Study on Radio Spectrum Pricing System: Final Report

A report for OFTA

December 2009

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Executive Summary

The Government of the Hong Kong Special Administrative Region has embarked on a programme of reforming its spectrum management policy to enable a more responsive and transparent approach to regulation. This has resulted in the publication of a Spectrum Release Plan and more emphasis on market-based mechanisms for non-government use of spectrum, including the use of auctions to assign spectrum and the application of a Spectrum Utilisation Fee (SUF) to all non-governmental users of spectrum. In the case of auctions, SUFs will generally be determined through the bidding process (though in some cases an annual fee will be preset) while for spectrum that is not assigned by auction the SUF will be determined administratively by OFTA. This report is concerned with the determination of SUFs for spectrum that is not auctioned and is not used for the delivery of public communications services.

In this Report we:

- Present a review of approaches used in twelve countries to set SUFs for spectrum that is not auctioned (i.e. administratively determined SUFs) in the context of the objectives they are intended to achieve (Section 2 and Appendix A).
- Discuss options for setting SUFs administratively in Hong Kong, taking account of international experience, and conclude with a recommended generic approach (Section 3).
- Assess the case for the application of SUFs and the where relevant calculate SUF values for frequency bands allocated to fixed services (Section 4), non-public mobile services (Section 5).
- Provide concluding comments on the implementation of SUFs (Section 6).

International experience

We have reviewed spectrum pricing approaches used in Australia, Ireland, Japan, New Zealand, Portugal, Singapore, the UK and the US, and have provided some additional information on Bahrain, Canada, France and Spain.

In all of the countries reviewed spectrum pricing that exceeds the costs of managing the spectrum is only applied in congested frequency bands. In these bands regulators have set prices that relate to the “amount” of spectrum licensed to the user and other key drivers of spectrum value. In particular, prices are a function of one or more of the following parameters:

- the amount of spectrum used measured by the bandwidth sterilised
- the geographic area over which use is sterilised – sometimes measured directly and in other cases it is proxied by power
- the type of service supplied often with higher fees for public mobile as compared with other services
- the frequency band, with higher values in bands that are internationally harmonised, that offer better propagation characteristics and that are more likely to be congested
- the location of use with higher values in more congested areas e.g. higher values in urban versus rural areas

- the fraction of the national population covered as a proxy for the value of a regional as compared with a national licence.

The levels of the key parameters in the formulae used are not directly related to opportunity cost or full market value, with the exception of New Zealand and the UK. Rather values are set judgmentally with ad hoc changes made over time as certain bands become more congested and so attract a higher fee than would be the case under pure cost recovery fees. In addition historical precedent heavily influences the level of prices because of the political difficulties of making major changes in fees paid by users. In some countries (e.g. Australia, Portugal, Spain and France) prices are discounted for government users or where public interest issues arise. These discounts are set on an ad hoc basis.

In the UK and New Zealand opportunity cost estimates have been derived for a range of services using either the “least cost alternative” approach or by calculating enterprise value, whichever is most practical taking account of service characteristics and the reliability of the information available to derive estimates. Where multiple values are obtained the tendency of policy makers has been to set prices on the low side to avoid spectrum being left idle. The New Zealand experience shows that uncertainty over future services, technology and revenues makes it difficult to arrive at a robust estimate of enterprise value. It was for this reason that the least cost alternative approach developed for the UK was applied in New Zealand to derive values for spectrum used by cellular operators. This approach is likely to provide a lower bound on the market value of the licences.

Implications for setting SUFs in Hong Kong

This report covers the setting of SUFs based on opportunity cost for spectrum which is not used for the delivery of public communications services and is assigned other than through market means. The prime examples of frequency bands which fall into this category are those which are allocated to private mobile radio and fixed links.

SUFs will be charged in addition to existing fees which are intended to recover OFTA’s spectrum management costs.

The Spectrum Policy Framework (SPF) provides that in principle SUFs will be applicable to all non-government use of spectrum. We propose that non-zero SUFs are applied only in congested frequency bands as this best promotes the spectrum policy objective set out in the SPF of “facilitating the most economically and socially efficient use of radio spectrum with a view to attaining maximum benefit for the community” and is consistent with international best practice.

Options for deriving opportunity cost estimates for SUFs are described in Section 3 of this report and are appraised against the following criteria: Incentives for efficient spectrum use; objectivity; simplicity; transparency.

We suggest the following multi-step process is applied:

1. What services or applications could potentially use the frequency band? (For this report only existing services and applications were considered as there was no policy to change the allocated use of the bands under consideration.)
2. For each application or service derive the value of spectrum from one or more of the following:

a. Market values: Are there market values revealed by auctions or trades in comparable market and spectrum use situations? If yes, then use these data to provide an estimate of value for the service in question.

b. Calculated values: Depending on the service directly calculate the value as follows.

   i. Calculate value based on the NPV of future cash flows with all inputs (including capital) valued at their market price. (This approach is only relevant where the service generates revenues specific to the use of spectrum. This is typically the case where services are provided to third parties (i.e. for public services) and so is not very relevant to this report.)

   i. Calculate value based on the least cost alternative approach. (This approach is most relevant to spectrums applications that support internal business processes (i.e. private services), but has also been used to value public services where revenues are highly uncertain.)

c. Where market and directly calculated spectrum values are obtained, make choice of value based on the direction of bias that seems likely to best promote welfare.

3. If there is an alternative use with an estimated value greater than that for the current use then set the SUF between the two values – generally towards the bottom end of the range so that spectrum is not left idle. However, if spectrum demand is not very sensitive to price changes a value towards the middle of the range may be appropriate.

4. If there is no alternative use with a spectrum value higher than the current use of the band then set the SUF at the spectrum value for the current use.

The SPF indicates that new SUFs will not apply during the course of an existing licence. This raises issues of fairness between:

- Operators who may have different licence durations. Those with a long time to run on their licence (e.g. FTNS/FC/UC licensees) may not pay the SUF for many years, while those with say annual licences (e.g. WBLRS licensees) will pay immediately.
- Incumbent operators and new entrants. SUFs may not apply immediately to the former but will apply to all new licensees.

To address these issues we recommend the government considers applying SUFs to all users of the relevant frequency band irrespective of the time at which the user’s licence is due for renewal. We also suggest the Government considers the application of a grace period and/or a phase-in arrangement to give spectrum users time to react to the new fees, for example by modifying their spectrum holdings.

SUFs for fixed services

Fixed links

We have estimated values based on the use of alternative technology, frequencies and services (both leased line and satellite links) as well as self provision by fibre / cable. These values are on top of the current spectrum fees where these would have to be paid anyway as a means of recovering OFTA’s costs. The least cost alternative methodology involves setting SUFs based on the least cost of reducing spectrum demand for a typical user.

We have selected both the use of higher uncongested frequencies (involving a double hop) and leased lines as the least cost alternative methods. In using the calculated values associated with these alternatives it is recommended that initially the lower value is applied to all fixed links in the congested bands below 10 GHz. The higher value is in any event not significantly higher so it can be expected that the value used will provide an incentive with respect to both least cost alternatives. The value to be used is therefore HK$2936 per MHz per annum using the FTNS licence as the reference.

This value can be applied as an SUF in the following form:

$$\mathbf{SUF = \$ \times BW \times F_{freq\ band} \times L_{licence} \times E}$$

where:

**$** = the reference value in HK$ per annum per MHz taken from the calculations (using the FTNS value as the reference) = HK$ 2936 per annum per MHz

BW = the bandwidth used in MHz (for the avoidance of doubt, noting that other administrations treat this factor differently, a bidirectional link should be considered to use twice the bandwidth of a unidirectional link)

$\mathbf{F_{freq\ band}}$ = 1 if frequency band between 5 and 10 GHz, otherwise = 0

$\mathbf{L_{licence}}$ = 1 for FTNS licence, = 1.73 for WBLRS licence (derived from the WBLRS value, 5086, divided by the FTNS value, 2936)

E = 6 if frequency is made available on an exclusive basis, otherwise=1

Recommendations have also been made regarding how the SUF for cross-polar links should be applied and how link lengths should be appropriately accommodated in the frequency bands available.

Application to higher frequency bands

OFTA data shows that fixed link frequency bands between 5 and 10 GHz are congested and hence we have derived an SUF which would be applied to these bands (on top of existing fees) in order to encourage links to migrate to higher uncongested frequency bands, this option being the least cost alternative. Although analysis of current assignments indicates that 11 GHz band is not congested, OFTA is currently making new assignments in the band and is experiencing additional requests for assignments in the band from government users, fixed network operators and mobile network operators. Consequently, it is expected that this band will become congested in the near term and certainly well before any SUF review which would be expected to be some years away. We therefore suggest that the 11 GHz band should be included in the SUF we are proposing for the 5 – 10 GHz range. We recognise this is rather approximate, but consider that it should provide sufficient incentive for efficient spectrum use until the first five yearly review of the SUFs.

If it is thought that other bands above 10 GHz (say between 10 and 20 GHz) are going to become congested at a later date (say when SUFs are reviewed) it will be necessary to apply the same methodology in order to derive an SUF to be applied to these higher frequency bands (10 – 20 GHz). Two steps need to be undertaken, namely:

1. To establish an SUF for the middle frequency bands (10 – 20 GHz)
2. To recalibrate the original SUF for the lowest frequency bands (5 – 10 GHz) in the light of the SUF to be applied to the middle frequency bands (10 – 20 GHz)

(**1**) When looking at an SUF for the middle frequency bands (10 – 20 GHz) it can be shown that moving to higher frequency bands, thereby incurring an extra hop, is still the least cost alternative.

The difference in the SUF calculated for the middle frequency band (10 – 20 GHz) when compared to the lower frequency bands (5 – 10 GHz) arises solely because of the relative differences in existing licence fees between 7 GHz and 15 GHz and between 15 GHz and 25 GHz. This situation arises because across the range of frequencies addressed here (i.e. 5 to 25 GHz) the cost of equipment and site rental is largely frequency independent. The SUF thus derived for the 10 – 20 GHz range amounts to HK$ 4,436 per MHz per annum in relation to an FTNS licence.

(**2**) Since the original SUF (as applied to the 5 – 10 GHz frequency bands) was calculated using fees that currently apply at 15 GHz, and the total fees paid will change now that an SUF is to be applied to the middle frequency bands (10 – 20 GHz), the original SUF (for the lower frequency bands, 5 – 10 GHz) needs to be recalibrated. It is important to recognise that the whole methodology has to be applied each time an SUF assessment is made, whether it is to establish a new SUF or recalibrate an existing SUF.

Looking at the picture as a whole shows that the imposition of the SUF calculated for the 10 – 20 GHz frequency range means that moving to a higher frequency band is no longer the least cost alternative for a licensee in the 5-10 GHz range. The least cost alternative is now the use of leased lines (including the assumption that some additional fibre has to be installed). With this leased line alternative the new SUF for the 5 – 10 GHz frequency range in total becomes HK$ 2,947 per MHz per annum i.e. there is an additional SUF of HK$ 11 per MHz per annum over and above that already applied. From a policy point of view the amount is so small that the 5 – 10 GHz SUF could remain at its original level.

It is noticeable that the SUF associated with the lower frequency range (5 – 10 GHz) is somewhat lower than the SUF associated with the higher frequency range (10 – 20 GHz). This appears counter-intuitive but is in fact correct because the proposed SUFs should not be considered in isolation from the existing fees which are already substantial, particularly at the lower frequency ranges, and already have their own frequency dependency. It is the frequency dependency in the existing fees that gives rise to this apparent anomaly. However considering total fees (i.e. existing licence fee + SUF) does result in the fees being higher in the lower frequency bands.

The discussion above relates to the FTNS licence as the baseline. We have also shown how an SUF for 10 – 20 GHz WBLRS licences can be derived.

Application to satellite bands

Regarding satellite bands, and most particularly C-band as the other bands are little used, the SUF should be related to the fixed link SUF in terms of the denial of fixed link usage. Since OFTA has largely separated satellite and fixed link usage into different allocations, the denial of use is somewhat theoretical. However, it can still form the basis for assessing the satellite link SUF. While the fixed link SUF has been developed with regard to fixed link congestion between 5 and 10 GHz it is appropriate that the same SUF be applied to C-band satellite links even though some of the C-band frequency range falls outside the fixed link SUF range.

Satellite link licensing has its own existing fee schedule with the level of fee linked to the type of terminal and whether coordination is required or not. There is no relationship with existing FTNS and WBLRS fee schedules which it is assumed will continue and which form the basis of the derivation of an appropriate fixed link SUF. Given that we have derived an SUF which applies different values to FTNS and WBLRS licensees, which of these values should be applied as a satellite SUF? In line with the general principle outlined earlier that an SUF should be set at the lower end of any range in order to avoid spectrum lying idle, it is proposed that the satellite SUF should be based on FTNS value which is the lower of the two values. This value, on the basis of exclusivity, is HK$ 17,616 per annum per MHz (i.e. 6 x HK$ 2,936 per annum per MHz). This value needs to be apportioned between satellite link users operating on the same frequency. Satellite frequency reuse is achieved across the orbit through the directionality and polarisation of ground terminals. In theory this means a frequency might be reused a maximum of 100 times in Hong Kong (based on an available orbital arc of about 150 degrees, satellite spacing of 3 degrees and dual polarisation). It is likely that actual frequency reuse is considerably lower than this theoretical maximum as the orbital arc is shared with other countries and practical issues such as rain attenuation may limit low elevation usability. Actual frequency reuse an order of magnitude lower (i.e. 10) might reasonably be expected. OFTA may wish to analyse their assignment database in order to arrive at a substantiated value with which to apportion the exclusive SUF value of HK$ 17,616 per annum per MHz to individual users.

While applying an SUF can be relatively clear cut for a transmitting earth station (as addressed in the previous paragraph) it is less easy for receive-only terminals, as noted in the discussion about Recognised Spectrum Access (RSA) in the main part of the report. Concerning the possible future interest of the mobile community in the IMT designated part of the C-band downlink, it will be difficult to use price unless a receive-only SUF is in place and it may well be more appropriate anyway to manage any refarming required administratively.

Application to ENG/OB

Insofar as ENG/OB bands are concerned, it has been noted that the ENG/OB bands are generally congested in the frequency bands near 2 GHz and that capacity is available in the OB bands above this range. In the first instance SUF should be applied to the bands near 2 GHz and we recommend applying this at the same rate as fixed links even though the fixed link SUF is applied in a narrower range (5 to 10 GHz). Given that ENG/OB links are currently licensed under the FTNS schedule and on an exclusive basis it is appropriate that the FTNS fixed link SUF be applied, namely HK$ 17,616 per annum per MHz (i.e. 6 x HK$ 2,936 per annum per MHz).

However, considering that 2 GHz frequencies are likely to be more attractive to mobile services than to fixed services, consideration could be given to linking the SUF for the 2 GHz ENG/OB bands to the private mobile SUF should the congestion in these bands persist after the introduction of an SUF linked to fixed link prices.

SUFs for non-public mobile services

We have obtained a value relating to the congested 440 – 470 MHz band based on the cost of moving to an uncongested frequency band (e.g. at VHF or at 800 MHz). The value is HK$ 336 p.a. per kHz which is comparable to values calculated for the UK but is higher than the auction benchmarks. It is noted however that the number of benchmarks available is limited and it should not be forgotten that the spectrum is auctioned as an unmanaged band whereas the comparison here is with spectrum that is managed by OFTA with all the cost that such management entails.

The situation regarding congestion in the VHF and 800 MHz non-public mobile service frequency bands (i.e. apart from the 440 – 470 MHz band) should be kept under review. Should these bands appear to be approaching congestion then an SUF should be applied. If only one of 800 MHz or the VHF band is congested then the SUF for the congested band should be set as the same value as that for the 440-470 MHz band (i.e. HK$336 per kHz per annum), as users still have the option of moving to another band. The same SUF should apply to all applications in either the VHF or 800 MHz band as the bands can potentially be used by all applications.

If all three frequency bands are congested then no user has the option of moving to another frequency band and so the least cost alternative then becomes either moving to narrower channelization or moving to digital equipment. It is possible that by the time this happens the costs of digital equipment will have fallen considerably in which case this may be the cheaper option. However, we do not know the future evolution of digital PMR equipment prices and so if all bands become congested in future the cost of the different options will need to be recalculated and the SUF set using the methodology we have proposed in this report. We have shown how this might be done for fixed link bands in Section 4. Again the same SUF should apply to all applications in the VHF and 800 MHz band as the bands can potentially be used by all applications.

It is notable that the balance of spectrum availability in the 440 – 470 MHz band is strongly weighted towards government users. It is clear that release of some of this spectrum would ease congestion amongst commercial users significantly. In any event there may be a requirement to temporarily release some of the government spectrum to help refarm commercial users to different technologies.

Implementation issues

In Section 6 we have examined a number of implementation issues. In summary we suggest that:

- SUFs are in general set as annual payments regardless of the duration of licences.
- SUFs are reviewed every five years and are only ever changed after the five yearly review. Between reviews OFTA should collect the data required to conduct the review (e.g. data on spectrum use by band). Less frequent reviews might be appropriate for long duration licences where the SUF is based on an auction price for long duration licences.
- In principle SUFs should apply immediately to all frequency bands where opportunity costs are non-zero. At a practical level there is likely to be a need to phase in the payments (as was done for the 2G licences) in order to moderate their impact on businesses and give them time to adjust their spectrum use taking account of the final fee level. We therefore recommend that SUFs proposed in this report should be phased in to give users time to adjust to the new level of fees.
- In congested bands below 3GHz the likely potential alternative uses of congested bands are mainly mobile services, in which case the relevant SUF for mobile services should be applied. Above 3GHz applications are generally fixed in which case the lower of the two fixed service SUFs should be applied.
- Before implementing SUFs, OFTA should consider whether it is likely to make changes to other related policies concerning spectrum allocations to government users, policies for access to hilltop sites and moving to a common basis for management fees for fixed link and possibly also private mobile radio users. In the longer term consideration might also be given to charging management fees and SUFs to government users to encourage efficient spectrum use.

1 Introduction

The Government of the Hong Kong Special Administrative Region has embarked on a programme of reforming its spectrum management policy to enable a more responsive and transparent approach to regulation. This has resulted in the publication of a Spectrum Release Plan and more emphasis on market-based mechanisms for non-government use of spectrum, including the use of auctions to assign spectrum and the application of a Spectrum Utilisation Fee (SUF) to all non-governmental users of spectrum. In the case of auctions, SUFs will generally be determined through the bidding process (though in some cases an annual fee will be preset) while for spectrum that is not assigned by auction the SUF will be determined administratively by OFTA. This study is concerned with developing a generic system for setting SUFs for spectrum that is not auctioned and is not used for the delivery of public communications services.

1.1 Current situation

All licensees pay licence fees that are intended to recover OFTA's costs of managing the spectrum (and target to earn a rate of 8.5% return on fixed assets under the trading fund arrangements[1]). These fees are payable on the issue or renewal of licences and the structure of fees varies by licence type. Fixed link fees depend on the bandwidth and (in some cases) frequency used, with lower fees per MHz applying in the less congested, higher frequency bands. In the case of private mobile services fees depend on the bandwidth used and the number of transmitting and receiving stations/outlets/receiving units but do not vary with frequency band.[2] In other cases a single fixed fee is generally paid.

In addition, the Telecommunications Authority (TA) may designate bands for the application of a spectrum utilisation fee (SUF), and the Secretary for Commerce, Industry and Technology may by regulation prescribe the level of SUF or the method for determining the SUF, for example by auction or tender.[3] At present frequency bands designated as subject to the payment of an SUF comprise bands used for 2G and 3G mobile services.[4] The level of SUF or the method for determining the SUF is prescribed in regulations made by the Secretary[5].

The approach used to set SUFs needs to have regard to the objectives and guiding principles for spectrum policy in Hong Kong as set out in Appendix A of the Legislative Council Brief on the Spectrum Policy Framework. The guiding principles require that for spectrum not released for auction or other market mechanisms the SUF is set to reflect the opportunity costs of spectrum. Where the use wholly or significantly supports public interest purposes the SUF may be adjusted to reflect the nature of such use.

[1] This rate of return is applied to annual net fixed assets, excluding interest earnings.

[2] Schedule 3 of the Telecommunications (Carrier Licences) Regulation (Cap 106V) and "Period of Validity and Licence Fees determined by the Telecommunications Authority, Issue 8, January 2006".

[3] See Section 32I of the TO and the associated regulations.

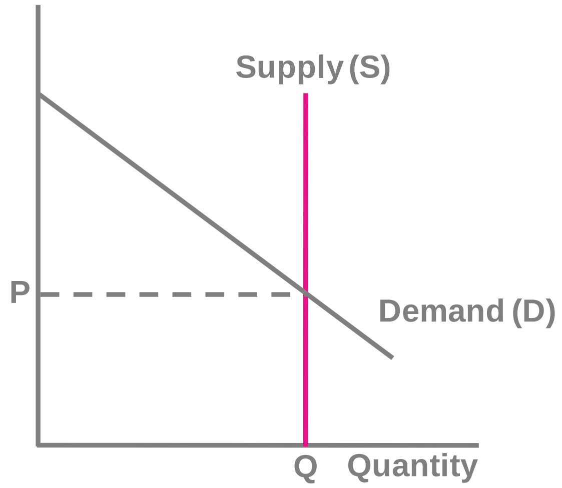
[4] Telecommunications (designation of frequency bands subject to payment of spectrum utilisation fee) order, CAP 106 sub.leg.Y

[5] Telecommunications (Method for Determining Spectrum Utilization Fees) (Third Generation Mobile Services) Regulation (Cap.106X) and Telecommunications (Level of Spectrum Utilization Fees) (Second Generation Mobile Services) Regulation (Cap.106AA).

