these new services. (See below). OFTA recognizes the difficulty the industry has in the absence of accepted standards, but also has an obligation to protect the consumer's right to access the services of their choice.

   Most set-top boxes have two functions, an access function and security functions, such as locking, and their combination can obstruct customer access to other service providers. OFTA will review the possibility of separating these functions, and requiring disclosure of interface specifications and related issues after digital terrestrial transmission of television has begun.

Set-Top Boxes

OFTA will require the following:

1. Set-top boxes should not distort, restrict or prevent competition in broadcasting or telecommunications services.
2. Set-top boxes should be equipped with by-pass outputs so that signals within the frequency range 50-862 MHz can by-pass the set-top boxes with minimum attentuation.
3. Set-top boxes should be capable of operating on adjacent channels so that they will be compatible with the new channel plan. (See Annex 12C and 12D)
4. Set-top boxes should be tunable in the range of 54-862 MHz
5. Set-top boxes should be equipped with audio/video (A/V) outputs to simplify the connection with the television set and other A/V equipment.
6. None of these requirements apply to set-top boxes used by existing licensees or for digital terrestrial transmissions, which will be determined later.

It is clear that broadband and conditional access issues are difficult to resolve in the short term because many older buildings are not well equipped and have ancient wiring, while standards issues continue to hold back developments in modern buildings.

The demands upon frequency assignments are likely to grow rather than diminish, so every advantage needs to be taken of technologies such as digital compression techniques, but these in turn may cause as yet unknown issues of interference unless handled with foresight and planning. For that reason, a reliable and up-to-date database covering IBCCDS systems is essential.

Third Generation (3G) Public Mobile Radio Services

A major development in mobile communications is taking place, the shift from circuit to packet switched networks. This has been called second-and-a-half generation mobile phone or 2.5G, but so far as the issuing of new frequencies are concerned it is the development of UMTS or 3G that is important.

There are many complex policy issues surrounding the issuing of 3G licences, for example whether they should be auctioned, and if so what method of auctioning is preferable. This debate has been vigorous in Hong Kong, and focuses on OFTA's two Consultation Papers, issued in March and October 2000.

OFTA has allocated frequencies at 1920 – 1980 MHz and 2110 – 2170 MHz per second FDD and 20 MHz for unpaired TDD, and WRC2000 recommended additional frequencies become available. Managing spectrum allocations and assignments for 3G and future generations of broadband mobile services will clearly be a major role for regulators in the coming years.

Spectrum Management Appendix:

Hong Kong Frequency Allocation Chart

Hong Kong Frequency Allocations Chart