1.2 Principles

The opportunity cost of spectrum is the value of the opportunity forgone by the current spectrum use (i.e. it is the value to the next best alternative user of the spectrum) at the point where supply and demand for spectrum are in balance. This is the price at which supply and demand for spectrum are balanced. In Figure 1-1, where the demand for spectrum is given by the (grey) downward sloping line and the supply is given by the vertical (pink) line, the opportunity cost of spectrum equals the market clearing price (P). Such prices are sometimes referred as administered incentive pricing (AIP).

Figure 1-1: Supply and demand for spectrum



A balance between supply and demand can be achieved by auctioning spectrum. Setting prices administratively can be thought of as an attempt to estimate the market value of the spectrum as would be revealed by prices paid in an auction.

If the spectrum is in plentiful supply (i.e. is not congested) then the opportunity cost is zero. This means that in determining whether an SUF applies or not we must first establish whether the relevant frequency bands are congested or not and then calculate an SUF for those bands that are congested.

A band is congested if demand exceeds supply for either the current use or a potential other use of the band. For example the UHF broadcasting band is congested both because of demand for frequencies from broadcasting applications and because other new mobile applications would like access to the band. Prices for spectrum in a given band might be expected to vary by geographic location and frequency according to the degree of congestion, much as land prices vary by strength of demand. For example, if a band is moderately congested prices might be expected to lie between those in heavily congested and uncongested areas or frequencies. In the Hong Kong context the variation in congestion by location is not considered because of the small size of the territory.

As a practical matter there is no agreed definition of when a band used by a particular service is congested. In deciding whether a frequency band is congested we need to consider:

1 Is there excess demand for spectrum now or in the near future from existing uses of the spectrum?

2 Can the spectrum be used for another purpose and if so, is there excess demand from other uses?

In the case of an existing use, when it is no longer possible (technically) to make further assignments in a band without causing harmful interference to existing licensees and/or excluding existing licensees then the band could be said to be congested. However, this definition is too narrow as prices in most markets reflect anticipated as well as current supply/demand balances. This means that if demand is growing and bands are not full but are expected to become so in the near future, then the band could be said to be congested. The working rule we have adopted is that if a band is at least 75% occupied and demand is growing over time then the band is congested. We may deviate from this rule, taking a lower threshold in circumstances where we expect demand to grow rapidly in the near future (i.e. the next 3-5 years).

In the case of an alternative use a judgement is required about whether the demand from this potential use of the spectrum is likely to exceed the available supply.

1.3 Terminology

For clarity the following terminology is used for the purpose of this report:

- Spectrum utilisation fees (SUFs): prices charged to spectrum licensees that are set by the regulator and are intended to reflect the opportunity cost of spectrum use (and thereby provide effective incentives for efficient use of spectrum).
- Administered incentive prices (AIP) and Spectrum Pricing: These are terms used in other countries and have the same meaning as SUFs. The report uses the terms SUF, AIP and spectrum pricing interchangeably.
- Administrative charges/management charges: charges to spectrum licensees that are set by the regulator and are intended to recover the regulator's administrative costs i.e. costs incurred in spectrum policy development, management and enforcement.
- Opportunity cost: The value of the opportunity forgone by the current spectrum use (i.e. it is the value to the next best alternative use of the spectrum) at the point where supply and demand for spectrum are in balance. Depending on the situation being examined the value of this opportunity arises from either the ability to make cost savings and/or earn additional profit from access to more spectrum.
- Full market value: The value of spectrum that would result from an efficient auction of the spectrum. This is the opportunity cost of the spectrum and, if the auction is efficient, is given by the value paid by the lowest winning bidder.
- Spectrum licences: These are licences for a block of spectrum that are defined in terms of frequency band, geographic area and permitted emissions outside the designated frequency band and geographic area.
- Apparatus licences: These are licences that permit the use of particular apparatus (transmitters or receivers) at a specific location according to specified technical parameters (e.g. frequency, power or power density level, directivity etc).

1.4 Report structure

In this report we:

- Present a review of approaches used in twelve countries to set SUFs for spectrum that is not auctioned (i.e. administratively determined SUFs) in the context of the objectives they are intended to achieve (Section 2 and Appendix A).
- Discuss options for setting SUFs administratively in Hong Kong, taking account of international experience, and conclude with a recommended generic approach (Section 3).
- Identify fixed service bands that are or might in future be congested and so where SUFs should be applied. In these cases we provide calculations of SUF values (Section 4 and Appendices B-D).
- Identify mobile service bands that are or might in future be congested and so where SUFs should be applied. In these cases we provide calculations of SUF values (Section 5).
- Make recommendations concerning the implementation of SUFs (Section 6).

2 International Experience in Setting SUFs

2.1 Overview

This Section summarises examples from twelve countries of approaches used by regulators to set spectrum prices for licences that are not auctioned. In these cases regulators are seeking to set prices that go beyond simple cost recovery to provide incentives for efficient spectrum use.

Details of spectrum pricing approaches used in Australia, Ireland, Japan, New Zealand, Portugal, Singapore and the UK are given in Appendix A and this Section, and are summarised in Table 2-1: . Table 2-2: also gives some examples from other countries where we have somewhat less detailed information but we have given the background information we have been able to find in the final part of Appendix A.

The terms of reference for this study also asked us to examine the US situation. In the US spectrum fees set by the Federal Communications Commission (FCC)[6] and the National Telecommunications and Information Administration (NTIA) are set on a cost recovery basis. The FCC uses auctions to derive market prices. We understand from e-mail contact with the NTIA that they are currently undertaking an examination of approaches to setting incentive prices for Government users but so far there is no publicly available output from this activity.[7] We do not consider the US situation further in this document.

In all case study countries that we have reviewed regulators are seeking to set prices that provide incentives for efficient spectrum use while setting fees that are transparent and equitable.

What can be seen from examination of Table 2-1: and Table 2-2: is that in all of the countries reviewed the regulators have set prices that are related to the "amount" of spectrum licensed to the user and other key drivers of spectrum value. In particular, prices are a function of one or more of the following parameters:

- the amount of spectrum used measured by the bandwidth sterilised.
- the geographic area over which use is sterilised – sometimes measured directly and in other cases it is proxied by power.
- the type of service supplied often with higher fees for public mobile as compared with other services.
- the frequency band, with higher values in bands that are internationally harmonised, that offer better propagation characteristics and that are more likely to be congested.
- the location of use with higher values in more congested areas e.g. higher values in urban versus rural areas.
- the fraction of the national population covered as a proxy for the value of a regional as compared with a national licence.

The levels of the key parameters in the formulae used are not directly related to opportunity cost, with the exception of New Zealand and the UK. Rather values are set judgmentally with ad hoc changes

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[6] See pp 1280129 in Towards More Flexible Spectrum Management, WIK, December 2005

[7] *Federal Strategic Spectrum Plan*, issued by the NTIA (a unit of the Department of Commerce), March 2008

made over time as certain bands become more congested and so attract a higher fee than would be the case under pure cost recovery fees. In addition historical precedent heavily influences the level of prices because of the political difficulties of making major changes in fees paid by users. In some countries (e.g. Australia, Portugal, Spain and France) prices are discounted for government users or where public interest issues arise. These discounts are set on an ad hoc basis.

New Zealand and the UK are the only countries we know of where the regulator has sought to estimate opportunity cost directly. The rest of this Section discusses the approaches adopted in the UK and New Zealand, the objectives the regulators are trying to achieve and issues encountered in deriving estimates of opportunity cost.

Table 2-1: Spectrum pricing approaches in case study countries

Country	Parameters in pricing formula	Derivation of levels
Australia	Scaling constant; spectrum band; geographic location; bandwidth; power; adjustment factors e.g. for frequency reuse. Regulator is required to take account of the public interest when setting prices.	Historic precedence; CPI inflation
Ireland	For PMR and fixed links – frequency band; bandwidth; coverage area (for PMR); geographic location; degree of sharing	Cost recovery for PMR; rationing congestion for fixed links. Changes from historic fees governed by what was thought to be to politically acceptable
Japan	Frequency bandwidth; frequency band; geographic location.	A target sum to be raised. 3:1 ratio of costs borne by users under 3GHz relative to those in 3-6 GHz. Over 6 GHz fees reflect spectrum management costs.
New Zealand	For broadcasting licences: auction value increased by a compound growth factor; regional licence values are set pro-rata to the share of national population. For cellular licences: the price/MHz is based on the incremental cost of being deprived divided by the amount of spectrum.	Both approaches seek to estimate opportunity cost
Portugal	Number of base stations, bandwidth, frequency band, economic and social factors, exclusivity, power and type of user.	More than cost recovery. Judgemental, opportunity cost based prices will apply to GSM/UMTS licences later this year. The main change will be to relate the fee charged to the amount of spectrum used and not the number of base stations and number of subscribers.
Singapore	Bandwidth, exclusivity and area of use. Fees do not vary by frequency band.	Initially cost recovery across all applications. Possible use of opportunity cost in congested bands in future.
UK	Opportunity cost/MHz calculated on a national basis and then price adjusted to take account of bandwidth, area/population over which use sterilised or degree or reuse, location of use (i.e. degree of congestion).	Opportunity cost estimated using “least cost alternative” approach. AIP set at 50% of opportunity cost.

Source: Plum and Aegis analysis

Table 2-2: Further examples of spectrum pricing approaches

Country	Parameters in pricing formula	Derivation of levels
Bahrain	Constant based on local conditions and costs; frequency band; geography; bandwidth; power.	Not applied yet
Canada	Fees are a function of bandwidth, population in geographic area covered in areas where there is scarcity	Judgemental
France	Bandwidth and location for PMR, PAMR, fixed links and wireless local loop licensees. Number of base stations/links and whether the spectrum is shared or not also affects the level of fees. Market benchmark used for 3G licences.	Judgemental
Spain	Coverage area; bandwidth; occupancy and demand for service; public vs private services; exclusive or shared use; efficiency of technology used; social and economic benefit from the service. Market benchmark used for 3G licences.	Judgemental

Source: Plum and Aegis analysis

2.2 UK approach

Opportunity cost prices are applied to bands that are congested in the UK. A band is said to be congested if there is or is likely to be excess demand from the existing use or a potential alternative use of the band. The approach to calculating the opportunity cost of spectrum in the UK has been developed over the last decade. We describe each of the main changes in methodology and discuss some implementation issues.

Opportunity cost – fixed allocations

Smith-NERA (1996) proposed a method for evaluating AIP based on opportunity costs calculated at the margin.[8] The approach focused primarily on assignment within frequency bands. It sought to answer the question: what should be the price of spectrum to ensure an efficient assignment amongst potential users assuming the allocated use of spectrum remains constant?

The high level answer to this question was: an efficient assignment would result from a price set equal to the opportunity cost of spectrum. The assumed situation was as shown in Figure 1-1.

[8] Study into the Use of Spectrum Pricing, NERA and Smith System Engineering, Radiocommunications Agency, April 1996.

Opportunity costs were estimated by calculating the impact of a hypothetical marginal (i.e. small) change in spectrum on the costs of an "average firm" assuming the level of output and service quality were kept constant. For example, suppose a firm was provided an extra unit of spectrum then the marginal benefit would equal the minimum cost savings the firm would enjoy. These cost savings were calculated by examining the least cost alternative action an "average firm" might take when given/denied access to a small amount of spectrum.[9] The options examined included one or more of:

- Investing in more/less network infrastructure to achieve the same quantity and quality of output with less/more spectrum.
- Adopting narrower bandwidth equipment.
- Switching to an alternative frequency band.
- Switching to an alternative service (e.g. a public service rather than private communications) or technology (e.g. fibre or leased line rather than a fixed radio link).

This approach to estimating opportunity cost makes the following assumptions:

- Demand exceeds supply in the current use (at current prices).
- Output and service quality are both constant – so revenue effects and other non-cost aspects of value (e.g. convenience) do not need to be considered.
- Value is based on choices faced by users in the near term – either currently or in the next few years.
- Increases/decreases in spectrum are roughly symmetric – so only one set of calculations is required.
- Changes in allocations are not feasible – so only values for the current use need to be considered.
- The user is able to afford the additional costs imposed by being denied spectrum access i.e. in the case of a private firm it does not go out of business and in the case of a public sector user there is sufficient budget to cover the additional costs.
- The private and social values of spectrum are equal.

The relaxation of the assumption that output is kept constant gives the decision tree reported in Plum and Aegis (2008)[10] and reproduced below as Figure 2-1:. This starts by considering whether it is feasible to consider a change in spectrum use with output kept constant (i.e. only use of other inputs changes). If this is practical then the least cost alternative can be adopted, though a check on viability is still necessary. If this is not practical then the marginal benefit of the spectrum must be estimated by calculating the above normal profits that might be made from a small amount of spectrum.

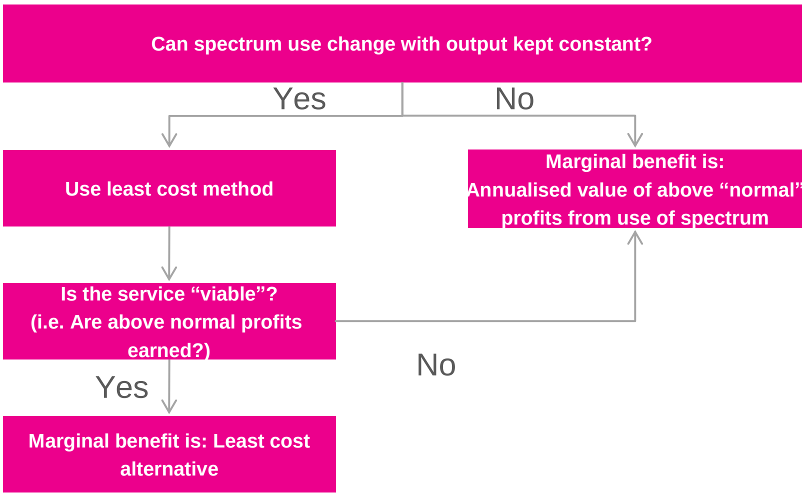
The issue of how to use market information has not yet been addressed directly in the development of AIP in the UK, though we note that for digital radio and TV values have been inferred from market information on the traded value of multiplex capacity.[11]

[9] Usually the smallest change in spectrum use that is technically feasible.

[10] "Administrative incentive pricing of radiofrequency spectrum",Final Report for ACMA, Plum and Aegis, October 2008

[11] Op cit.

Figure 2-1: Generalised approach to estimating marginal benefits



Opportunity costs were calculated by Smith-NERA (1996) for mobile services (i.e. PMR, PAMR and cellular services) and fixed links and were intended to result in a more efficient assignment of spectrum to these services. Opportunity cost estimates for mobile services were over 10 times those for fixed links.

Smith-NERA(1996) suggested that mobile and fixed link prices could in principle be used to set benchmark prices for other spectrum that could be used by either mobile or fixed link services respectively. As a general rule mobile prices were applied by the UK Government below 3 GHz while fixed link prices were applied above 3 GHz. The level of actual prices (i.e. AIP) charged were determined by the political process, with increases phased in over 3 or 4 years up to a maximum of 50% of the calculated opportunity cost estimate.

Opportunity costs – varying allocations

The approach just described was reviewed in 2004[12] and extended to cover the situation in which changes in spectrum allocations might occur as a result of the incentives provided by spectrum pricing. The methodological issue this raises is that it can no longer be assumed that one is looking at an equilibrium situation as drawn in Figure 1-1. Rather the situation shown in Figure 2-2: applies.

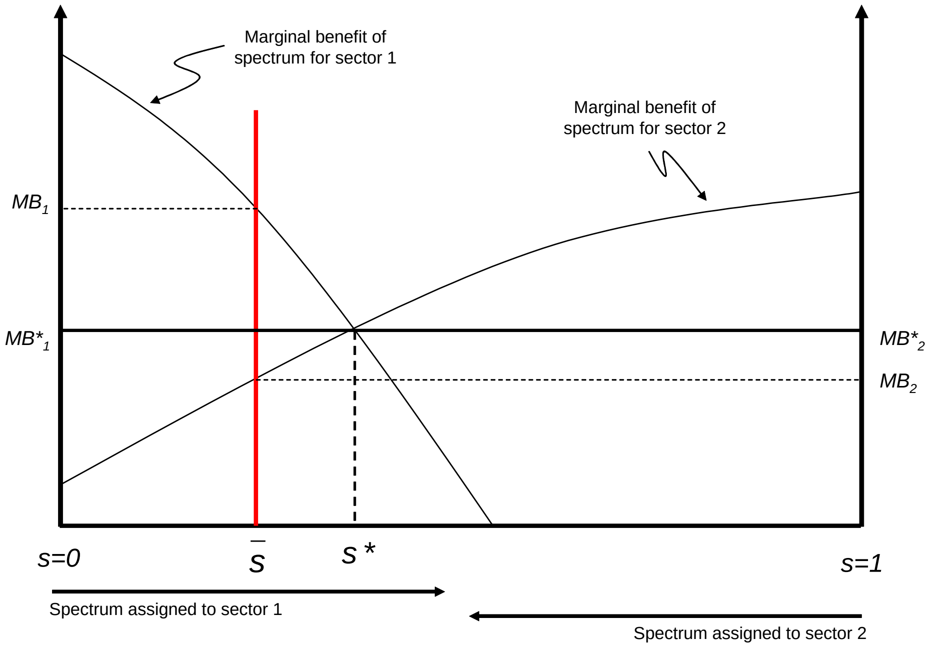
What the figure shows is a situation in which the current allocation between the two uses (S*) (shown by the vertical red line) is not at the market equilibrium (MB*) – defined as the point at which marginal benefits to users are equalised between the two uses. The reason for this is that allocations have historically been determined by a political process (at national and international levels) that has not been informed directly by information on economic and social benefits. It would therefore only be by chance that allocations were in any sense optimal.

The marginal benefits calculated (MB_1 and MB_2) will not give an optimal price i.e. will not give the opportunity cost of spectrum with flexible allocations. However, a price set between MB_1 and MB_2 will provide users with incentives to move from the current disequilibrium towards the more efficient

[12] "An Economic Study to Review Spectrum Pricing", Indepen, Aegis Systems and Warwick Business School, Ofcom, February 2004.

equilibrium (MB^*_1, S*). Taking an intermediate opportunity cost estimate also reduces discontinuities in value as one moves from one frequency band to another and arguably better represents a longer term view of the value of different bands, as restrictions on the allocated use of a band get relaxed.

Figure 2-2: Marginal benefits from spectrum use



So what is the best estimate of opportunity cost in the range MB_2 to MB_1? The 2004 review of spectrum pricing in the UK suggested that it is generally more efficient to err on the side of caution to ensure that overall spectrum is not left idle. Subsequent work showed there are circumstances where it is more efficient not to set prices on the low side, namely when demand for spectrum for the potential alternative use is likely to be relatively insensitive to changes in the spectrum price.

In summary, the extension of the original Smith-NERA (1996) approach involved:

- Marginal benefit calculations for all potential uses of a given block of spectrum using the least cost-alternative method. Unlike the case where there is only one use, the opportunity cost of spectrum does not equal the marginal benefit of the current spectrum use. Rather marginal benefits for other potential uses of the spectrum need to be taken into account.
- A judgement about where to set the opportunity cost in the range of values obtained. In general the value is set on the low side, though when demand for an alternative use is likely to be insensitive to changes in spectrum price a higher level may be appropriate.
- Taking the status quo as a starting point for calculating opportunity cost, and then relying on iteration to achieve a closer approximation to the social optimum over time as direct estimation of the social optimum is infeasible because of lack of information concerning the shape of marginal benefit curves.

This extension of the original UK approach more closely approximates the real world situation where allocations have the potential to change. However, it requires more information and judgement. In particular information on current and potential future uses of the band and their respective least cost alternative actions are required. The derivation of a range of values and the need for judgement about the level to choose can mean that the chosen levels may be perceived as being somewhat arbitrary.

Application of the approach

The methodology for determining AIP is as follows:

- For a given frequency band identify the current and other potential uses. These uses may be variants of the same allocation category (e.g. PMR and cellular mobile) or alternative allocations such as broadcasting and fixed link services.
- Calculate the marginal benefit of spectrum for the current use of the band and other uses until a use is found which has a higher marginal benefit than the current use.
- If there is a use with a marginal benefit greater than the current use then set the AIP between the two values – generally towards the bottom end of the range but there may be circumstances where a value towards the middle of the range will be appropriate.
- If there is no use with a marginal benefit higher than the marginal benefit for the current use of the band then set the AIP at the marginal benefit for the current use.

The approach to deriving marginal benefits is as shown above in Figure 2-1:. This has been used to derive opportunity cost estimates for spectrum used by public cellular systems, private mobile radio, fixed links, TV and radio broadcasting, aeronautical and maritime applications.[13]

AIP was first introduced in 1998 and was applied to spectrum use in congested bands allocated to fixed links and public and private mobile services. Since 1998, AIP has been extended to other services and is now applied to some or all spectrum that has not been auctioned and is allocated to[14]:

- Defence (some internationally managed bands and frequencies above 15 GHz are currently excluded)
- Fixed links
- Maritime business radio
- Private business radio
- Public mobile networks
- Public safety services (police, fire, ambulance services)
- Satellite uplinks (permanent and transportable earth stations and VSATs)[15]
- Scanning telemetry (national channels only)
- Radio astronomy[16]

The values calculated for public and private mobile services have been applied to all bands below 3 GHz regardless of the actual use of the bands, on the grounds that mobile use is displaced. The

[13] An economic study to review spectrum pricing, Indepen, Aegis and Warwick Business School, for Ofcom, 2004 ;

[14] Appendix D, Spectrum Strategy, Radiocommunications Agency 2002.

[16] Policy evaluation report: AIP, Ofcom, July 2009.

fixed link prices apply to all congested bands above 3 GHz regardless of the application or service using the band, on the grounds that these services generally displace fixed link use.

AIP paid is a function of the bandwidth assigned and the coverage area of services in the case of local services such as land mobile and fixed links. In the case of fixed links fees are related to path-length, frequency band (and degree of congestion in the band) and availability demanded. It is important to note that as currently applied AIP levels are roughly half the calculated value of opportunity cost for each application. Details of the approach taken for private business radio (PBR), point to point fixed links and satellite earth stations are given below and we conclude this section with a summary table showing the current AIP charges.

Private Business Radio

Private business radio has historically been licensed under 21 licence products but these are to be rationalised into 5 licence products as follows:

- **Area defined** – this covers the whole UK, one or more Nations or a region down to a 50 km grid square. Spectrum masks, boundary conditions and exclusive frequencies are defined. There is no limit on base station deployments or mobile numbers and assignments are made by the licence holder.
- **Technically assigned** – this is for on-site wide area coverage but for an area less than a Nation. Shared or exclusive spectrum is provided with assignment and coordination undertaken by Ofcom. Base station locations are specified and the technical specification of the base station (in an application-neutral way) defines coverage. There is no limit on the number of mobiles.
- **Simple UK** (light licensing) – this provides a set of frequencies available for mobile to mobile use only anywhere in the UK. There is no coordination by Ofcom. Standard technical conditions apply and there is no limit on the number of mobiles.
- **Simple Site** (light licensing) – this provides a set of frequencies available for on-site shared use at a fixed location. There is no coordination by Ofcom. Standard technical conditions apply and there is no limit on the number of mobiles.
- **Suppliers** (light licensing) – this provides a set of frequencies available for on-site to wide area shared use. There is no coordination by Ofcom. Standard technical conditions apply and there is no limit on the number of mobiles.

The last three licence categories (designated as light licensing) are not tradable and their fees are collected every 5 years. The other two licences (area defined and technically assigned) have been designed in such a way that changes of use and transfers of rights and obligations (including partial transfers) can be made with little or no reference to Ofcom. Licence fees for these tradable licences are collected annually.

UK Business Radio fees are charged with reference to a UK wide 12.5 kHz channel pair at £9,900 per annum. The fees for the first two main categories (i.e. excluding the light licensing categories) are based on:

- The extent of coverage of the system – UK wide down to a trading unit (50 km grid square) for the area defined licence. Three categories that reflect power and antenna height for the technically assigned licence. These power / antenna height categories are a proxy for typical coverage areas of 6 km (site or building), 30 km (local services) and 60 km (bigger town or region)[17].

- Whether a location is highly populated – three population categories depending on the population density and defined by grid squares.
- Whether the frequency band is congested – categorised in terms of highly (VHF High band, UHF 1 and 2), medium (VHF Mid band and Band III) and less popular bands (133 – 147 kHz, Paging, Band I and VHF Low band).
- The amount of bandwidth used – linear relationship between channel bandwidth and fees.
- Whether the spectrum is shared with other users – modifier applied to fee depending on whether exclusive or shared. Half the fee is payable in shared spectrum but the effect of this reduction is capped by a minimum fee payable of £75 per 2 x 12.5 kHz.

The licence fees for 2 x 12.5 kHz are:

- Area defined – a maximum of £9,900 p.a. and covering the whole range (depending on one or more of the factors identified above) down to the minimum fee of £75 p.a.
- Technically assigned – a maximum of £1,480 p.a. and covering the whole range (depending on one or more of the factors identified above) down to the minimum fee of £75 p.a.
- Simple site - £75 per site per 5 years
- Simple UK and Suppliers - £75 per 5 years

Point-to-point fixed links

The annual fee for a coordinated bi-directional fixed link is given by the following formula

Sp x Bwf x Bf x Plf x Avf

where:

Sp = is a reference spectrum price and is a fixed sum of £88 per 2 x 1 MHz bandwidth for each coordinated bi-directional fixed link.

Bwf = is a bandwidth factor. It is the bandwidth (in MHz) associated with a bi-directional link. For a bi-directional link using B MHz in each direction it is B and B cannot be less than 1.

Bf = is a band factor and ranges from 1 at 1.35 MHz to 0.17 at 57 GHz.

Plf = is a path length factor which is derived from the link path length and the minimum path length[18]. The factor is 1 when the link path length is equal to or greater than the minimum path length. It increases as the square root of the minimum path length to link path length ratio (up to a maximum value of 4) for link path lengths smaller than the minimum path length.

Avf = is an availability factor which ranges from 0.7 (availabilities equal to or less than 99.9%) through 1.0 (for an availability of 99.99%) to 1.4 (for an availability of 99.999%.

Unidirectional links pay 75% of the bi-directional link fee.

[17] The coverage area here is defined by its diameter.

[18] The minimum path length (which is also related to whether a high or low data rate is being carried by a link) ranges from 30 km at 1.35 GHz to 1.5 km at 33.4 GHz. Some of the highest frequency bands do not have a minimum path length.

An additional link operating co-channel and cross-polar over the same path as an existing assigned link pays 50% of the fee.

Satellite earth stations

The annual fee for a satellite permanent earth station (site) is given by the following formula

$$\sqrt{433.4 \times \sum_{ijk} (P_{ijk} \times BW_{ijk} \times MOD_{ijk})}$$

where:

i = the number of earth station terminals on a site

j = the number of satellites being accessed at the site

k = the number of transmission paths being supported at the site

Pijk = the transmitter peak power (in Watts) at the flange of the antenna

BWijk = the transmit authorised bandwidth (MHz)

MODijk = Modifier value. 1 for shared frequency bands and 0.5 for exclusive frequency bands.

The same formula is used for satellite networks (e.g. VSATs, aircraft satellite terminals and earth stations on board vessels). In this instance the ijk parameterisation of the formula is replaced by the factor n which is the number of earth station terminals in the network.

The minimum annual fee for a permanent earth station is £500 and for satellite networks is based on 50 as the minimum number of terminals.

The annual fee payable for a transportable earth station is based on the product of its maximum operational power (in Watts) and the widest bandwidth employed (in MHz). The fee ranges from £200 (product less than or equal to 100) through £1,000 (product greater than 100 and less than or equal to 2,500) to £3,000 (product greater than 3,000).

It can be noted that satellite fees are shortly to be modified so that the revised formula defining the annual fee takes the form:

$$\sum_{band=1}^{b} \left[\beta \times BF \times \sqrt{\sum_{ijk} (P_{ijk} \times BW_{ijk})} \right]$$

The parameter definitions given above apply but in addition:

b = the number of frequency bands used

β = a constant = 28

BF = the band factor which ranges from 2.33 (frequencies below 5 GHz) to 0.60 (frequencies above 24 GHz) with three other categories in between (5 to 10, 10 to 16 and 16 to 24 GHz).

As before the same formula will be used for satellite networks (e.g. VSATs, aircraft satellite terminals and earth stations on board vessels) with the ijk parameterisation of the formula being replaced by the factor n which is the number of earth station terminals in the network. The minimum annual fee for satellite networks will be £200.

The annual fees for transportable earth stations (£200, £1,000 and £3,000 above) will be increased to £300, £1,400 and £4,300.

It can be seen from the change in the formula (β = 28 compared to $\sqrt{433.4}$ = 20.8, and a band factor of 0.6 to 2.33 compared to √shared/exclusive modifier of 0.7 to 1) that there could be some significant rises in fees particularly for lower frequency bands. For permanent earth stations there will be an interim year when only 50% of the increase will be applied. Also, note that there is no longer a distinction between shared and exclusive satellite spectrum.

Current fees

Table 2-3: summarises some of the current fees charged (the new regime for business radio outlined above has not been applied). Note that in recent years the status of some fixed link bands has changed and these are no longer regarded as congested. This is largely due to the migration of many long haul, high capacity links to fibre. Fees are still based on the original AIP values but whereas previously these applied a higher fee in certain geographic areas that were more congested than others, the same (low congestion) fees now apply in all areas.

Ofcom reports the following examples of the impact of AIP on spectrum use[19]:

- 12 MHz between 2290 and 2302 MHz was returned by the Ministry of Defence, saving them fees of nearly £3m p.a. and 100 MHz between 8400 and 8500 MHz.
- 1 MHz by the police in Scotland in the 450-462.5 MHz band.
- About 70MHz of spectrum returned by private sector licensees – about 60 MHz at 10GHz and 10 MHz in the range 410-430 MHz[20].
- 384.5 MHz by radio astronomy in a wide range of bands.
- Reduction of 50% in the number of fixed links in the 11 GHz band reflecting migration of many trunk radio links to fibre.
- Acceleration of technology change in utility, transport and other sectors with consequent reduction in spectrum demand.

[19] Policy evaluation report: AIP, Ofcom, July 2009.

[20] Spectrum Framework Review for the Public Sector, Ofcom, January 2008

Table 2-3: Examples of UK AIP as applied to some example services[21]

Service	Fees for service as described in first column	Parameters determining fees
PBR base station with 50 mobiles exclusive frequency, uncongested area, taxi or courier firm (2 x 12.5 kHz)	£205 £90 under the new regime (VHF Mid band and power / height for maximum radius)	Geographic area (congested area – 2x fee applies, very congested area – 4x fee applies), number of mobiles (4 categories), type of user (4 categories) and bandwidth.
Regional PBR system covering England. 2 x 12.5 kHz in VHF High band.	£6,435 £8,275 under the new regime	Geographic area, frequency band and bandwidth.
Fixed link 7.5 GHz band, 2 x 3.5 MHz bandwidth, 99.9% availability, path length > minimum path length	£159.54	Frequency band, bandwidth, link length in relation to minimum link length, availability Also whether uni-directional and if use cross polar
Fixed link 7.5 GHz band, 2 x 28 MHz bandwidth, 99.9% availability, path length > minimum path length	£1276.35	Frequency band, bandwidth, link length in relation to minimum link length, availability Also whether uni-directional and if use cross polar
Fixed link 18 GHz band, 2 x 3.5 MHz bandwidth, 99.9% availability, path length > minimum path length	£64.68	Frequency band, bandwidth, link length in relation to minimum link length, availability Also whether uni-directional and if use cross polar
Fixed link 18 GHz band, 2 x 28 MHz bandwidth, 99.9% availability, path length > minimum path length	£517.44	Frequency band, bandwidth, link length in relation to minimum link length, availability Also whether uni-directional and if use cross polar
GSM national network – for 2x1 MHz	£712,800 (900 MHz), £554,400 (1800 MHz)	Frequency band, bandwidth
GSM-R (for each 2 x 200 kHz)	£158,400	Geographic area (national) and bandwidth. Same value per MHz as private business radio.

2.3 New Zealand approach

In New Zealand for spectrum that is not auctioned cost reflective fees are applied. For auctioned spectrum licensees pay the price set by the auction. However, spectrum licences used to supply radio, TV and cellular mobile services, many of which were originally auctioned, will expire from 2010 onwards. The New Zealand Government has offered the incumbent licensees the opportunity to

[21] Statutory Instrument, 2005, No 1378, The Wireless Telegraphy (Licence Charges) Regulations 2005

renew these licences for a fee that was administratively determined. If the incumbents rejected this offer then the licences would have been auctioned. [22]

In this case the approach to setting administratively determined fees is intended to provide a proxy for the market value of the rights. It was initially decided that the best way to do this was to model the licensee's business in a way that is simple and transparent but gives a reasonable approximation to market value. In the event this proved impractical for cellular licences and a variant of the least cost alternative approach was adopted. While this report is concerned with setting an SUF for private services, this experience illustrates the difficulties in setting prices to reflect market value and the practical compromises that need to be made to derive acceptable estimates.

Radio and TV

The approach to setting the SUF recommended by the Government's consultants [23] and adopted for radio and TV licence fees involved using the original auction price as a base price and then applied a growth factor that equalled the average of past and future growth in revenues. In the case of regional licences the value was pro-rated for the ratio of regional to national population.

In the case of a national TV licence using four 8MHz frequencies at UHF, the calculated offer price is $NZ961,451 (plus GST).

Proposals for new fees for broadcast stations based on a study of the likely market value were announced. One of the examples provided in the study that underpinned the proposals[24] was that of an FM radio station covering the city of Wellington (population 163,000). The price set for this licence (a once-off payment for the 20 year licence) was around $NZ18,000.

This approach used by the New Zealand Government makes the following assumptions:

- Revenue growth is a good proxy for net cash flow growth – this requires an assumption of constant profit margin.
- The growth factor is stable over time.
- The growth factor is the same for each licensee i.e. market shares are constant over time
- The original auction was efficient.

Of these assumptions the first two are arguably the most difficult to defend – particularly for TV. The market environment for advertiser financed and pay TV could change significantly in the next 20 years as mobile TV and TV delivered over broadband networks are introduced and as audiences fragment further with more choice offered. In addition to increasing competition for audience viewing time from new TV channels and on-demand content, TV advertising as a whole is not expected to grow (and may decline) partly as a result of the loss of young audiences and partly as a result of advertising budgets moving to the internet and other more directly measurable forms of marketing. In the UK for example, TV advertising revenues are not expected to grow in the real terms in future and may well decline, despite expanding numbers of channels.[25] We note the outlook in this respect has changed

[22] All relevant documents can be found at the website of the Ministry for Economic Development.

[23] Development of Price setting Formulae for Commercial Spectrum rights at Expiry, Covec, October 2003.

[24] "Development of Price Setting Formulae for Commercial Spectrum Rights at Expiry for the Ministry of Economic Development", Covec Ltd, October 2003

[25] See Section 5 of Appendix 7 of Ofcom's Second Public service Broadcasting Review, 14 April 2008.

considerably since the methodology was initially developed and applied to broadcasting licences in New Zealand in 2003/2004.

Cellular

The formula developed for broadcast licences was not applied to cellular licences as in the latter case projections of future revenue growth based on historic data were judged to be unreliable because of uncertainty concerning future technology and market developments.

A further consultancy study re-examining options for estimating market value was commissioned. This study considered approaches based on 1) benchmarking, 2) earnings and 3) avoided costs or deprival value.[26] Benchmarking was rejected on the grounds that there are few, if any, like for like comparators. Earnings based approaches suffer from the uncertainties about future revenue growth and service/technology change and so the consultants recommended an approach based on deprival value.

The incremental optimal deprival approach adopted involves valuing spectrum as the difference in network roll-out and operating costs arising from deprival of a given quantity of spectrum for the life of a cellular licence for a generic operator.[27] This is similar to the least cost alternative approach adopted in the UK. A key advantage of this approach is that the information requirements are not unduly onerous. It requires assumptions concerning:

- Traffic forecasts.
- The technology deployed in future.
- Network configuration with/without the marginal spectrum.
- Network capital and operators costs with/without the marginal spectrum.

Values were calculated and an offer price of $NZ3.8m/2x1MHz was announced.[28] Incumbent cellular operators accepted this price and other conditions attached to the new licences.[29]

2.4 Conclusions

International experience suggests that the main issues in deriving estimates of the opportunity cost of a given block of spectrum are:

- How to suitably characterise the alternative uses of a given block of spectrum and the choices facing users if denied /given access to an increment of spectrum.
- What assumptions to make about future choices that face users and their costs and future traffic levels that will need to be supported. In particular should current values be used or future changes anticipated?

[26] Renewal of Spectrum Rights for Cellular Services pricing methodology, Discussion paper, July 2006, PriceWaterhouseCoopers and NZIER, Ministry for Economic Development,

[27] Renewal of management Rights for cellular Services (800/900 MHz), Network Strategies, Ministry of Economic Development, October 2007

[28] Government makes offers for renewal of cellular spectrum rights, Minister of Communications and Information Technology, Mediastatement, 27 November 2007

[29] These included a use it or lose conditions expressed in terms of coverage requirements.

- The uncertainty over revenue forecasts for the licence period where an earnings-based model is applied.

The annual opportunity cost values calculated in the UK are essentially static based on current traffic levels, costs and technologies. However, this gives a relatively firm basis for setting values. The simplifying assumptions made tend to bias the estimates obtained downwards. When multiple values are obtained charges are set at the low end of the range.

The New Zealand approach had to be forward looking, as the value of a 20 year licence had to be obtained. The New Zealand experience shows that uncertainty over future services, technology and revenues makes it difficult to arrive at a robust estimate of market value. It was for this reason that the least cost alternative approach developed for the UK was applied in New Zealand to derive values for spectrum used by cellular operators.

3 Implications for setting SUFs in Hong Kong

3.1 Introduction

Policy in respect of SUFs is set out in the Legislative Council Brief on the Proposed Spectrum Policy Framework (SPF).[30] This indicates that SUFs are to apply to non-government use of spectrum not assigned by market means, unless the spectrum is used to wholly or significantly support a public interest purpose at the request of the Government. This will be decided on a case by case basis and relevant public policy reasons for not applying an SUF will be published. The Brief also states (para 29) that "any new SUF to be implemented should not be applicable during the course of an existing licence".

While the SPF provides that in principle SUFs will be applicable to all non-government use of spectrum, we propose that non-zero SUFs are applied only in congested frequency bands. This best promotes the spectrum policy objective set out in the SPF of "facilitating the most economically and socially efficient use of radio spectrum with a view to attaining maximum benefit for the community" and is consistent with international best practice.

The SPF indicates that new SUFs will not apply during the course of an existing licence. This raises issues of fairness between:

- Operators who may have different licence durations. Those with a long time to run on their licence (e.g. FTNS/FC/UC licensees) may not pay the SUF for many years, while those with say annual licences (e.g. WBLRS licensees) will pay immediately.
- Incumbent operators and new entrants. SUFs may not apply immediately to the former but will apply to all new licensees.

To address these issues we recommend the government considers applying SUFs to all users of the relevant frequency band irrespective of the time at which the user's licence is due for renewal. We also suggest the Government considers the application of a grace period and/or a phase-in arrangement to give spectrum users time to react to the new fees, for example by modifying their spectrum holdings.[31]

This report covers the setting of SUFs based on opportunity cost for spectrum which is not used for delivery of public communications services and is assigned other than through market means or is re-assigned administratively to incumbents. The prime examples of frequency bands which fall into these categories are those which are allocated to private mobile radio and fixed links.

In this Section we discuss options for deriving opportunity cost estimates. The options described are appraised against the following criteria:

- Incentives for efficient spectrum use – both static and dynamic efficiency aspects need to be addressed here and the approach adopted may differ depending on the relative importance placed on these two aspects of efficiency. Whether appropriate incentives are given in each case depends on the accuracy of the opportunity cost estimates, the upside and downside risks of welfare losses from having poor estimates which in turn depend on the extent to which the modelling approximates real life choices by spectrum users.

[30] Legislative Council Brief, Proposed Spectrum Policy Framework – Outcome of Consultation. CTB(CR) 7/4/16(06)

[31] The issue of a transition path is also considered in Chapter 6 of this report.

- Objectivity – this depends on the extent to which judgement as opposed to calculations and objectively derived information is used to derive values.
- Simplicity – this is determined by the simplicity of the analysis and the number of assumptions that are required to derive values. Simplicity can aid transparency.
- Transparency – this is indicated by the ease with which third parties can replicate the analysis and the extent of use of publicly available information. If the pricing approach is not transparent then it will be difficult to demonstrate that it is objective.

At the end of this section we provide recommendations for a particular approach to estimating opportunity cost. This is then applied in Sections 4-5 of this report.

3.2 Approaches to calculating value

Directly calculated values

Spectrum may be acquired either to enhance an existing service or to start a new service. In the case of service enhancement, the value of the spectrum will depend on the extent to which it allows the licensee to earn additional net returns (i.e. profits/or non-monetised benefits) or in a competitive market to maintain profits. Such profits may arise from:

- Additional revenues/benefits: For an existing service additional revenues/benefits may arise from being able to support increased demand or to provide higher service quality.
- Cost savings: The total costs of providing a given service may be reduced if spectrum rather than some other input (e.g. infrastructure, another service) is used.

Alternatively a new service may be launched with the spectrum and this may offer the opportunity to earn above normal returns. Only if above normal returns can be made is the project worth undertaking[32] and the scale of these above normal returns sets an upper bound on the spectrum value.

The direct calculation of spectrum value involves numerous assumptions about the situation being modelled so that revenues and costs can be estimated. Firstly an assumption about the size of the change in spectrum holdings needs to be made depending on the choices that users face in practice. If large changes in spectrum holdings are relevant then revenue as well as cost changes may need to be taken into account. If small changes in spectrum use are feasible then changes in cost alone may give a reasonable estimate of value because revenues can be assumed to be constant.

It is also necessary to consider whether opportunity cost estimates are to be derived assuming changes in the allocated use of the spectrum are possible in addition to changes in assignments.

Taken together these aspects give the following options:

- Single service, change in costs: least cost alternative approach, no change in allocations, value based on current use
- Multiple service, change in costs: least cost alternative approach, change in allocations, value at least as high as in current use

[32] Otherwise the money could as well be invested in other activities offering an expectation of above normal returns.

- Single service, change in net revenues: NPV of cash flows, no change in allocations, value based on current use
- Multiple service, change in net revenues: NPV of cash flows, net revenues, change in allocations, value at least as high as in current use.

The option that is most appropriate depends on the information available and type of use considered. Where spectrum is used to meet an internal business need value is entirely driven by the relative cost of using radio technology versus other substitute services, whereas for others (where spectrum is used to support a service delivered to the public) it is derived from the ability to earn revenues as well as make cost changes.

Market benchmarks

Market determined prices contain information about the expectations of market players regarding spectrum value. This is private information that the regulator will not know (e.g. expectations about future uses of the spectrum, changes in allocations etc). Market prices are therefore likely to give a more reliable indication of value or opportunity cost than prices calculated by regulators.

The types of market information that might be used to derive estimates of opportunity cost and full market value include:

- Spectrum market transactions: The price of spectrum in auctions or trades could be used to directly.
- Capacity sales: Information on the sale price of capacity for which spectrum is an input (e.g. sale of DTT multiplex capacity or sale of wholesale capacity on a mobile network) provides a valuation of the spectrum plus the value of the other inputs. The spectrum value can be estimated by deducting the value of other inputs from the capacity price.
- Company value: Information on the market value of companies holding spectrum rights provides a valuation of the spectrum plus the value of other assets. The spectrum value can in principle be estimated by deducting the value of other assets from the company value.

The first of these options is in principle the simplest, and most objective and transparent as it does not require the potentially uncertain value of other inputs/assets to be deducted from the revealed market price in order to provide an estimate of the spectrum value. The errors introduced by uncertainty about the value of non-spectrum assets could be very large in the case of company valuations especially if spectrum is only a minor input to the company's main activities, as will be the case for example with private applications such as fixed links and private mobile radio.

Even using values obtained from spectrum market transactions is not straightforward. The difficulties of making like for like comparisons between frequency bands and between market values revealed in different countries and different points in time are well known. Some differences can be reconciled by using econometric analysis to adjust for factors such as geography, demographics and GDP (as a proxy for revenue/user). Other factors relating to the local competitive environment may require deeper consideration of a licensee's business case to obtain tighter reconciliation.

Volatility in market values can also sometimes mean they are an unreliable guide to long term value and in particular care needs to be taken in not over reacting to what may be short term market fluctuations. A clear example of this is given by the European 3G auctions, where the Spanish

Government set a price for 3G licences (which were awarded by beauty contest) many times higher than existing GSM fees, based on the results of the UK and German auctions. The Government then had to reduce these values substantially when it became apparent that the UK and German auction results were not representative of the market more generally after the dotcom crash. Administratively determined spectrum prices set in other countries could however provide a further benchmark to compare with directly calculated values, though such comparisons would need to allow for differences between countries in the nature of demand for spectrum and the radio equipment deployed.

Summary

Table 3-1: summarises our views on the suitability of different options for frequency bands used by particular applications. What this says is that the choice of approach depends importantly on the characteristics of the frequency band under consideration. We identify the feasible set of options and then appraise the options against the criteria listed in the introduction to this section.

Table 3-1: Suitability of options for different bands/services

Options	Bands/services where most applicable
Directly calculated values	
Single service, change in costs	Bands where change of use is highly unlikely because of international or regulatory constraints or where it is clear current use is highest value application. Bands where spectrum is used for private applications. But possible for bands used for public services where demand difficult to forecast and/or marginal changes in spectrum use are practical.
Multiple service, change in costs	Bands where there are few constraints on change of use or where change of use may be desirable. Bands where spectrum is used for private applications. But possible for bands used for public services where demand difficult to forecast and/or marginal changes in spectrum use are practical.
Single service, change in net revenues	Bands where change of use is highly unlikely because of international or regulatory constraints or where it is clear current use is highest value application. Bands where spectrum is used by publicly provided services and changes in spectrum use are non-marginal.
Multiple service, change in net revenues	Bands with few constraints on change of use or where change of use may be desirable. Bands where spectrum is used by publicly provided services and changes in spectrum use are non-marginal.
Market values	
Spectrum transactions	Bands in a similar frequency range and with similar licence duration and other conditions
Capacity sales	Public mobile, BWA and digital broadcasting
Company value	Public mobile, BWA and broadcasting

Source: Plum and Aegis analysis

3.3 Appraisal for private services

Table 3-2: appraises options for bands used by private services. In this case market values have limited applicability because such frequency bands tend not to be auctioned, capacity is not traded and spectrum forms a small part of the company value. Amongst the directly calculated options, only those based on cost changes are relevant and multiple service approaches should give greater efficiency but require more judgement and assumptions and so tend to score less well on other criteria.

Table 3-2: Appraisal of options for estimating opportunity cost – bands used by private services

Options	Dynamic Efficiency	Static efficiency	Objectivity	Simplicity	Transparency
Directly calculated values					
Single service, change in costs	-	+	++	++	+
Multiple service, change in costs	+	+	-	-	-
Single service, change in net revenues – not applicable	n.a.	n.a.	n.a.	n.a.	n.a.
Multiple service, change in net revenues– not applicable	n.a.	n.a.	n.a.	n.a.	n.a.
Market values					
Spectrum transactions – limited applicability	++	+	+	-	-
Capacity sales – limited applicability	+	+	+	-	-
Company value – not applicable	n.a.	n.a.	n.a.	n.a.	n.a.

Source: Plum and Aegis analysis

3.4 Conclusions

The discussion in the previous section indicates that the choice of approach to deriving opportunity cost estimates is contingent on the objectives the regulator is seeking to achieve, the frequency band being considered and the quality of the information available. In some circumstances multiple approaches may need to be used and reconciled.

The appraisal given above suggests the following multi-step process:

1. What services or applications could potentially use the frequency band? (For this report only existing services and applications were considered as there was no policy to change the allocated use of the bands under consideration.)
2. For each application or service derive the value of spectrum from one or more of the following:
    a. Market values: Are there market values revealed by auctions or trades in comparable market and spectrum use situations? If yes, then use these data to provide an estimate of value for the service in question.
    b. Calculated values: Depending on the service directly calculate the value as follows.
        i. Calculate value based on the NPV of future cash flows with all inputs (including capital) valued at their market price. (This approach is only relevant where the service generates revenues specific to the use of spectrum. This is typically the case where services are provided to third parties (i.e. for public services) and so is not very relevant to this report.)

i. Calculate value based on the least cost alternative approach. (This approach is most relevant to spectrums applications that support internal business processes (i.e. private services), but has also been used to value public services where revenues are highly uncertain.)

c. Where market and directly calculated spectrum values are obtained, make choice of value based on the direction of bias that seems likely to best promote welfare.

3. If there is an alternative use with an estimated value greater than that for the current use then set the SUF between the two values – generally towards the bottom end of the range so that spectrum is not left idle. However, if spectrum demand is not very sensitive to price changes a value towards the middle of the range may be appropriate.

4. If there is no alternative use with a spectrum value higher than the current use of the band then set the SUF at the spectrum value for the current use.

The implementation of SUFs using this approach is discussed in the next three sections.

4 SUFs for Fixed Service Bands

4.1 Introduction

This Section addresses the potential application of SUFs to frequency bands allocated to fixed links supporting telecommunications services and television and radio programme production, and to fixed satellite services. The bands available for use by these services are shown respectively in Table 4-1, Table 4-2 and Table 4-3.[33]

Table 4-1: Frequency bands for fixed links

Frequency band (not necessarily contiguous)	Application	% vacant (relating to sub-bands when more than one value shown)
3.2 – 27.5 MHz	P-P fixed links	72 / 93 / 38 / 67 / 45 / 24 / 71 / 88 / 98 / 98 / 55 / 82 / 78 / 80 / 81 / 85
175.5 – 181.5 MHz	P-P fixed links	68
1429 – 1530 MHz	P-P fixed links	40 / 80
4400 – 4990 MHz	P-P fixed links	43
5850 – 5950 MHz	P-MP distribution systems	0
6425 – 8500 MHz	P-P fixed links	9 / 40 / 21 / 19 / 20 / 35
10.15 – 11.7 GHz	P-P fixed links	95 / 68 / 50
12.5 – 13.25 GHz	P-P fixed links	47
14.4 – 15.35 GHz	P-P fixed links	20 / 65
17.7 – 19.7 GHz	Largely MMDS	51
21.2 – 23.6 GHz	P-P fixed links	80 / 44
24.45 – 31.3 GHz	LWFTNS34	70
37 – 39.5 GHz	P-P fixed links	94
50.4 – 51.15 GHz	P-P fixed links	100

Source: OFTA

[33] Extracted from The Hong Kong Table of Frequency Allocations. OFTA, April 2008 updated by OFTA October 2008.

[34] Local Wireless Fixed Telecommunication Network Services.

Table 4-2: Frequency bands for services ancillary to broadcasting

Frequency band (not necessarily contiguous)	Application	% vacant (relating to sub-bands when more than one value shown)
33 – 56 MHz	9 x Wireless microphone frequencies	Licence-exempt if 10 mW ERP or less [1]
174 – 175 MHz [2]	Wireless microphones	One licence-exempt frequency, otherwise licence required. [1] 20 mW ERP or less.
184 – 185.4 MHz [2]	Studio wireless intercommunication service	Includes licensed wireless microphones. 20 mW ERP or less. [1]
215 – 226 MHz	Studio & OB links	% vacant not specified
819.1 – 823.1 MHz	UHF wireless microphones	Licence-exempt [1]
2055 - 2095 MHz	ENG / OB	25 (4 x 10 MHz channels) – 3 assigned
2200 – 2290 MHz	ENG / OB	0
7100 – 7421 MHz	OB links (shared with Fixed)	60
11.7 – 12.2 GHz	OB links	55
12.5 – 13.25 GHz	OB links (shared with Fixed and Fixed Satellite)	46
14.4 – 15.35 GHz	OB links (shared with Fixed and Mobile Satellite)	20 / 65

Source: OFTA;

Note [1]: With regard to wireless microphones, OFTA report that the licensed frequencies are not congested. Insofar as frequencies for licence-exempt wireless microphone use are concerned, spectrum utilisation fees are not relevant and congestion in this regard is therefore not of interest. Note [2]: These bands are commonly used by users other than broadcasters.

Table 4-3: Frequency bands for fixed satellite services

Band	Frequency	Sharing
C-band downlink	3400 – 4200 MHz	Exclusive
C-band uplink	5850 – 5950 MHz	Fixed P-MP distribution systems
	5950 – 6425 MHz	Exclusive
Ku-band downlink	12.2 – 12.5 GHz	Exclusive
	12.5 – 12.75 GHz	OB and Fixed
Ku-band uplink	12.75 – 13.25 GHz	OB and Fixed
	14.0 – 14.4 GHz	Exclusive
Ka-band downlink	18.8 – 19.7 GHz	Fixed and MMDS
	19.7 – 21.2 GHz	Exclusive
Ka-band uplink	28.5 – 31 GHz	Not explicitly designated under the band plan and existing utilisation.

Due to heavy rainfall in Hong Kong, permissible path lengths for point-to-point links are about 14 km, 5-14 km and 1- 5 km for fixed links operating in bands “below 10 GHz”, “10-20 GHz” and “above 20 GHz” respectively. Most of the fixed links operating below about 20 GHz are deployed to provide links between two hill-top sites, a hill-top site and an inland fixed point (particularly in the remote areas) and a hill-top site and a fixed point on an outlying island. Fixed links above 20 GHz are commonly used by mobile network operators to connect their base stations located at building roof-tops.

Priority for use of fixed link spectrum is always accorded to government users, broadcasters and public utilities. Private companies are generally required to use leased lines provided by FTNS operators. In line with this policy access to hilltop sites is restricted to the same group of users (i.e. government / broadcasters / utilities) with other private use being limited to country park coverage.

For the same propagation reason noted above satellite services mainly use the C-band allocations as significant outages due to rain would be experienced in the higher allocations (Ku- and Ka-band). The importance of C-band to satellite services was demonstrated when proposals were made, not only in Hong Kong but also at WRC-07, to allocate part of the band to mobile services. These proposals were vigorously opposed by the satellite industry. The C-band allocations are available to satellite services on an exclusive basis (apart from a portion of the uplink allocations which is shared with fixed point-to-multipoint distribution systems).

The current licences and associated fees are shown in

Table 4-4: . The key point to note here is that the fees for fixed links as used by the utilities and MNOs (under the wideband link and relay licence) are expressed as a sum per kHz with no taper for higher frequency bands. The situation differs for broadcasters and fixed carriers (under the fixed / unified carrier licence) where there is a degree of taper with respect to higher frequency bands. However, as a general rule higher frequency bands are less congested than lower ones both because of the poorer propagation (particularly in times of high rainfall) and there is more spectrum available. This is only partially reflected in the current fee structure insofar as it does not apply to all users uniformly.

Table 4-4: Fixed service licence fees (2008)

Licence	Application	Fees
Wideband link and relay station licence (WBLRS)	Fixed communications link	$0.15/kHz (this is per frequency which is not necessarily the same as per assignment)
Self provided external telecom system licence	Satellite earth station[35]	$750 plus $6000/Vsat if co-ordination required $5000/Vsat if no co-ordination $17000/other earth station if co-ordination required $11000/other earth station if no co-ordination
Fixed carrier or unified carrier licence[36] (FTNS)	Fixed links, OB links, MMDS, UHF broadcasts	$50 for every 1kHz or part thereof for frequencies below 1 GHz $(50-4F) for every 1kHz or part thereof for frequencies from 1-10.999 GHz $(20-F) for every 1kHz or part thereof for frequencies from 11-18.999 GHz $1 for every 1kHz or part thereof for frequencies above 19 GHz No fees for certain frequency ranges[37] The above fees relate to exclusive use of a frequency. Where a frequency is assigned on a non-exclusive (shared) basis the above fees are proportionally reduced by a reduction factor equal to the number of authorised users sharing the band. The currently applied reduction factor for sharing is 6[38].

Source: OFTA

4.2 Congestion

The figures relating to the percentage vacancy of a band (or sub-band) indicated in Table 4-1 suggest that there are few bands where congestion exists. For example, if we assume that anything less than 25% vacancy (i.e. greater than 75% occupancy) can be considered to be congested, then only a few sub-bands such as 5850 – 5950, 6425 – 7075, 7250 – 7750, 7750 – 7900 and 7900 – 8000 MHz would qualify.

[35] A Space station carrier licence may also be held. The initial fee is $120,000 and an annual fee of $80,000 is payable for such a licence.

[36] The fee schedules are prescribed in the Telecommunications (Carrier Licences) Regulation (Cap. 106V). See fee schedule of the Fixed Carrier Licences on OFTA's website.

[37] No fee is payable for the following bands: 6.765-6.795 MHz; 13.553-13.567 MHz, 26.957-27.283 MHz, 40.66-40.7 MHz, 2400-2500 MHz, 5.725-5.875 GHz, 24-24.25 GHz, 61-61.5 GHz, 122-123 GHz, 244-246 GHz.

[38] The factor 6 is directly related to the reuse factor achieved in the lower frequency bands (i.e. below 10 GHz). While practical reuse factors increase as frequency bands get higher, the same factor has historically been applied to all frequency bands.

A more detailed analysis suggests that congestion is slightly more widespread than suggested by the Hong Kong Frequency Allocation Table. It can be seen from the table below that the 8275 – 8500 MHz band is also congested. Congestion is therefore contiguous across all bands falling in the range 5 to 10 GHz and these bands should be considered candidate bands for an SUF.

We note that in general the bands used for services ancillary to broadcasting are not consistently congested across a frequency range. Generalising though, it can be said that the ENG/OB bands are mostly congested in the bands near 2 GHz. The bands available for OB above this are not generally congested but given the shared use of these bands congestion could arise from the OB services displacing fixed links.

Similar considerations apply to the C-band satellite allocations where OFTA has determined that while they should be available on a largely exclusive basis in principle they could be used by fixed links in line with the ITU allocation. On this basis it can be considered that satellite use of the band is denying use of the band by fixed links and this is a proxy for congestion. Furthermore, and recognising OFTA's current position on this[39], the footnote that designates the band 3.4 – 3.6 GHz for IMT and which includes China as a signatory, may give rise to pressure from the mobile community to gain access to this band in the future – a proxy for potential future congestion.

The argument regarding satellite usage denying fixed link usage has led the UK to consider how licensing might be applied to downlink services supporting receive-only terminals which are generally licence-exempt. Such terminals are licence-exempt in Hong Kong also (excepting Satellite Master Antenna Television systems which receive and redistribute signals).

The UK has proposed the voluntary licensing of receive-only terminals under a scheme called Recognised Spectrum Access (RSA). However, there has been significant delay in its introduction with respect to receive-only satellite terminals. One of the main disadvantages of such a scheme centres on the fact that the first satellite service operator or provider to take out a licence and thereby obtain protection from fixed services (whether real or putative) implicitly provides protection for other satellite services operators / providers using the same frequencies through other satellites.

[39] There is no plan to allocate the band for IMT until there are improved interference mitigation techniques sufficient to protect the satellite services.

Table 4-5: Occupancy for fixed service bands

Frequency band	Available channels or spectrum [1]	Vacant channels or spectrum	Congestion [2]	Main user / type of use	Main deployment type
30 – 300 MHz	33.2 MHz	24.4 MHz	No	Government + Private / Low capacity	Not hilltop
300 – 3000 MHz	264.4 MHz	143.3 MHz	No	Government + Private	Not hilltop
4400 – 4990 MHz	7	3	No	Government	Not hilltop
5850 – 5950 MHz	100 MHz	0 MHz	Yes	Private / Low power	Not hilltop
6400 – 7100 MHz	8	0	Yes	Broadcasters + Government + Utilities	Studio to Hilltop
7420 – 7750 MHz	10	0	Yes	Utilities + Government	Hilltop
7750 – 7900 MHz	150 MHz	28 MHz	Yes	Government	Hilltop
7900 – 8000 MHz	10	0	Yes	DTT infrastructure	Studio to Hilltop
8275 – 8500 MHz	6	0	Yes	Government	Hilltop
10.15 – 10.30 GHz 10.5 – 10.68 GHz	150 / 180 MHz	143 / 98 MHz	No	Government	Hilltop
10.7 – 11.7 GHz	12	6	No	Fixed carrier + Government	Hilltop
12.50 – 13.25 GHz	750 MHz	358 MHz	No	Government + also earmarked for OB	Hilltop (Government use)
14.4 – 15.35 GHz	16	6	No	Government + Broadcasters	Hilltop (Government use)
17.70 – 19.70 GHz	35	18	No	Broadcaster (MMDS)	Rooftop
21.2 – 23.6 GHz	20	6	No	Government + MNOs + Fixed carrier + Private	Rooftop
24 / 26 GHz	6	5	No		
38 GHz	160	153	No		

Source: OFTA

Notes:

[1] Where the value is expressed in MHz this denotes there is no channel plan for the band.

[2] A band is considered to be congested when OFTA experiences difficulty in making additional assignments in the band. An appropriate metric is that a band is congested when the spectrum utilisation exceeds 75% judged with respect to the vacant spectrum indicated in this table.

4.3 Estimated SUF for congested fixed bands

Market benchmarks

Frequency bands for fixed links are not typically auctioned and so there are very few market benchmarks for setting SUFs. Table 4-6: summarises the lump sum prices obtained in some auctions of fixed service bands conducted in the last 5 years.

Table 4-6: Results from recent auctions of fixed bands

Country, date	Frequency band and date	Winning bids	Implied Prices paid/MHz million pop (in HK dollars)
Ireland, June 2008	26 GHz band, each block is 2x 28 MHz for national use	€70,000 per 2x28 MHz One bidder paid an additional €30,679 per block and another paid an additional €39,609 per block to secure their preferred blocks	$3353-5251
UK, February 2008	10 GHz band, 28 GHz, 32 GHz and 40 GHz bands[40]	Prices for national blocks range from £60-975/MHz	$14-225 Values decrease as the frequency range increases.
US, July 2004	880 licences of 80 MHz in a range of geographic areas	Only 7 licences sold prices ranged from $13,000 to $62,400 depending on the area	$1552-2384

Source: Regulator websites

As can be seen when normalised for population the values differ considerably. The values for Ireland and the US differ by a factor of 2 but those for the UK are an order of magnitude smaller. This may be because while national blocks were assigned bidders expect to use the frequencies on a more localised basis.

Incentive pricing elsewhere

As already noted in Section 2.2.3 the current reference AIP fee for a point-to-point fixed link in the UK is £88 per annum for 2 x 1 MHz or equivalently £44 per MHz per annum which is HK$ 660 per MHz per annum.

[40] The lot sizes were as follows: 1x10 MHz at 10 GHz; 2x112 MHz at 28 GHz; 2x126 MHz at 32 GHz and 2x250 MHz at 40 GHz.

Calculated values

For direct calculation of the opportunity cost of spectrum for fixed links we have used the least cost alternative approach applied in the UK. The objective here is to think about the position of a spectrum user operating in a congested part of the spectrum and to consider what that user might do in terms of identifying alternative means of supporting the same service if their existing spectrum were to be taken away. If the alternative means of supporting the same service costs more (i.e. the result of the calculation is positive) then the calculated additional cost represents the value of the spectrum to that user. In this situation an incentive, i.e. SUF, (directly related to the value of the spectrum to that user) is required for the spectrum user to take up the alternative means of delivering services. If the alternative means costs less (i.e. the result of the calculation is negative) then it would be expected, notwithstanding other factors, that the user would migrate to that alternative in the normal course of events as it implies the spectrum user would save money.

There are several possibilities that can be considered here as alternative means for supporting a service; use of more efficient technology (higher modulation state), use of alternative (higher) frequencies, use of alternative services (i.e. leased line or satellite link), self provision of cable connections, but no one of these is ideal in terms of being appropriate in all situations.

There are two licence schedules that could apply when considering choices faced by a user of fixed links; the wide-band link and relay station licence (WBLRS) which applies to the utilities and MNOs, and the fixed telecommunications network services licence (FTNS) which applies to the broadcasters and fixed carriers. With reference back to Table 4-4, it can be seen that the WBLRS licence as held by utilities and MNOs charges HK$ 0.15 per kHz for a frequency and the FTNS licence held by broadcasters and fixed carriers charges HK$ 22 per kHz at 7 GHz for example – more than two orders of magnitude greater (although this is ameliorated by the application of a reuse factor when the frequency is shared as noted in the following paragraph). The costings that follow have used the fees associated with both these licences as the amounts are significantly different. The consequences of this are discussed later.

It can be further noted that although the current licence fees are per frequency rather than per assignment we have assumed that the whole fee is attributed to a single link in the assessments that follow. We do however take account of the fact that the FTNS licence fee is in any event divided by 6 (representing a reuse factor) when a frequency is assigned on a shared rather than exclusive basis.

Alternative technology – higher modulation state

For links where additional capacity is required on a user's carrier it is technically and economically efficient to use a higher modulation state on the existing carrier rather than use an additional carrier. Most, if not all, current fixed link equipment is software controlled and can be readily changed to support higher bitrates. It can be noted that although there is no real cost involved in moving from one modulation state to another because it is simply software controlled, vendors of this equipment still extract value from their customers.

It can be noted that higher order modulations are more susceptible to interference so some of the spectral efficiency gains obtained by moving to higher order modulations are offset by the reduced frequency reuse that is subsequently achievable.

Table 4-7: below gives some indication of how equipment costs change as the bit rate supported by a link increases, where the increase in bit rate is achieved through a combination of channel bandwidth and modulation level. While the first category below relates to 3.5 / 7 / 14 MHz channels and the middle three categories relate to 28 / 29.65 MHz channels, it is likely that the last category would require a larger RF channel bandwidth.

Table 4-7: Fixed link bit rates and equipment costs (including installation costs)

Bit rate (Mbps)	Equipment cost > 8GHz (HK$)	Equipment cost <8GHz (HK$)
2 – 34	83,000	108,000
>34 – 50	110,000	144,000
>50 – 100	155,000	200,000
>100 – 200	200,000	260,000
>200 – 400	230,000	300,000

Source: Equipment vendor

These are broadly in line with fixed link costs quoted by a local Hong Kong source as follows:

Up to 50 Mbps = HK$ 110,000

> 50 and up to 100 Mbps = HK$ 150,000

>100 and up to 200 Mbps = HK$ 180,000

It can be noted that the current OFTA fee structure for fixed links is bandwidth dependent so there is already some incentive to use higher order modulations when increased capacity is required.

In order to estimate the value of alternative modulation schemes we need to make an assumption about the equipment cost structure recognising that one element will constitute the hardware and the other element will be the payment of a licence to the equipment vendor to increase the bit rate through software. For the purposes of this exercise we will assume that the lowest cost is the base cost for the hardware and that no additional vendor licence fee is payable to operate at bit rates between 2 and 34 Mbps. Changing to a bit rate higher than 34 Mbps would then incur a vendor licence fee amounting to the difference between the base cost and the cost indicated for the higher bit rate in the table above. Since the costs quoted by the local Hong Kong source are closest to the costs for equipment >8 GHz in the table above we will use the costs in the left hand column of the table and assume they apply below 8 GHz.

A number of assumptions need to be made regarding the situation where an increase in capacity on a link is required:

- The lifetime of equipment is 15 years
- The initial capacity is 34 Mbps in a 28 MHz[41] channel (bidirectional)
- The increased capacity is 100 Mbps (bidirectional) and the requirement for this occurs half way through the equipment lifetime
- The increased capacity can be supported by:
  - new equipment and additional carriers (Scenario 1), or
  - the same equipment (upgraded) and the same carriers (Scenario 2)

[41] A 28 MHz channel can support 34 Mbps, 2 x 34 Mbps, 100 Mbps or 155 Mbps depending on modulation state.

The difference in costs between scenarios 1 and 2 gives the price of spectrum that would need to be charged to make the user indifferent between the two options. Setting a SUF slightly above this amount gives an incentive to move to the more spectrally efficient scenario.

Scenario 1 costing

The additional costs in this case are:

- New equipment (2 x 34 Mbps[42]). This amounts to HK$ 155,000 (including the installation cost) annualised over 15 years (10%) = HK$ 18,526 per annum. Annual running costs and maintenance associated with the additional equipment can be considered to be 10% of the capital cost at HK$ 15,500 per annum giving a total figure of HK$ 34,026 per annum.
- Additional 28 MHz channel to carry 2 x 34 Mbps. The spectrum fee for this, at 7 GHz say, is HK$ 102,667 per annum per 28 MHz carrier based on the FTNS licence fee schedule. Two of these spectrum fees are payable on a bidirectional link that the equipment supports.
- The total additional costs for Scenario 1 are HK$ 239,360 per annum. If the WBLRS licence schedule is considered the total additional costs for this scenario are HK$ 42,426.

Scenario 2 costing

The additional costs in this case are:

- Upgraded equipment. This amounts to HK$ 155,000 – HK$ 83,000 = HK$ 72,000 annualised over 7.5 years (10%) = HK$ 12,857 per annum.
- No additional spectrum fees.
- The total additional costs for Scenario 2 are HK$ 12,857 per annum (the type of licence not being relevant here).

It can be seen from the overall cost of Scenario 1 compared to Scenario 2 that when operating under an FTNS licence there is already a huge incentive to use more spectrally efficient equipment where this incentive comes from existing spectrum fees. In the case of the WBLRS licence the incentive is still there but not so great.

In this case the value of the spectrum attains a negative value (HK$ - 4,045 per MHz per annum in the FTNS case and HK$ - 528 per MHz per annum in the WBLRS case) as the cost of using more spectrum (Scenario 1) is greater than the cost of using more efficient equipment (Scenario 2). This means that under the current fee arrangements one would expect users to naturally migrate towards more efficient equipment (Scenario 2) in order to save money and consequently this alternative (more efficient equipment) cannot be considered as a candidate as the next best alternative for the purposes of setting a spectrum utilisation fee.

Alternative frequencies

It is often the case that users can be encouraged to migrate to other frequency bands that are less congested. This can also sometimes be done by the user without increasing the number of hops required. The Hong Kong situation is less than ideal in this regard because the lower frequency bands are significantly congested and the higher less congested bands have less utility because of the impact of rain. As noted earlier path lengths for point-to-point links are about 14 km, 5 - 14 km and 1 -

[42] Moving from a capacity of 34 Mbps to 100 Mbps requires an additional 66 Mbps. We are assuming that this can be supported by 2 x 34 Mbps in a 28 MHz channel and will require additional equipment in the >50 – 100 Mbps range.

5 km for fixed links operating in bands "below 10 GHz", "10-20 GHz" and "above 20 GHz" respectively. It can be seen therefore that relocating links from below 10 GHz to the 10 to 20 GHz range is likely to require an additional hop. We can therefore make an assessment of the cost of moving to a higher frequency in terms of the cost of scrapping existing equipment, the cost of an additional hop and the difference in cost of equipment on the original hop when moving from a lower to a higher frequency (if there is a difference).

As above, a number of assumptions need to be made regarding the situation where an additional hop is required in moving to a higher frequency:

- The lifetime of equipment is 15 years
- The capacity of the linkage is 2 x 34 Mbps in a 28 MHz channel (bidirectional)
- The existing link operates below 10 GHz (at 7 GHz say) and has a path length of 14 km. This link is scrapped half way through the equipment life, and is replaced by
- The new pair of links (i.e. double hop) which operate between 10 and 20 GHz (15 GHz say) each having a path length around 7 km[43].
- As in the technology case above, we will assume that there is no difference in equipment cost between the two frequency bands and will therefore use the costs in the left hand column of the earlier table.

The additional costs are:

- Scrapping of the "below 10 GHz" equipment. HK$ 155,000 / 2 = HK$ 77,500 annualised over 7.5 years (10%) = HK$ 13,839 per annum
- Two lots of "10 – 20 GHz" equipment. 2 x HK$ 155,000 = HK$ 310,000 annualised over 15 years (10%) = HK$ 37,052 per annum. Also, annual running costs and maintenance associated with the additional hop at 10% of capital = HK$ 15,500 giving a total of HK$ 52,552 per annum.
- The establishment of a new site. In general we are dealing with the replacement of fixed links involving one or more hilltops. It is therefore likely, but not always essential, that the additional site will also be a hilltop site or at least at a raised ground level. We can therefore assume that the site has to be developed in the same way that existing hilltop sites have been developed. Existing hilltop sites will have been developed by the original users who paid for capital costs and who make a lease payment to the Land Department. Newcomers to a site pay a rental reflecting these capital and lease costs. It is understood from a user (via OFTA) of these hilltop sites that a typical rental is HK$ 15-20,000 per month. We will therefore assume a mid-point cost associated with the additional site (without the radio equipment which is covered by the bullet above) of HK$ 210,000 per annum.
- An additional 28 MHz channel (at higher frequency) for second hop offset by lower spectrum fee (higher frequency) for first hop in the case of the FTNS licence. The spectrum fees for the original link at 7 GHz are HK$ 205,334 and for the alternative two hops are HK$ 93,332 giving a saving of HK$ 112,002 per annum. In the case of the WBLRS licence the spectrum fees in both bands are the same so there is no offset by way of cost reduction but instead there is an additional cost coming from the spectrum fees associated with the extra hop.

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[43] OFTA have confirmed, with reference to their fixed link records and propagation behaviour in Hong Kong, that the majority of fixed links operating in the 6 / 7 GHz bands could be replaced by double hops in higher frequency bands around 15 GHz.

It can be seen once again from the costs above that in the case of the FTNS licence there is already some incentive to use higher frequency bands where this incentive comes from existing spectrum fees.

The calculations suggest an additional incentive is required to make the user indifferent between moving to higher frequency band and paying higher fees in the congested band. This amounts to the additional cost associated with moving to a higher frequency band and having to implement an additional hop and, in the FTNS case, amounts to HK$ 13,839 (scrapped old equipment) + HK$ 52,552 (new equipment) + HK$ 210,000 (site) + HK$ 93,332 (new spectrum fees) – HK$ 205,334 (old spectrum fees) = HK$ 164,389 per annum. On a per MHz basis this amounts to HK$ 2,936 per MHz per annum.

In the case of the WBLRS licence, since there is no existing incentive in the licence fees to move to a higher band the same calculation indicates that a greater incentive is required amounting to HK$ 5,086 per MHz per annum.

Alternative services - leased line

The most obvious alternative to a fixed link is a leased line, although in many cases (links between distant hilltops and to islands for example) this may not be a practical possibility and even links up to hilltops may not be well served. Notwithstanding these caveats it is possible to carry out a costing by comparing the cost of establishing a fixed link versus the cost of a substitute leased line.

Official tariffs for leased lines are published on the OFTA website[44]. In reality what is paid will be subject to individual commercial arrangements so listed prices can be regarded as the maximum.

We can take two examples here; a 2 Mbps service and a 100 Mbps service.

The tariff for a 2 Mbps leased line could be up to HK$ 7,000 per month per end with an installation charge of approximately HK$ 4,500 per end. If the installation charge is annualised over 15 years at 10%, the total charge would be HK$ 169,076 per annum. This can be considered to substitute for a fixed link using a 3.5 MHz channel (one in each direction) and the cost therefore becomes HK$ 24,154 per MHz per annum.

The tariff for a 100 Mbps leased line could be up to HK$ 18,800 per month per end with an installation charge of HK$ 12,000 per end. If the installation charge is annualised over 15 years at 10%, the total annual charge would be HK$ 454,069 per annum. This can be considered to substitute for a fixed link using a 28 MHz channel (one in each direction) and the cost therefore becomes HK$ 8,108 per MHz per annum.

The discrepancy between these two figures (a factor of 3) is down to opposing spectral efficiencies in the two examples (2 Mbps in a 3.5 MHz channels would use the most basic modulation / coding whereas 100 Mbps in a 28 MHz channel would have to use a higher rate modulation) offset by the leased line provider's non-linear charge rate for the two examples.

Recognising that there is unlikely to be suitable fibre infrastructure to substitute for links between distant hilltops and to islands, the emphasis on moving links from microwave to fibre should be centred on those fixed links which make a connection from a location in or near a ground level urban centre to a hilltop. For these links it is likely to be the case that there is only partial fibre infrastructure which will not be enough to provide complete end-to-end substitute connectivity. However, additional fibre could be installed between the existing fibre infrastructure and the hilltop(s) to provide the

[44] See page on OFTA website titled Tariffs of Fixed Network Operators- Data Services

necessary connectivity. The cost of this additional fibre should be added to the leased line cost identified above as this latter cost component is attributable to use of the existing fibre infrastructure.

We assume that the new fibre has to cover a distance of 2 km from the existing fibre infrastructure to the hilltop and that a third of this distance is in a dense urban area (HK$ 2,000 per metre laying cost) and the remaining two thirds is in a rural environment (HK$ 500 per metre laying cost). It is assumed that the new fibre would support all the non-government fixed links going from ground level to the hilltop. OFTA records indicate that for the fixed link frequency bands below 10 GHz non-government users require a total bandwidth to a hilltop site of 83.5 MHz on average, the range being 14 to 280 MHz. The additional fibre cost, on top of the leased line costs, can then be annualised and apportioned per MHz based on the 83.5 MHz average. The additional cost on this basis is HK$ 2,863 per MHz per annum.

In order to determine the difference in cost between the original (fixed link) and the alternative (leased line) we need to know the cost of a fixed link supporting 2 Mbps and 100 Mbps (each bidirectional). Fixed link costs are assumed to be made up of:

- Site rental. HK$ 210,000 per annum. This rental is on the same basis as the site rental discussed earlier for the alternative frequency case. In this instance we are dealing with two ends of a fixed link rather than a single additional site so two lots of site rental should apply. However, many of the fixed links to hilltop sites originate / terminate at user sites so no site rental applies at that end of the link. We have therefore assumed one site rental when assessing the fixed link costs.
- Equipment and installation. HK$ 83,000 (2 Mbps) or HK$ 155,000 (100 Mbps) which are equivalent to HK$ 9,920 (2 Mbps) per annum and HK$ 18,526 per annum (100 Mbps) when annualised over 15 years at 10%.
- Maintenance and running costs. 10% of equipment costs = HK$ 8,300 per annum (2 Mbps) or HK$ 15,500 per annum (100 Mbps).
- Spectrum fees. Two lots (i.e. bidirectional) of:
  - HK$ 12,833 per annum (3.5 MHz carrier, FTNS)
  - HK$ 525 per annum (3.5 MHz carrier, WBLRS)
  - HK$ 102,667 per annum (28 MHz carrier, FTNS)
  - HK$ 4,200 per annum (28 MHz carrier, WBLRS)
- FTNS TOTAL = HK$ 253,886 per annum (2 Mbps) or HK$ 449,360 per annum (100 Mbps).
- WBLRS TOTAL = HK$ 229,270 per annum (2 Mbps) or HK$ 252,426 per annum (100 Mbps)

The difference in cost between the original 2 Mbps fixed link (HK$ 253,886 p.a.) under an FTNS licence and the alternative leased line plus fibre extension (HK$ 189,117 p.a.[45]) is significantly negative. It is also significantly negative under a WBLRS licence. This indicates that, where leased lines are available, there is already sufficient incentive (under both existing licence schemes) for leased lines rather that fixed links to be used when a 2 Mbps link is required.

[45] This value made up of the leased line cost of HK$ 169,076 p.a. and the additional fibre cost apportioned with respect to 2 x 3.5 MHz (7 x HK$ 2,863).

The difference in cost between the original 100 Mbps fixed link (HK$ 449,360 p.a.) under an FTNS licence and the alternative leased line (HK$ 614,397 p.a.[46]) fees is HK$ 165,037, in this case a positive value. Under a WBLRS licence the difference (positive) is significantly greater at 361,971. This implies that further encouragement (in the form of spectrum fees over and above existing fees) needs to be given to users to migrate from fixed links to leased lines.

Alternative services – satellite link

Satellite links can be used as a substitute although for relatively short hops the cost can be great. For some situations (e.g. links to islands) satellite links are an easily implemented option.

In general a satellite link (unidirectional) at Ku-band costs between US$ 6,500 and US$ 7,000 per month per Mbps[47] and C-band costs are less than these amounts. The equivalent figure from the tariffs published for Sinosat is US$ 4,333 per month at Ku-band and US$ 3,750 per month at C-band[48].

From this range of values (US$ 3,750 to 7,000 per month) we can see that the cost of a link based on a satellite substitute is US$ 45,000 to US$ 84,000 per Mbps per annum which is HK$ 351,000 to 655,200 per MHz per annum (where the spectral efficiency is 1 Mbps = 1 MHz).

The fixed link costs in the leased line example above are HK$ 171,686 p.a. for a 2 x 3.5 MHz link and HK$ 187,492 p.a. for a 2 x 28 MHz link. These equate to HK$ 24,527 per annum per MHz and HK$ 3,348 per annum per MHz respectively. Strictly, one or other of these fixed link costs should be subtracted from the satellite costs in order to assess the value of the spectrum – we have not done so as they are so insignificant compared to the satellite costs. The high cost of satellite links means we can effectively discount these as a practical alternative to fixed links (although in the specific case of the islands it might be one of only two alternatives, the other being the deployment of an underwater cable).

Self provision

For those cases where leased lines are not available through providers of such services, self provision can be considered. As for the satellite case costs are high and it is difficult to make a direct comparison as fibre provides a huge bandwidth all of which may not be required.

The main cost involved in self provision is that of laying the fibre / cable. Laying costs can amount to anything up to the equivalent of HK$ 2,800 per metre in the densest city areas with the cost of the fibre itself being relatively insignificant (around HK$ 50 per metre). It is noted that a fixed carrier licence is required to lay a cable in public streets and government land. Because of this it would be expected an operator holding such a licence would probably undertake such provision on behalf of the user needing to take up this option.

If one considers a 10 km link and assumes that the cost of laying a fibre link is somewhat less that the maximum, HK$ 2,000 per metre say, then the total cost would be of the order of HK$ 20 million. This would substitute for any high capacity microwave link (e.g. 2 x 28 MHz or 2 x 40 MHz) and more as noted above. If we assume that the cost of laying the fibre is annualised over 15 years (at 10%) and

[46] This value made up of the leased line cost of HK$ 454,069 p.a. and the additional fibre cost apportioned with respect to 2 x 28 MHz (56 x HK$ 2,863)

[47] See Internet VSAT access via satellite costs on the website for satsig.

[48] China Digital Satnet Limited, General Conditions of Service. OFTA website.

costs are attributed to the equivalent of a bidirectional 28 MHz link then the normalised cost is HK$ 42,686 per MHz per annum.

Taking the high capacity fixed link cost from the leased line example above (i.e. HK$ 8,024 per annum per MHz under an FTNS licence and HK$ 4,508 per annum per MHz), the value of the spectrum evidenced by self provision would amount to HK$ 34,662 per annum per MHz (FTNS) or HK$ 38,179 per annum per MHz (WBLRS).

With reference to the leased line option earlier it was noted that leased lines may not exist for a number of situations (i.e. between distant hilltops and to islands for example and possibly links up to hilltops). It is believed that only 6 of the 12 most important hilltop sites have T1 (1.5 Mbps) circuits available and only one or two hilltop sites are connected by fibre.

4.4 Implications for setting SUF

Table 4-8 summarises the estimates derived above. By way of comparison with the derived figures the current spectrum fees are HK$ 3,667 per annum per MHz (at 7 GHz for example) and HK$ 833 per annum per MHz (at 15 GHz for example) for an FTNS licensee and HK$ 150 per annum per MHz (independent of frequency) for a WBLRS licensee.

The estimated values are on top of the current spectrum fees where these would have to be paid anyway as a means of recovering OFTA's costs. The least cost alternative methodology involves setting SUFs based on the least cost of reducing spectrum demand for a typical user.

In order to compare these values with international benchmarks it is necessary to add existing fees, take account of frequency reuse and relate to population. As noted earlier existing fees at 7 GHz are HK$ 3,667 per annum per MHz (FTNS) or HK$ 150 per annum per MHz WBLRS) Frequency reuse at this frequency is 6. Using the "higher, uncongested frequencies" values in the table above as an example and taking account of Hong Kong's population 7 million, gives a value of HK$ 4,488 (WBLRS) to 5,660 (FTNS) p.a. per MHz per million population. This is considerably higher that the international values shown in Table 4-6 in Section 4.3.1 which are not annualised. This is not surprising however given the greater importance of lower frequency bands in Hong Kong and the fact that the international benchmarks relate to much higher frequency bands. Furthermore, the international spectrum is auctioned as unmanaged whereas the comparison here is with spectrum that is managed by OFTA. These aspects make any comparison difficult.

As identified in Section 4.3.2 the current reference AIP fee for a point-to-point fixed link in the UK is £88 per annum for 2 x 1 MHz or equivalently £44 per MHz per annum.

This level of AIP was in the first instance based on new technology (i.e. higher orders of modulation/coding) using values calculated by Smith-NERA in 1996[49]. The Smith NERA calculations in fact gave a value of £190/MHz but the regulator chose to set a value significantly below this level. Before comparing the proposed Hong Kong value with the UK AIP value it is also worth noting that fixed link equipment prices have fallen significantly since the original UK study was undertaken so this will also distort the comparison to some degree.

The option of improving spectrum use through new technology based on higher order modulation/coding is not available in Hong Kong because existing fee structures will have ensured that operators move to a higher order modulation as a matter of course (if needed). Our calculations

[49] Study into the use of Spectrum Pricing – Smith-NERA for the Radiocommunications Agency. April 1996.

arrive at negative value which supports this assertion. More recent UK AIP calculations based on moving to a higher frequency band (which is comparable to the Hong Kong case) give a result some 4 to 10 times higher than using higher order modulation depending on the carrier size assumed[50]. The original Smith-NERA work indicated a price differential of just over 10 when comparing the move to a higher frequency band with the use of narrowband equipment (i.e. higher order modulation).

For the comparison we start with the reference fee of £44 per MHz per annum. This value can then be increased by 4 to 10 times (which reflects the difference between moving to a higher frequency band and using a higher order modulation) to give £176 to £440 per MHz per annum or equivalently HK$ 2,640 to HK$ 6,600 per MHz per annum. From these values it can be seen that the figures we have derived for Hong Kong are comparable and in fact fall within this range, noting that there are bound to be some differences because of changes in equipment costs as mentioned earlier.

[50] An Economic Study to Review Spectrum Pricing: Final Report – Indepen, Aegis Systems and Warwick Business School for the Radiocommunications Agency. February 2004.

Table 4-8: Summary of costs of alternatives to fixed link

Alternative	Calculated value (HK$) per MHz per annum for a typical link (based on Fixed Carrier (FTNS) licence fees)	Calculated value (HK$) per MHz per annum for a typical link (based on Wideband Link and Relay licence fees)	Comments
Technology	-4,045	-528	Negative value implies use of better technology likely to occur as a matter of course (when required)
Higher, uncongested frequencies	2,936	5,086	Additional to current spectrum fees in congested bands.
Services – leased line	84 (2,947, including additional shared fibre installation)	3,601 (6,464 including additional shared fibre installation)	Value derives from relatively high bit rate carriers. Relatively small value for the FTNS case (where no additional fibre required) implies value already extracted by site rentals and reflects already high spectrum fees.
Services – satellite link	351,000 – 655,200	351,000 – 655,200	Based on substituting a satellite link for a single fixed link hop. Fixed link costs not subtracted because insignificant.
Self provision – fibre / cable	34,662	38,179	Based on high capacity 10 km link.

Source: Plum and Aegis analysis

Which alternative?

In principle we are looking for the least cost alternative to quantify a spectrum fee which will then provide adequate incentive for some spectrum users to use that alternative thereby vacating their spectrum (for higher value users) and relieving congestion.

In the first instance we can reject any negative values that have been derived as the use of alternatives associated with negative values are likely to occur in the normal course of events. This is because incentives already exist in the form of cost savings to be had by moving to that alternative.

The spectrum fee should therefore be based, at least initially, on the lowest positive value that has been derived. This should provide incentive for some spectrum users to take up the alternative associated with that lowest positive value thereby vacating spectrum for higher value users and relieving congestion. In the event that use of the lowest positive value does not lead to relief in the degree of congestion then the spectrum fee should be increased based on the next highest value and so on.

There are however two complications in this seemingly straightforward process:

- because of the different types of fixed link usage in Hong Kong, not all alternatives are practical in all cases, and
- there are two very different licence fees currently in place and these directly influence the level of spectrum fee that will need to be charged.

The main use of the congested fixed link bands below 10 GHz revolves around the use of hilltop sites in order to achieve the necessary distances across the hilly terrain of the territory. Use of these hilltop sites involves two types of fixed link configuration; hilltop to hilltop and urban area (or some location at a lower level of elevation) to hilltop. From a practical point of view it is not expected that a leased line would sensibly substitute for a hilltop to hilltop link whereas use of a higher frequency involving a double hop might. Conversely, it is far less practical (but not impossible) to substitute an urban area to hilltop fixed link with a double hop rather than using a leased line, acknowledging that this might mean the fresh installation of fibre.

We can therefore select both the use of higher uncongested frequencies (involving a double hop) and leased lines as the least cost alternative methods. In using the calculated values associated with these alternatives it is recommended that initially the lower value is applied to all fixed links in the congested bands below 10 GHz. The higher value is in any event not significantly higher so it can be expected that the value used will provide an incentive with respect to both least cost alternatives. The value to be used is therefore HK$ 2,936 per MHz per annum using the FTNS licence as the reference.

Application of the selected value in relation to existing licences is discussed in the next section.

Use of alternative cost to derive SUF

When applying the derived value of spectrum fee to individual spectrum users a number of variables are often taken into account. In the Hong Kong context these will be more or less relevant as discussed here:

- Bandwidth – this is the key to the exercise and is the fundamental variable that will be applied
- Frequency – this is often used to reflect different levels of frequency reuse in different frequency bands. We only consider it applicable in terms of identifying the frequency bands to which spectrum fees should be applied. We do not consider it applicable in a more complicated way because the main fixed link congestion is broadly restricted to a very narrow range of spectrum (bands between 5.85 and 8.5 GHz). It is expected that in the case of the FTNS licence the frequency band factor in existing fees will in any event remain and offer wider encouragement to use higher frequency bands.
- Power – this is sometimes used to reflect the fact that lower powers allow for greater reuse. Availability is also sometimes used as a proxy for power. Given the limited number of hilltop sites it is not clear that encouraging the use of lower power will achieve anything practical.
- Location – this is generally used to define congested and non-congested geographic areas. This is more applicable to countries having an extensive land mass with wide variations in population density. We do not consider this applicable to Hong Kong given its small size and the relatively uniform distribution of important hilltop sites.

Other factors that can be considered when thinking of optimal spectrum use for fixed links relate to the deployment of cross polarisation and the encouragement of appropriate link lengths in different frequency bands (i.e. shorter links in higher frequency bands). The issues here are as follows.

Cross polarisation

Co and cross polar channels are already included in some channel plans and therefore available for assignment as channels that are interleaved with some or no frequency overlap. The planning process therefore already takes this form of cross polar operation into account. Further benefit (in terms of spectrum utilisation) can be obtained by using co and cross polar carriers on the same channel (i.e. complete overlap) and the same path. This is more difficult from a technical viewpoint and in general is best done by the same user deploying interference mitigation equipment if difficulties are to be avoided. This technique is therefore mainly of benefit when the same user requires additional capacity on a path that cannot be satisfied by the use of higher order modulation schemes as discussed earlier. When co-channel cross polar links are deployed there is clearly a general benefit in that spectrum is released that would otherwise be used (i.e. an additional channel on the same polarisation). It is therefore reasonable to apply a discount for a user who uses this cross polar technology. This can be related to the additional cost of the equipment or it can be an arbitrary value - Ofcom applies a 50% to the second cross-polar channel and ComReg applies a 100% discount. It is not thought that there will be many users wishing to deploy this technology so we recommend that OFTA apply a straightforward discount of 50% (recognising that this is an arbitrary value) to the SUF for a second cross polar channel when deployed by a single user on a route.

Link length

It is not desirable to have short links operating in the congested bands (< 10 GHz) when they could operate satisfactorily in uncongested bands. The SUF for these bands should discourage this to a certain extent in that it should encourage links generally to move out of the congested bands to higher frequency bands. However, if additional encouragement is required then it would be possible to either institute a minimum link length policy per band (as Ofcom once had) or allow but penalise (in terms of additional fees) shorter links (as Ofcom now has). This latter approach has the benefit of encouraging short legacy links (those from before the time any link length policy was in place) to move out of lower frequency bands and is closer to a market rather than administrative approach to policy. Given the tight control that OFTA has had on fixed link assignments in the past we assume that there are few if any links that have been assigned without regard to link length spectrum efficiency. We therefore recommend that OFTA implements a simple link length policy associated with the various fixed link bands. This can probably be based on groupings “below 10 GHz”, “10 – 20 GHz” and “above 20 GHz” and could be a minimum path length of 10 km (“below 10 GHz) and 5 km (“10 – 20 GHz”) with anything less than 5 km having to operate above 20 GHz. These proposed minimum path lengths should be confirmed by OFTA with reference to the propagation conditions in Hong Kong

Other variables

In addition to all these variables Hong Kong has an additional variable in the form of different licences (FTNS and WBLRS) which could apply to the same physical fixed link depending on the nature of the operator. Assuming the existing licence fee structure is to be retained the application of a spectrum fee needs to take this into account in order to provide the same or similar incentive to the different types of operator.

SUF Formula

The variables we therefore include are bandwidth (as a continuous variable), frequency band (as an on/off switch variable) and type of licence, including exclusivity or not, (as an adjustment variable).

An appropriate algorithm would therefore take the form:

$$\mathbf{SUF = \$ \times BW \times F_{freq\ band} \times L_{licence} \times E}$$

where:

**$** = the reference value in HK$ per annum per MHz taken from the calculations (using the FTNS value as the reference) = HK$ 2936 per annum per MHz

BW = the bandwidth used in MHz (for the avoidance of doubt, noting that other administrations treat this factor differently, a bidirectional link should be considered to use twice the bandwidth of a unidirectional link)

$\mathbf{F_{freq\ band}}$ = 1 if frequency band between 5 and 10 GHz, otherwise = 0

$\mathbf{L_{licence}}$ = 1 for FTNS licence, = 1.73 for WBLRS licence (derived from the WBLRS value, 5086, divided by the FTNS value, 2936)

E = 6 if frequency is made available on an exclusive basis, otherwise=1

As noted earlier we recommend that the fee determined by the above algorithm be discounted by 50% for a second co-channel cross-polar assignment for single user on a route. Note that the link length policy as recommended does not apply to the fee algorithm – it could be if complete market orientation is required but at the expense of uncalled for complexity.

4.5 Generalising the approach to higher frequency bands

So far we have assumed that fixed link frequency bands between 5 and 10 GHz are congested and we have derived an SUF which would be applied to these bands (on top of existing fees) in order to encourage links to migrate to higher uncongested frequency bands, this option being the least cost alternative. In order to derive a value for the SUF we have taken a 14 km link operating at 7 GHz and replaced it with two 7 km links operating at 15 GHz. The calculated value of SUF for frequency bands between 5 and 10 GHz (for an FTNS licence) is HK$ 2,936 per MHz per annum. Although the analysis of current assignments indicates that 11 GHz band (10.7 – 11.7 GHz) is not congested (see Table 4-5), OFTA is currently making new assignments in the band and is experiencing additional requests for assignments in the band from government users, fixed network operators and mobile network operators. Consequently, it is expected that this band will become congested in the near term and certainly well before any SUF review which would be expected to be some years away. We therefore suggest that the 11 GHz band should be included in the SUF we are proposing for the 5 – 10 GHz range. We recognise this is rather approximate, but consider that it should provide sufficient incentive for efficient spectrum use until the first five yearly review of the SUFs.

If it is thought that other bands above 10 GHz (say between 10 and 20 GHz) are going to become congested at a later date (say when SUFs are reviewed) it will be necessary to apply the same methodology in order to derive an SUF to be applied to these higher frequency bands (10 – 20 GHz). In applying the methodology again we find that migrating links to a higher frequency band is still the least cost alternative. So the SUF will be set to encourage 7 km links operating at 15 GHz to migrate to 25 GHz where two 3.5 km links would be needed.

Assuming that we have already established the SUF for the lowest frequency bands (5 – 10 GHz) as identified in the first paragraph above (see Appendix B for summary of costing), we need to undertake two further steps, namely:

- Establish an SUF for the middle frequency bands (10 – 20 GHz), using the same methodology
- Recalibrate the original SUF for the lowest frequency bands (5 – 10 GHz) in the light of the SUF to be applied to the middle frequency bands (10 – 20 GHz), again using the same methodology

Across the range of frequencies addressed here (i.e. 5 to 25 GHz) the cost of equipment and site rental is largely frequency independent. We can therefore use values reported for these factors in the calculations for the SUF addressing the lowest frequency bands (5 – 10 GHz) given in sections 4.3 and 4.4 and simply adjust the licence fee factors as appropriate.

The next two sections of this discussion focus on costings based on existing FTNS licence fees. A final section addresses the relationship between SUFs for FTNS and WBLRS licences.

SUF for middle frequency bands (10 – 20 GHz)

When looking at an SUF for the middle frequency bands (10 – 20 GHz) it can be shown that moving to higher frequency bands, thereby incurring an extra hop, is still the least cost alternative (see Appendix C for a summary of the costing).

Further, it will be seen by comparing Appendix B (the original costing for the 5 – 10 GHz SUF) with Appendix C (the new costing for the 10 – 20 GHz SUF) that the difference in the SUF calculated arises solely because of the relative differences in existing licence fees between 7 GHz and 15 GHz and between 15 GHz and 25 GHz. This situation arises because across the range of frequencies addressed here (i.e. 5 to 25 GHz) the cost of equipment and site rental is largely frequency independent – it will be seen that the equipment / site rental costs are the same for both SUF calculations (Appendices B and C).

The SUF thus derived for the 10 – 20 GHz range amounts to HK$ 4,436 per MHz per annum in relation to an FTNS licence. Although the impact on WBLRS licences is addressed later it can be noted here that the SUF for a WBLRS licence in the frequency range 10 – 20 GHz is the same as that for the range 5 – 10 GHz because existing WBLRS licence fees do not have a frequency dependent element (and because we have assumed that the cost of equipment and site rental is largely frequency independent across the frequency range 5 – 25 GHz).

Recalibration of SUF for lowest frequency bands (5 – 10 GHz)

Since the original SUF (as applied to the 5 – 10 GHz frequency bands) was calculated using fees that currently apply at 15 GHz, and these fees will change now that an SUF is to be applied to the middle frequency bands (10 – 20 GHz), the original SUF (for the lowest frequency bands, 5 – 10 GHz) needs to be recalibrated (see Appendix D for a summary of the costing).

It is important to recognise that the whole methodology has to be applied each time an SUF assessment is made, whether it is to establish a new SUF or recalibrate an existing SUF. This example is a good case in point.

If it were assumed that we simply recalculate the higher frequency band / double hop approach with the new SUF for the 10-20 GHz band we would end up with an additional SUF to be applied to the original SUF (5 – 10 GHz) of some HK$ 8,872 per MHz per annum, giving a total SUF of HK$ 11,808 per MHz per annum for the lowest frequency bands (5 – 10 GHz).

However, looking at the picture as a whole shows that the imposition of the SUF calculated for the 10 – 20 GHz frequency range means that moving to a higher frequency band is no longer the least cost alternative for a licensee in the 5-10 GHz range. The least cost alternative is now the use of leased lines (including the assumption that some additional fibre has to be installed). Originally this option was calculated to give rise to an SUF of HK$ 2,947 per MHz per annum (see section 4.3). Note that this is only HK$ 11 per MHz per annum more that the SUF of HK$ 2,936 per MHz per annum that has been applied based on the higher frequency band / double hop least cost option. The situation has therefore changed in two ways:

- The SUF applied to the middle bands makes the higher frequency band / double hop option less attractive than the leased line (+ additional fibre) alternative.
- With the leased line alternative the new SUF in total becomes HK$ 2,947 per MHz per annum i.e. there is an additional SUF of HK$ 11 per MHz per annum over and above that already applied.

We can therefore conclude that the additional SUF required to encourage the use of this alternative amounts to only HK$ 11 per MHz p.a. This means that only a small uplift to the original SUF would be required. From a policy point of view the amount is so small that the 5 – 10 GHz SUF could remain at its original level.

Why is the 10 – 20 GHz SUF greater than the 5 – 10 GHz SUF?

It is immediately noticeable that the SUF associated with the lower frequency range (5 – 10 GHz) is somewhat lower than the SUF associated with the higher frequency range (10 – 20 GHz). This appears counter-intuitive but is in fact correct because the proposed SUFs should not be considered in isolation from the existing fees which are already substantial particularly at the lower frequency ranges and already have their own frequency dependency. The explanation with reference to detailed figures as contained in Appendices B and C is as follows.

Part of the calculation for the original SUF for the lowest frequency bands (5 – 10 GHz) offset two 7 GHz licence fees amounting to HK$ 205,334 per annum (for a bidirectional 28 MHz carrier) against four (because of the double hop) 15 GHz licence fees amounting to HK$ 93,332 per annum. The difference (HK$112,002 per annum as a cost saving), when translated using all the equipment / site values etc, gave rise to an SUF of HKS 2,936 per MHz per annum.

In the case of the calculation of the SUF for the middle frequency bands (10 – 20 GHz) two 15 GHz licence fees amounting to HK$ 46,666 per annum (once again for a bidirectional 28 MHz carrier) are saved and four (because of the double hop) 25 GHz licence fees amounting to HK$ 18,668 are incurred - the difference being a cost saving HK$ 27,998 per annum.

There is less of a cost saving (in absolute terms) in the middle frequency bands (because of the current licence fee structure) and the difference between the bands amounts to HK$ 112,002 – HK$

27,998 = HK$ 84,004 per annum. As this is releasing a bidirectional 28 MHz carrier this difference amounts to HK$ 1,500 per MHz per annum. The cost saving is less in the middle frequency bands and therefore the SUF has to be greater at HK$ 2,936 + HK$ 1,500 = HK$ 4,436 per MHz per annum.

Looking at the total fees (i.e. existing licence fee + SUF) does however result in the fees being higher in the lower frequency bands.

Summary of process

The table below summarises the steps described in the preceding text. In moving from left to right:

- The three cells shaded show the application of the original SUF to the lowest frequency bands.
-
- The three cells shaded show the application of the SUF to the middle frequency bands.
-
- The three cells shaded show the recalibration of the SUF for the lowest frequency bands.

Frequency	Representing the frequency range shown	Current fees	Original SUF calculated for low frequency bands	New fees i.e. Current fees plus SUF (low frequency bands)	New SUF calculated for middle frequency bands	Interim calculation i.e. New fees plus SUF (middle frequency bands)	Additional SUF calculated for lowest frequency bands	Future fees i.e. Current fees plus SUFs including addition to original SUF
7 GHz	5 – 10 GHz (low)	3,667	+ 2936	= 6,603	-	6,603	+ 11	= 6,614
15 GHz	10 – 20 GHz (middle)	833	-	833	+ 4436	= 5,269	-	5,269
25 GHz	> 20 GHz (high)	167	-	167	-	167	-	167

All fees in this table expressed in HK$ per MHz per annum

WBLRS SUFs in relation to FTNS SUFs

The analysis above, as before, uses the FTNS licence as the baseline because it has the added complication of a frequency dependent factor in the existing fee structure whereas the WBLRS licence does not. Remembering the algorithm proposed for the application of the initial SUF to the 5 –10 GHz frequency range:

- The FTNS SUF is HK$ 2,936 per MHz per annum
- The WBLRS SUF is HK$ 5,086 per MHz per annum[51]
- Leading to a ratio of 1.73 for the algorithm.

Similarly for the SUF parameter values for the middle frequency range 10 – 20 GHz:

- The FTNS SUF is HK$ 4,436 per MHz per annum
- The WBLRS SUF remains HK$ 5,086 per MHz per annum[52]
- Leading to a ratio of 1.15 for the algorithm.

In the case of the recalibration of the original SUF (5 – 10 GHz) once the new SUF (10 – 20 GHz) is applied it is, as in the FTNS case, necessary to look at the next best alternative which is now leased line (+ fibre extension). The recalibrated SUF for the 5 – 10 GHz frequency range is then:

- The FTNS SUF is HK$ 2,947 per MHz per annum
- The WBLRS SUF becomes HK$ 6,464 per MHz per annum
- Leading to a ratio of 2.19 for the algorithm.

4.6 Application to other fixed services bands

Satellite bands

Regarding satellite bands, but most particularly C-band as the other bands are little used, the SUF should be related to the fixed link SUF in terms of the denial of fixed link usage. Since OFTA has largely separated satellite and fixed link usage into different allocations, the denial of use is somewhat theoretical. However, it can still form the basis for assessing the satellite link SUF. While the fixed link SUF has been developed with regard to fixed link congestion between 5 and 10 GHz it is appropriate that the same SUF be applied to C-band satellite links even though some of the C-band frequency range falls outside the fixed link SUF range as the costs of using the band will be similar to those in the 5-10 GHz range.

Satellite link licensing has its own existing fee schedule with the level of fee linked to the type of terminal and whether coordination is required or not. There is no relationship with existing FTNS and WBLRS fee schedules which it is assumed will continue and which form the basis of the derivation of an appropriate fixed link SUF. Given that we have derived an SUF which applies different values to

[51] Calculated on the same basis and for the same alternative (i.e. higher frequency / double hop) but using existing WBLRS licence fees.

[52] No frequency dependency in existing WBLRS licence fees.

FTNS and WBLRS licensees, which of these values should be applied as a satellite SUF? In line with the general principle outlined earlier that an SUF should be set at the lower end of any range in order to avoid spectrum lying idle, it is proposed that the satellite SUF should be based on FTNS value which is the lower of the two values. This value, on the basis of exclusivity, is HK$ 17,616 per annum per MHz (i.e. 6 x HK$ 2,936 per annum per MHz). This value needs to be apportioned between satellite link users operating on the same frequency. Satellite frequency reuse is achieved across the orbit through the directionality and polarisation of ground terminals. In theory this means a frequency might be reused a maximum of 100 times in Hong Kong (based on an available orbital arc of about 150 degrees, satellite spacing of 3 degrees and dual polarisation). It is likely that actual frequency reuse is considerably lower than this theoretical maximum as the orbital arc is shared with other countries and practical issues such as rain attenuation may limit low elevation usability. An actual frequency reuse an order of magnitude lower (i.e. 10) might reasonably be expected. OFTA may wish to analyse their assignment database in order to arrive at a substantiated value with which to apportion the exclusive SUF value of HK$ 17,616 per annum per MHz to individual users.

While applying an SUF can be relatively clear cut for a transmitting earth station (as discussed in the previous paragraph) it is less easy for receive-only terminals, as noted earlier in the discussion about Recognised Spectrum Access (RSA). Concerning the possible future interest of the mobile community in the IMT designated part of the C-band downlink, it will be difficult to use price unless a receive-only SUF is in place and it may well be more appropriate anyway to manage any refarming required administratively.

ENG/OB

Insofar as ENG/OB bands are concerned, it has been noted that the ENG/OB bands are generally congested in the frequency range around 2 GHz (i.e. the bands 2055 – 2095 and 2200 – 2290 MHz) and that capacity is available in the OB bands above this range. In the first instance SUF should be applied to the two bands near 2 GHz and we recommend applying this at the same rate as fixed links, as in general ENG/OB links are essentially fixed links even though many of them are transportable. Given that ENG/OB links are currently licensed under the FTNS schedule and on an exclusive basis it is appropriate that the FTNS fixed link SUF be applied, namely HK$ 17,616 per annum per MHz (i.e. 6 x HK$ 2,936 per annum per MHz).

However, considering that 2 GHz frequencies are likely to be more attractive to mobile services than to fixed services, consideration could be given to linking the SUF for the 2 GHz ENG/OB bands to the private mobile SUF should the congestion in these bands persist after the introduction of an SUF linked to fixed link prices. We note the bands in question may not be used for high density mobile services (under a footnote to the ITU-RR) and so private rather than public mobile applications are a more likely alternative use of the band.

The SUF calculated earlier for fixed links has been based on the application of existing licence fees and has considered the valuation on an annual basis. Since ENG/OB assignments in Hong Kong are made on an exclusive basis (i.e. they are available to the user the whole year round) the fixed link SUF is directly comparable. However, recognising that ENG/OB usage is often temporary, consideration could in future be given to making temporary assignments so as to promote more intensive use of the spectrum in which case fees should be pro rated on a time basis. However, because there are two elements to the fees it could be necessary to pro rate these separately with slightly different considerations applied. Existing licence fees which cover administration costs could be pro rated on a time basis but there would need to be a minimum charge to ensure that OFTA's administrative costs are covered. This minimum charge would need to be calculated based on OFTA's activities and internal costs. The proposed fixed link SUF could also be pro rated on a time basis and it would be appropriate that a minimum charge be applied here as well.

5 SUFs for mobile bands

5.1 Introduction

In this section we are concerned with estimating SUFs for the following types of services:

- Systems for private use which are licensed under the private mobile radio system licence and in the case of taxis under the taxi radiocommunications service licence.
- Private radio paging licensed under the private radio paging system licence.

The bands available for use by these services are shown in the following table[53]:

Table 5-1: Frequency bands for non-public mobile services

Frequency band (MHz) – not necessarily contiguous	Application	% vacant (relating to sub-bands when more than one value shown)
66 – 84 *(all 12.5 kHz)* VHF Low band	Single frequency simplex Double frequency simplex (paired) Open channel frequencies	50 / 56 / 55 / 61 / 53 / 65 / 61 / 51
138 – 156 *(all 12.5 kHz)* VHF Mid band	Ditto + Common channel frequencies	40 / 66 / 10 / 64 / 49 / 40 / 47
165 – 197.5 *(all 12.5 kHz except paging = 25 kHz)* VHF High band	Ditto + Paging + Community repeater (double frequency simplex paired)	72 / 46 / 72 / 67 / 86 / 88
226 – 235 *(all 12.5 kHz)*	Single frequency simplex Double frequency simplex (paired)	90
279 – 281 *(25 kHz)*	Paging	40
440 – 470 *(all 25 kHz)* UHF	On-site repeater systems Single frequency simplex Double frequency simplex (paired) Common channel frequencies On-site paging	24 / 9 / 10 / 45 / 63 / 45
806 – 825 *(all 25 kHz except paging = 12.5 kHz)*	Conventional or trunked / Trunked cross border / paging	33 / 54 / 33
851 – 870 *(all 25 kHz except paging = 12.5 kHz)*	Conventional or trunked / Trunked cross border / paging	33 / 54 / 33

Source: OFTA

The current licence fees paid are given in Table 5-2: . As can be seen only the licences relating to systems providing taxi radiocommunications services have a fee component directly referenced to the amount of spectrum used. For licences relating to other services (mainly private closed user group systems except those for taxi radiocommunications services) the fees paid do not directly take account of the amount of spectrum used though to the extent that use of more fixed stations involves use of more frequencies or the same frequencies over a wider geographic area there is a loose link to

[53]Extracted from the Hong Kong Table of Frequency Allocations, OFTA, April 2008.

the quantity of the spectrum resource used. However, users who make more efficient use of the assigned frequencies by increasing the number of mobiles per channel pay higher fees than less efficient users.

Table 5-2: Mobile service licence fees and SUF (2008)

Licence	Application	Fees
Private mobile radio system licence	Private mobile radio trunked and non-trunked	$270/mobile and $22.5/month for each additional mobile $750 for a fixed station and $62.5/month for each additional fixed station
Taxi radiocommunications service licence	Taxi associations (closed user group operation)	$3600 for the first 200 mobiles and $1800 for each additional 100 mobiles $1000/fixed station for 1-50 base stations $500/station for 51-100 base stations $100/station for 101+ base stations $50 per kHz of frequency assigned
Private radio paging system licence	Private radio paging	$80/ mobile $750/ fixed station

Source: OFTA

5.2 Congestion

Current use of the various mobile business radio bands for non-public mobile services is shown in the table below.

Table 5-3: Frequency use and occupancy in bands for non-public mobile services

Band (MHz)	Sub-band (MHz)	No. of available chs.	Ch. Sp. (kHz)	Occupancy (%)			Comment
				06	07	Now	
66 – 235	66 – 83.2	532	12.5	42	42	41	(67.5 – 70 MHz paired with 72.3 – 74.8 MHz) (76.7 – 78.7 MHz paired with 81.2 – 83.2 MHz)
	138 – 156	447	12.5	61	61	61	(138 – 142 MHz paired with 150.75 – 154.75 MHz) (143 – 143.6 MHz paired with 148 – 148.6 MHz) (148.65 – 149.9 MHz paired with 154.75 – 156 MHz)
	165 – 172	280	12.5	33	33	33	(165 – 167.5 MHz paired with 169.5 – 172 MHz)
	226 – 235	218	12.5	8	8	8	(226.5 – 227.4875 MHz paired with 233.5 – 234.4875 MHz)
440 – 470 (25 kHz UHF PMR)	440 - 458	715	25	74	75	82	Mixed use – mainly government users

	458 - 470	254	25	90	94	88	Mixed use – mainly commercial users (459 – 460 MHz paired with 464 – 465 MHz) (465 – 466 MHz paired with 469 – 470 MHz)
806 – 826 (some TETRA but mostly analogue)	806 – 818	480	25	71	67	60	Conventional / trunked MRS and mobile data (Paired with 851 – 863 MHz)
	818 – 819.1	44	25	46	46	46	Cross border trunked radio (Paired with 863 – 864.1 MHz)
	823.7 – 824 (12.5 kHz x 24)	24	12.5	67	67	67	Paging (Paired with 868.7 – 869 MHz)
851 – 871 (some TETRA but mostly analogue)	851 – 863	480	25	71	67	60	Conventional / trunked MRS and mobile data (Paired with 806 – 818 MHz)
	863 – 864.1	44	25	46	46	46	Cross border trunked radio (Paired with 818 – 819.1 MHz)
	868.7 – 869	24	12.5	67	67	67	Paging (Paired with 823.7 – 824 MHz)

Source: OFTA

It can be seen that congestion is evident in the 440 – 470 MHz UHF band and relatively heavy but not congested use is apparent in some of the 800 MHz sub-bands and the VHF mid-band. It can also be noted that whereas VHF usage is based around 12.5 kHz channelisation usage at UHF and the main 800 MHz sub-band is based on 25 kHz channelisation.

The major part of the 440 – 470 MHz band (i.e. the 440 – 458 MHz sub-band) is predominantly used by government. The rest (i.e. the 458 – 470 MHz sub-band) is predominantly used by commercial users but their access to the band is somewhat restricted by particular reservations at the top end of the sub-band. Commercial use of the remainder is generally for low power single frequency simplex and two frequency simplex systems at building sites and other specific locations. OFTA records show that the average loading on a channel at a specific location is 35 mobiles. Given the limited coverage and operational needs of these systems a typical frequency reuse of around 20 can be expected.

Although there is relatively heavy usage in the main 800 MHz sub-band (paired) it can be noted that usage is actually falling. This sub-band is mainly used by trunk systems operated by utilities, transport and as public systems. A number of these systems have or are in the process of migrating to digital systems resulting in the return of some frequencies to OFTA. Furthermore, a public trunk mobile system has ceased operating. Both these situations have resulted in declining spectrum occupancy over the past few years. The 800 MHz bands can therefore be regarded as uncongested and it is possible that occupancy will continue to decrease as further analogue systems migrate to digital or conversely demand might start to increase. It is recommended that OFTA keeps this situation under review over the forthcoming years.

5.3 Estimated SUFs

International benchmarks

International benchmarks are shown in Table 5-4: . The sale of residual spectrum in the 500 MHz band in 2007 for land mobile and earlier auctions of spectrum in the 400 MHz and 500 MHz bands in Australia and elsewhere could provide useful benchmarks. However, it should be noted that purchasers of these spectrum licences have to be able to plan the use of the spectrum with engineering models and this limits demand for these frequencies i.e. depresses the price.

Table 5-4: International values of spectrum used for land mobile services

Country	Auction	Bandwidth	Duration	Coverage	Equivalent annualised cost per kHz ($HK)	Equivalent annualised cost/million pop per kHz ($HK)
Australia	Residual 500 MHz (2007)	(2x12.5 kHz) + (2x25 kHz) + (2x37.5 kHz)	5 years	Sydney	93.6	21.7
Australia	Reallocated 500 MHz (2007)	12.5 kHz to 1 MHz	5 years	Sydney	15 to 106	3.5-24.6
UK	412 / 422 MHz	2 x 2 MHz	15 years	National	616.2	10.1
Ireland	413 / 423 MHz	2 x 2 MHz	10 years	National	86.5	21.1
Ireland	411 / 421 MHz	2 x 2 MHz	10 years	National	44.2	10.8
Sweden	454 / 464 MHz	2 x 1.8 MHz	15 years	National	3315	368.3
Ireland	874 / 919 MHz	2 x 4 MHz	10 years	National	36.9	9.0
Denmark	874 / 919 MHz	2 x 4 MHz	15 years	National	137.9	25.1

Source: Regulator websites

We note that use of the UK spectrum is significantly constrained by the need to protect a military early warning radar at Fylingdales, and this will have depressed the UK values. We also understand that the winning Swedish bid was significantly higher than bids made by other participants in the auction and as such may not be a reliable indicator of value.

Incentive pricing elsewhere

As identified in Section 2.3.2, the current reference AIP fee for business radio in the UK is £9,900 per annum for 2 x 12.5 kHz on a national basis or equivalently £396 per kHz per annum.

For comparison purposes this needs to be scaled down according to Ofcom metrics to represent a system equivalent to the one we will be costing for Hong Kong in the 440 – 470 MHz band. The Ofcom characterisation for a comparable technical assignment would include:

- Operational radius of 0 to 3 km (Category 1)
- High population (Category A)
- Highly popular band (this includes 425 – 466 MHz)
- Exclusive use (in the area)

The fee for this would be £200 per annum for 2 x 12.5 kHz and a single channel (i.e. 1 x 12.5 kHz) would be pro-rated. This is equivalent to £8 per kHz per annum or HK$ 120 per kHz per annum.

It is important to note that the value of £9,900 per annum used by Ofcom is significantly less than the originally calculated value of £22,000 per annum which implies a value of HK $267 per kHz per annum for a system comparable to that we have costed for Hong Kong in the 440-470 MHz band (see below).

Calculated Values

As for the fixed link case, the objective here is to think about the position of a spectrum user operating in a congested part of the spectrum and to consider what that user might do in terms of identifying alternative means of supporting the same service if their existing spectrum were to be taken away. If the alternative means of supporting the same service costs more (i.e. the result of the calculation is positive) then the calculated value represents the value of the spectrum to that user. In this situation an incentive, i.e. SUF, (directly related to the value of the spectrum to that user) is required for the spectrum user to take up the alternative means. If the alternative means costs less (i.e. the result of the calculation is negative) then it would be expected, notwithstanding other factors, that the user would migrate to that alternative in the normal course of events as it implies the spectrum user would save money.

The main issue for business radio is congestion in the 440 – 470 MHz band. It is notable that usage of the band is based on 25 kHz channelisation. The most obvious alternative means for providing the same service therefore is to use more efficient technology in the form of 12.5 kHz channelisation. Other alternatives would be the use of a different frequency band, digital technology or a public trunked system.

12.5 kHz channelisation

We can estimate spectrum value to a “typical “user based on the cost to such a user of moving from 25 kHz to 12.5 kHz channels. In order to do this we need to define a scenario and make a number of assumptions regarding system usage as follows:

- There are two types of system in general use; one based on single frequency simplex whereby mobile hand-held communicate directly with one another, and the other based on two frequency simplex whereby hand-held mobiles communicate with one another through a repeater.
- For each channel (single frequency or frequency pair) we understand from OFTA records that there are on average 35 mobile users.
- Assume that all mobiles and the repeater are not capable of being reconfigured to use 12.5 kHz channelization and therefore have to be replaced.

- It is further assumed that the cost of 12.5 kHz equipment is the same as 25 kHz equipment. As there is no difference in ongoing costs the only cost that needs to be considered concerns the scrapping of existing equipment.
- We assume that the scrapping of the old 25 kHz system occurs half way through its useful life of 10 years
- The licence that is applicable to such a system is the Private Mobile Radio Systems licence. For this licence there is currently no difference in spectrum fees for 12.5 kHz and 25 kHz channels so these costs do not need to be included in the calculation.

The costs[54] that have to be considered are therefore as follows:

- Basic repeater cost = HK$ 7,800
- $3,900 is therefore written off = HK$ 935 annualised (10% / 5 years)
- Basic hand-held radios in volume can be as little as HK$ 500. For the purposes of this costing we will assume a hand-held cost of HK$ 2,000 which represents a more reliable device of moderate sophistication.
- Although the loading on a channel can be expected to vary widely we know from OFTA records that the average loading is 35 mobiles so we therefore have 35 mobiles (HK$ 2,000 each), HK$ 35,000 written off = HK$ 8,394 annualised (10% / 5 years)

For the two types of systems we therefore have:

Single frequency simplex (no repeater)

Total = HK$ 8,394 p.a. = HK$ 671 p.a. per kHz considering 1 x 12.5 kHz saving in spectrum.

Two frequency simplex (with repeater)

Total = HK$ 9,329 p.a. = HK$ 373 p.a. per kHz considering 2 x 12.5 kHz saving in spectrum.

When adjusted relative to the population of Hong Kong (7 million) the value becomes HK$ 53 (two frequency) or 96 (single frequency) p.a. per kHz per million population compared to 400 MHz values in Table 5-5 ranging from HK$ 10.1 to HK$ 21.1 (but ignoring the high value of HK$ 368.3 from Sweden).

Different frequency band

Moving to a different frequency band can also be considered as an alternative means of providing the same service. Costing this alternative is similar to the costing of the change in channelisation described above in that the first cost involves the writing-off of existing equipment half way through its life. There are two issues that also need to be considered:

- Is the cost of new equipment in the different frequency band the same? We will assume that this is the case.
- Can the same functionality be achieved in the different frequency band without incurring additional cost? We will assume that this is the case although quality of service is likely to be lower if moving to the VHF band and coverage potentially less if moving up to 800 MHz.

[54] Costs provided by a local Hong Kong source.

Most importantly however, the amount of spectrum saved (or released in the congested band) by moving to another frequency band is greater than the saving (release) made in moving from one channelization to another in the same frequency band.

Taking these factors into account we arrive at spectrum value of HK$ 187 per kHz per annum for a repeater based system and HK$ 336 per kHz per annum for a single frequency system (i.e. no repeater).

Digital technology

Newer digital technology using 12.5 kHz channelisation is also available for use. Costing a change from 25 kHz analogue to 12.5 kHz digital is once again in many respects similar to the first assessment which just looked at change in channelization. The main similarity is the cost of writing-off of existing equipment half way through its life. However, in this case there are three further factors to consider:

- Cost of new equipment – it is reasonable to assume that there will be a premium to be paid for equipment associated with this new type of system – we assume a 50% uplift. We need to take account of the additional cost not the absolute cost.
- Spectral efficiency of equipment – it is claimed that these systems will operate and coexist within the existing regulatory framework and that two voice channels instead of one can effectively be supported which is equivalent to 6.25 kHz channelization
- Synchronisation – these systems will have to work through a repeater in order to obtain system wide synchronisation.

Taking these factors into account we arrive at spectrum value of HK$ 402 per kHz per annum.

Public trunked system

We have not been able to obtain information regarding the tariffs charged by operators for the use of their public mobile trunked systems operating in the 810 / 860 MHz band. In the absence of such information it is not possible to make an assessment. Were such information available the costing of this alternative would need to take account of the following:

- The annualised cost of providing a system in terms of equipment costs, operational / maintenance costs and licence fees
- The annual cost of leasing equipment and network capacity from a system operator
- The spectrum released in the congested band by moving to a public system

The value of the spectrum released (third bullet) is then represented by the difference between the first two bullets.

If the annualised cost of providing one's own system is greater than leasing equipment and network capacity from a public system then the spectrum has no value and one would expect a natural migration towards the public system notwithstanding other factors.

If the annualised cost of providing one's own system is less than leasing equipment and network capacity from a public system then the spectrum has a value which is the difference between the two costs.

Which alternative?

As before we are looking for the least cost alternative to quantify a spectrum fee which will then provide adequate incentive for some spectrum users to use that alternative thereby vacating their spectrum (for higher value users) and relieving congestion.

The spectrum fee should therefore be based on the lowest value that has been derived. This should provide incentive for low value users to adopt the alternative thereby allowing higher value users to obtain access to the congested band.

Table 5-5: Summary of calculated values

Alternative	HK$ per annum per kHz	Comment
Channelisation	373 / 671	With repeater / Without repeater
Different frequency band	187 / 336	With repeater / Without repeater
Digital technology	402	Repeater based system
Public trunked system	n.a.	Data not available

Source: Plum and Aegis analysis

It can be seen that the spectrum value based on the lowest cost alternative comes from use of a different frequency band, largely driven by the fact that this releases the whole amount of the frequency being used in the congested band. It is further driven down by the two frequency case because the written off costs are nearly the same as the single frequency case (i.e. dominated by writing-off the mobiles) but spectrum associated with two frequencies is released.

It can be noted that if we use the lowest figure (i.e. HK$ 187 per kHz per annum) only the repeater based systems will have adequate incentive to move and the single frequency systems will not. In these circumstances, the segments of the band reserved for repeater based systems will have congestion reduced whereas congestion will remain in those segments of the band reserved for single frequency systems. We therefore propose that the value associated with single frequency systems be used as the reference point for both types of system, namely HK$ 336 per kHz per annum.

Use of alternative to derive SUF

It is assumed that the existing licence structure will stay in place. It has already been noted that public mobile systems already have a spectrum based fee element (amounting to HK$ 50 per kHz per annum) so there is a precedent.

We therefore recommend the application of a similar spectrum fee element amounting to HK$ 336 per kHz per annum for private mobile systems operating in the 440 - 470 MHz band.

5.4 Conclusions

The calculated value for mobile business radio for non-public mobile services based on congestion in the 440 – 470 MHz band is HK$ 336 p.a. per kHz. As identified in Section 2.3.2 the current AIP fee for an equivalent private business radio system in the UK is to £8 per kHz per annum (HK$ 120 per kHz per annum) and the originally calculated value of spectrum in the UK was around £17.8 per kHz per annum or HK$267 per kHz per annum. The latter compares quite closely with the HK$ 336 per kHz per annum that we are proposing for Hong Kong, and certainly more closely than the market values discussed earlier.

The value identified above (HK$ 336 per kHz per annum) should be charged as an SUF to users in the 440 – 470 MHz band. Since the other mobile bands at VHF and around 800 MHz that are used for private mobile radio, paging and public trunked data systems are not congested no SUF should apply in these cases.

The situation regarding congestion in the VHF and 800 MHz non-public mobile service frequency bands (i.e. apart from the 440 – 470 MHz band) should be kept under review. Should these bands appear to be approaching congestion then the following issues arise:

- What should be the SUF for VHF and/or 800 MHz band?
- Should the SUF for the 440-470 MHz band remain the same or change?
- Should the same SUF apply to all services in congested VHF and 800 MHz bands?

If only one of 800 MHz or the VHF band is congested then an SUF should be applied to this band and this should be set as the same value as that for the 440-470 MHz band (i.e. HK$336 per kHz per annum), as users still have the option of moving to another band. The same SUF should apply to all applications in either the VHF or 800 MHz band as the bands can potentially be used by all applications.

If all three frequency bands are congested then no user has the option of moving to another frequency band and so the least cost alternative then becomes either moving to narrower channelization or moving to digital equipment (see Table 5-6). It is possible that by the time this happens the costs of digital equipment will have fallen considerably in which case this may be the cheaper option. However, we do not know the future evolution of digital PMR equipment prices and so if all bands become congested in future the cost of the different options will need to be recalculated and the SUF set using the methodology we have proposed in this report. We have shown how this might be done for fixed link bands in Section 4. Again the same SUF should apply to all applications in the VHF and 800 MHz band as the bands can potentially be used by all applications.

It is notable that the balance of spectrum availability in the 440 – 470 MHz band is strongly weighted towards government users. It is clear that release of some of this spectrum would ease congestion significantly. In any event there may be a requirement to temporarily release some of the government spectrum to help refarm commercial users to different technologies.

6 Implementation Issues

The legislative basis for setting SUFs is given in Section 32I of the Telecommunications Ordinance. Under para 2 "The Secretary may by regulation prescribe

a. The level of spectrum utilisation fees

b. The method for determining the spectrum utilisation fees, which may be by

   i. Auction or tender or a combination of auction and tender; or

   ii. Such method as the Secretary thinks fit, including any method combined with a method mentioned in subparagraph (i)"

Section 32I is silent on aspects of the detailed implementation of SUFs where these are not determined by auction or tender, which is the case being considered in this report. This is therefore an area for OFTA to recommend and the Secretary to determine the detailed policy.

In this Section we address the following detailed implementation issues

- Should SUFs be set as annual fees or a lump sum payment?
- How often should SUF levels be reviewed?
- What should be done at an SUF review?
- Should SUFs be introduced immediately or is a gradual transition appropriate?
- Can the values calculated in this report for fixed and mobile services be applied to other bands?
- Are there changes in OFTA policies that could impact on the level and application of SUFs?

Our approach to these issues has been informed by experience in the UK[55]. In the UK AIP levels and the bands AIP should be applied to are expected to be reviewed every five years. AIP is set on annual basis and applies to spectrum where there is likely to be excess demand and where licences are awarded on an administrative basis. It is applied to frequency licences for many different applications including, public mobile (at 900 MHz and 1800 MHz), private mobile radio, fixed links, satellite uplinks and some Ministry of Defence use. In all of these cases frequency licences are held separately from any fixed or mobile operator licences. All tradable licences (e.g. those for PMR and fixed links) have a perpetual duration with a five year notice period although AIP is paid on an annual basis.

AIP levels are only revised after a review of the level of congestion and the appropriate level for AIP. If at the review it is found that

- bands where AIP is applied are no longer congested then AIP is removed and fees are set to reflect administrative spectrum management costs
- bands where AIP is not applied have become congested then AIP is applied in these cases
- AIP levels have changed then a statutory instrument will be passed changing the level of AIP.

The workload involved in reviewing congestion and AIP is such that sometimes reviews for particular services/frequency bands may be staggered over time.

[55] This experience is reviewed at Policy evaluation report: AIP, Ofcom, July 2009

For licences sold at auction AIP is not applied. Licences sold at auction have an initial term (anything from 10 to 20 years, depending on the frequency band but normally 15 years) and at the end of the initial term the licences may be extended in perpetuity subject to a 5 year notice period after which Ofcom may reclaim the licence for spectrum management reasons. Ofcom has reserved the right to apply AIP after the initial term consistent with its general spectrum pricing policy at the time. So far Ofcom has not given any details of how it intends to use this power.

6.1 Lump sum versus annual fee

In Hong Kong access to radio frequencies is granted under a wide range of licence types. Most licences are annual and in these cases SUFs should clearly be set as annual payments.

However, frequency access for operators that are licensed to provide fixed and mobile services is covered by the relevant fixed, mobile or unified carrier licence all of which have a relatively long duration (i.e. typically in excess of 10 years). In these cases SUFs could either be formulated as a lump sum payment (as is often the case for an auction) or as an annual fee over the life of the licence.

We note that in New Zealand the SUF for long duration licences was set as a lump sum whereas in the UK and Australia[56] it is an annual payment as is also the case for the SUF for 900 and 1800 MHz spectrum used to supply 2G services.

The choice between a lump sum payment and an annual fee depends on the balance of a number of considerations including:

- Whether it is thought that annual payments provide a better on-going incentive for efficient spectrum use as the user is regularly reminded of the cost of spectrum use. This incentive will be stronger if the spectrum is not tradable.
- The impact on operator cash flows of a large upfront payment. This consideration is important if it is thought capital markets are not working efficiently, as may be the case at present.
- Consistency in treatment of payments for access to similar spectrum. For example, SUFs for access to fixed link spectrum under a unified carrier licences should be set on the same basis as SUFs under an annual WBLRS licence.

All three points argue in favour of SUFs expressed as annual payments regardless of the licence duration.

6.2 Frequency of review for SUFs

While it may appear administratively simple, licence duration is not a relevant factor for considering the frequency with which SUFs for frequencies assigned administratively should be reviewed. Rather the relevant considerations concern practical matters and the extent to which the SUF is still at an appropriate level. Specifically the following factors need to be taken into account

- The administrative costs and time taken to undertake a pricing review;
- The time taken to collect a useful time series of data about changes in spectrum use;

[56] For the case of 5 year apparatus licences at 900 MHz.

- The volatility of demand for spectrum and related to this the likelihood of there being significant changes in spectrum use and value;
- The need to give licensees some certainty concerning the charges they will pay so they can plan their spectrum use and make investment decisions with full knowledge of the costs they will incur.

A pricing review can take up to one year - three to six months to do the work and possibly the same again for public consultation. This suggests a minimum of two years between reviews. We would expect that at least three to four years' data would be required to see any impact on spectrum use from a change in pricing, given users' behaviour is likely to be slow to change because of their existing investments, and to detect changes in trends in demand for spectrum. A pricing review would have to start at least a year in advance of implementing new prices and so this suggests there should be at least five years between reviews. This would also give users a reasonable degree of certainty around which to plan but means that the SUF can be revised in response to changes in technology and market circumstances (e.g. the relative cost of alternatives in those cases where the SUF is set based on the least cost alternative approach).

The issue we need to consider is whether SUFs should be set for periods much longer than 5 years. In a fast moving sector such as the telecommunications sector setting SUFs for much longer periods opens up the possibility that the SUF will be set at the wrong level – either too high or too low. Significant changes in technology, equipment costs and the costs and functionality of alternative services can occur over such a time period. For example, the relative costs and functionality of cellular networks have changed considerably over the last 5 years meaning that for some PMR users it now provides a good substitute service. In the case of fixed links, even though equipment costs have fallen and higher order modulation schemes have become more cost effective, "leased line" product offerings have reduced in cost even more and therefore increasingly provide a substitute for fixed links for some users.

We therefore suggest that SUFs are in general reviewed every 5 years unless there are good reasons to review them less frequently. One reason for less frequent reviews might be if the SUF is set with reference to auction or tender bids that apply to a much longer period. In this case the auction/tender values will include a view on long term developments. For example, the SUF for MNOs 2G spectrum has been set for 15 years based on 3G licence payments which provide an appropriate long term benchmark.

6.3 Action taken at SUF reviews

In between reviews of SUFs OFTA needs to collect data that would allow it to assess spectrum congestion at the SUF review (using data in each band such as that reported in Sections 4 and 5 of this report). For example, it is possible that demand growth for fixed links could lead to congestion in higher bands (e.g. 10-20 GHz) where no SUF is applied in which case an SUF may need to be applied at the 5 year review. (In Section 4.5 we have shown how the SUF for the higher and lower bands would need to be recalculated in this instance.) In Section 5.4.1 we have also described how SUFs might be set for the VHF and 800 MHz bands used by private mobile radio, were these found to be congested at the 5 yearly review.

OFTA's activities involving the collection of data on the level of use of different bands may indicate a change in the status of some bands – becoming more or less congested - between reviews. The issue of whether OFTA should take action on the basis of this action needs to be considered. Our view is that it should only make changes at the time of the formal five yearly reviews. The reason for this is that it takes time to build up a consistent picture of what is happening – a one or two year change in the use of a frequency band may not be sustained and should not therefore form the basis of a policy change.

We therefore recommend that changes in SUFs and the designation of bands as congested or not are only undertaken at the 5 yearly review point.

6.4 Transition path

In principle SUFs should apply immediately to all frequency bands where opportunity costs are non-zero. At a practical level there may be a need to phase in the payments (as was arguably done for the 2G licences) in order to moderate their impact on businesses and give them time to adjust their spectrum use taking account of the final fee level. The phase in could take the form of a grace period and/or a period of time in which fees below full opportunity cost estimates are applied.

A judgement is required here depending on the timing of when OFTA announces the new fees relative to the time they are implemented. If there is relatively little time between the announcement and the new fees being introduced then some phasing would seem desirable. In the UK for example there is generally at least a year between the initial consultation on new fee levels and the passing of the relevant statutory regulations implementing the fees. If this is not the case in Hong Kong and timescales are much shorter then there is a much stronger justification for phasing in any increase in fees.

6.5 Extension of values to other bands

In the UK and Australia the SUF calculated for frequencies used by private or public mobile bands applies to all congested bands below 3 GHz on the grounds that one of these two services is the most likely potential alternative use of the bands. For congested bands above 3 GHz the fixed link value applies for the same reason. We therefore suggested in Section 4 that the lower of the two fixed SUFs applies to some satellite bands and more generally suggest that this is applied to any congested bands above 3GHz. For example if in future bands allocated for other services such as amateur are found to be congested because of demand from other competing uses such as fixed links, then the fixed link SUF should be applied. While this approach is inevitably approximate it has the advantage of simplicity and low costs of administration.

In Sections 4.5 and 5.4.1 we discuss the extension of the methodology from the currently congested bands to other bands should they become congested. In some cases this requires a recalibration of values in others the existing SUF can simply be applied to the newly congested bands.

6.6 Impact of changes in other OFTA policies

OFTA policies that could have a direct impact on congestion and the application of SUFs are as follows

- Spectrum release from government users as a result of the current review of government spectrum holdings: This could help ease congestion in a number of the bands that we have examined (e.g. at 400 MHz and 7 GHz) but the significance of this depends very much on the amount of spectrum released, if any. If substantial amounts of spectrum are released then it is possible that bands currently classed as congested would become uncongested and the SUF would no longer apply.

- Changes in policies concerning access to hill top sites and fixed link bands. If the current restrictions on access by the commercial sector were relaxed then demand could be expected to increase in lower frequency ranges in which case the level of congestion would rise and SUFs might apply in more bands.
- Putting all fixed link users on the same basis as regards the payment of management fees. If all users shift to the FTNS then there will be a stronger incentive to use higher frequency bands and fees will in general be higher than under the WBLRS. This change could help moderate demand for fixed link bands under 10 GHz (particularly in respect of demand by utilities).

We have highlighted the large allocations to government users in some bands and the negative impact on other users, and have suggested that OFTA takes this into account in its review of government use. In particular, without spectrum release from government or the application of SUFs to government users or other policies aimed at incentivising more efficient spectrum use by government, the impact of the SUFs we have proposed on use of bands by the commercial sector may not be large.

In Sections 4 and 5 we noted that the level of SUF applied depends on the specific type of licence an organisation currently holds, because the management fee differs across licence category even if the spectrum assignments are identical. For a private mobile radio licensee some licence fees have a bandwidth (spectrum) component to them and others do not and this can complicate the calculation of SUFs (and confuse users if an SUF is applied on top of a licence fee that already has a spectrum component). The additional complication arising from current fee structures is also seen in our treatment of fixed links where FTNS and WBLRS licences have to be addressed separately. This situation seems anomalous and we suggest that in the longer term OFTA considers having a common basis for setting licence fees for all fixed users and all private mobile radio users.

Furthermore in the case of fixed links the management fee is high relative to the SUF and is related to the frequency bands used. It seems unlikely that OFTA's management costs are particularly high, however, it may appear so because spectrum management for government users is paid for from management fees gathered from the commercial sector. It may also be the case that there is cross subsidy between classes of commercial users. While it is not our task to review management fees we note that there are good spectrum management reasons for charging such fees to government users as well as the commercial sector. This is so that government users appreciate the costs they impose on OFTA and do not make unreasonable demands on OFTA's resources.

Spectrum management costs are likely to be weakly related to frequency (as interference is less likely at higher frequencies, all else being equal) and this could be considered if these fees are reviewed at some point in future.

6.7 Summary

In summary we suggest that:

- SUFs are in general set as annual payments.

- SUFs are normally reviewed every five years and are only ever changed after the five yearly review. Between reviews OFTA should collect the data required to conduct the review (e.g. data on spectrum use by band). Less frequent reviews might be appropriate for long duration licences where the SUF is based on an auction price for long duration licences.
- SUFs proposed in this report should be phased in to give users time to adjust to the new level of fees. This might involve a grace period.
- In congested bands below 3GHz the likely potential alternative uses of congested bands are mainly mobile services, in which case the relevant SUF for mobile services should be applied. Above 3GHz applications are generally fixed in which case the lower of the two fixed service SUFs should be applied.
- Before implementing SUFs OFTA should consider whether it is likely to make changes to other related policies concerning spectrum allocations to government users, policies for access to hilltop sites and moving to a common basis for management fees for fixed link and possibly also private mobile radio users. In the longer term consideration might also be given to charging management fees and SUFs to government users to encourage efficient spectrum use.

Appendix A: International approaches to setting SUF

Australia

Australia has had a long history of pricing access to spectrum with the aim of improving efficiency of use. While it has used auctions as a means of allocating spectrum where demand exceeds supply, most spectrum remains under the apparatus licence system. Apparatus licenses incur an annual transmitter or receiver licence fee (see box below).[57] The current apparatus licensing pricing system which was established in 1995 is based on a fee formula approach. ACMA employs a set of pricing principles so that licence fees contribute to the efficient allocation of spectrum, and to promote an equitable and consistent fee regime. These principles are:

1. charges should cover the direct administrative costs of issue, renewal and instalment processing;
2. taxes from licensees as a group should recover the indirect costs of spectrum management;
3. taxes should be based on the amount of spectrum denied to other users;
4. spectrum denied should be priced at its opportunity cost (the value of the best alternative use of that spectrum); and
5. if the opportunity cost is less than the indirect costs, attributable to the licensee, taxes should only recover costs.

ACMA states that the fee formula ensures fees are determinate, consistent, equitable and transparent.

Box : Australian approach to setting annual transmitter/receiver fees
The annual transmitter/receiver apparatus fee is calculated as follows:

$$Fee = K \times (Si, Gi) \times Bi \times Ai \times Adj$$

This formula takes into account four parameters: spectrum location, geographic location, bandwidth and power.

K is a scaling constant set at 0.2177 allowing the overall level of fees to be adjusted and is updated by CPI every year.

(Si, Gi) is a weight related to the spectrum location (i.e. frequency band) (S) and the geographic location (Australia wide, high, medium, low and remote density) (G) of the licence

B = bandwidth (in kilohertz)

Ai = power factor which is used to reduce fees for services that only deny spectrum to other users over a small area (1 for local or 0.1 for sub-local)

Adj = adjustment factors for particular sets of licensing options such as a premium to reflect the higher demand for mobile spectrum or a discount to reflect the frequency reuse possible with fixed links. This gives flexibility to adjust values according to parameters not included in the formula and to make adjustments to correct historic anomalies.

The formula has come under some criticism in the past. The Productivity Commission in its 2002 Radiocommunications report noted that the apparatus licensing charging model in use by the Australian Communications Authority had some deficiencies. It recommended a more transparent and flexible model for calculating the apparatus licence tax, and that to achieve efficient outcomes,

[57] Apparatus licence fee schedule, April 2009, ACMA.

spectrum charges should be based on opportunity cost. (The current ACMA fee formula is very similar to that previously used by ACA).

While ACMA has supported opportunity cost pricing in principle, it has not worked through the practicalities of calculating prices based on opportunity cost. In its recent response to the Independent Review of Government Spectrum Holdings, ACMA stated that it will consider approaches to assessing the relative value of parts of spectrum including seeking to identify where the opportunity cost of spectrum is likely to be significantly higher than current fees. This work is currently on-going.

The comments of the Productivity Commission and ACMA's own statements support the view that while ACMA's fourth principle above states that spectrum denied should be priced at its opportunity cost, the history of the development of the fee formula indicates that ACMA's system of charging for apparatus licences at best only very roughly approximates market prices or opportunity costs.

In 2006/2007 apparatus licence fees raised revenue of $133.2 million. Over a number of years revenue raised has exceeded costs of managing the spectrum, generally by a ratio of roughly four to one. Since being set in 1995, revenue from licence fees has been increased by the CPI each year (CPI movements have accounted for most of the total revenue variation in most years since then). There have been periodic reviews of charges taking account of demand in bands and with the fees adjusted to reflect the degree of congestion. However, these changes have largely been at the margin.

The Productivity Commission noted that the licence fee formula suffered from a number of defects including discontinuities in the formula (fees vary discretely rather than continuously), inflexibility and disparities arising from the fact that the formula cannot distinguish between users of scarce and non-scarce spectrum within the same broad bands.

Reviews over recent years have addressed some of these issues, for example by increasing fees for fixed services below 960 MHz to bring them more into line with charges for mobile services in the same band. However, these changes have not overcome the lack of a clear connection between the charges derived from the formula and the opportunity cost of the spectrum across the board.

Ireland

The Irish regulator last undertook a review of fees for spectrum use in 2005.[58] This review sought to bring licence fees in line with ComReg's administrative costs and, where spectrum resources were limited, the value of the spectrum resource. The fees were intended to ensure an equitable recovery of spectrum management costs and to further the objective of optimising the use of radio spectrum.

The review changed the basis on which fees for fixed links and PMR were set so that they reflect the amount of spectrum that is used. [59] This replaced the previous approach which was based on a flat fee per licensed station.

Under the new fee proposals fixed link fees depend on the frequency band, bandwidth and the geographic location. Links in a pre-defined area of particularly high usage around the capital Dublin attract a higher fee in some bands to reflect the scarcity of spectrum in these areas. Fees for PMR are based on the coverage area and the degree of sharing of the frequency.

[58] Review of fees applicable to rights of use for radiofrequencies, 05/58, July 2005, Comreg

[59] Review of fees applicable to rights of use for radiofrequencies, Response to Consultation, 05/59, December 2005, Comreg

Comreg's latest Spectrum Management Strategy Statement 2008-2010[60] states that ComReg intends to consider further use of incentive pricing to stimulate technologically efficient spectrum use and promote the release of underutilised spectrum.

Japan

The Japanese Spectrum User Fee system instituted in 1993 was a cost-recovery system with costs allocated between all spectrum users i.e. stations except license exempt services, based on the number of radio stations licensed. It provided little economic incentive for the efficient use of radio frequencies.

The third report (consultation paper) of the "Study group on the policy on the effective use of spectrum" [61] proposed methods of compensation for relocation of existing licensees (the new users should pay at least 50% of the compensation while the revenue fund of the Spectrum User Fee will pay the rest) and in the case of new users that are exempted from licensing, the manufacturers or the importers pay relocation costs. This contribution may be counted as a factor in the evaluation of applicants in comparative hearing.

The Japanese government also decided to use spectrum pricing as a key measure to promote efficient use of spectrum. It set up a study group to examine the issue of spectrum pricing in 2003 which developed proposals to substantially reform the fee structure, with fees being more directly related to spectrum used and congestion.

A new fees structure was implemented in October 2005. The reform of spectrum fees was one element of a package of reforms aimed at refarming spectrum below 6 GHz to cater for anticipated growth in demand for spectrum for new wireless broadband services (probably mobile) – often termed 4G services. Other elements of the reform package are

- Compensation payments made from the spectrum fee fund when a user voluntarily vacates a band or has its licence revoked by government. The compensation paid is 50% of the remaining book value of the equipment less a standard allowance for the terminal value (of 10% of the original value). The compensation formula is written into the radio law so there can be no dispute over values.
- Registration rather than licensing for services that could share spectrum such as high power outdoor wireless LANs. Registration will be provided on-line and will allow the government to readily refarm the spectrum if necessary (as compared with the situation if the spectrum was made licence exempt)
- Periodic (3 yearly) monitoring of spectrum use and publication of the results and the government's view on bands that are little used and could be beneficially reallocated to new uses. Following consultation on the proposals the government may seek to reallocate certain bands and so revoke some users' licences (in which case the afore mentioned compensation scheme would operate).[62]

[60] Spectrum strategy statement 2008-2010, July 2008, Comreg

[61] The approach to policy development has been described in "Spectrum Policy in Transition", Phillipa Marks and Kiyotaka Yuguchi, Keio Communications Review, No 26, 2004.

[62] Note that all licences in Japan have a 5 year duration.

Most spectrum below 3GHz in Japan is used by existing mobile and broadcasting services and the scope for refarming here is somewhat limited, though digital TV switchover will release around 100 MHz for mobile services and the government expect to recover some spectrum from private mobile radio services as a result of the incentives given under the new pricing arrangements.

Between 3 and 6 GHz there is considerable use of spectrum by fixed links, PMSE and satellite services. The new pricing structure is intended to encourage early migration of these services in order to release over 1GHz of spectrum. In any event all these users must vacate the band by 2011.

Level of Fees

The fee of fees was derived using a top down approach starting with the objective of seeking to recover a given level of costs. By law spectrum pricing must be related to the costs incurred in establishing and providing a favourable environment for radio spectrum use. However, the scope of costs counted was broadened in advance of the new fees being introduced. It includes: the usual spectrum management costs; the compensation costs incurred in refarming the spectrum; a fund for extending wireless services in rural areas (Y1bn) and a research and development fund which is mainly funding research on cognitive radio and supporting SDR technology (Y10bn). The "new" costs which total Y20bn are allocated across users under 3GHz and those between 3 and 6 GHz in a 3: 1 ratio. Fees for users above 6 GHz are only based on "traditional" spectrum management costs. The fraction of costs attributed to each base or mobile station depends on the bandwidth used and the degree of congestion in the location of use. Relative levels of congestion were assigned to different areas (4 levels) based on the Ministry's data on intensity of use.

50% discounts are given to users who announce they will migrate within two years.

So if the number of stations declines, say, as a result of migration to higher bands or alternative technologies then fees will rise when they are reviewed, unless the total bandwidth occupied by the allocated service in question (e.g. fixed links, satellite etc) falls. The resulting fees are written into the Radio Law and are to be reviewed every 3 years.

The government expects the new fees to lead to significant and quite rapid migration out of the 3-6 GHz bands. Although the fees only apply to commercial users, there is no government use in these bands. Refarming of government users is achieved through negotiation.

Structure of Fees

When the fees were reformed the structure of fees was not changed in order to limit the amount of disruption caused by the changes. Most fees are related to bandwidth, the number of base stations and, where relevant, the number of mobile stations.

Once exception to the latter is mobile operators using more than 3 MHz of spectrum pay only according to bandwidth used – this affects the public mobile operators and some big co-operatives of private users.

Portugal

Anacom's spectrum fees are defined in Administrative Rule 126-A/2005 and are based on the principles defined in Article 19 of Decree-Law 151-A/2000. The aim of the fees is to reflect the economic benefits arising from the use of the radio spectrum and nine specific factors are defined in the Decree that should be taken into account in setting spectrum usage fees, as follows:

- Number of stations
- Frequencies or channels assigned
- Frequency band
- Bandwidth
- Amount of congestion in the area where they are deployed
- Economic and social development in the implementation region
- Coverage area
- Type of use or user
- Shared or exclusive spectrum.

There are two fees payable; one is for the assignment of rights of use of frequencies and these should be cost-based and the other is for the use of the radio spectrum. Fees for the use of the radio spectrum may be set above cost recovery but currently are used to cover the costs of Anacom and any excess is used to fund communications or information society projects.

We understand that so far only the fees for private mobile radio (PMR) have been modified in accordance with Article 19. Fees for other services are to be modified in a similar way once the effectiveness of the new PMR fees had been assessed. Consequently there is a wide variation in the factors that are considered in setting fees for different services currently, as the following table illustrates:

Table A-1: Factors currently used in setting spectrum fees in Portugal

Service	**No of Stations**	**No of channels**	**Frequency Band**	**Bandwidth**	**Congestion**	**Economic/Social**	**Coverage**	**Type of user**	**Exclusivity**	**Power**
Private Mobile Radio	√	√		√		√	√		√	
Maritime Mobile	√		√							√
Aeronautical	√		√							√
Fixed Links	√	√		√			√	√		
Radiodetermination	√									
SAP / SAB	√							√		
Utilitarian/Recreation	√									
Telemetry/Telecontrol	√						√			
Satellite earth stations	√			√				√		
Public Mobile	√									√
FWA			√	√		√				
Broadcasting	√		√							√

Aegis has advised the regulator Anacom on setting spectrum fees and concluded that fees based on opportunity cost were only justified for frequency bands used for public mobile services and broadcasting. In both cases spectrum was assigned administratively. For other services, congestion is not an issue and so it was recommended that only cost recovery fees should be applied and the existing fees formula simplified to exclude economic and social factors. In the case of public mobile services existing fees are very high (the highest per capita in Europe and higher than values revealed by auction of spectrum at 900 and 1800 MHz) as they are determined by the number of subscribers and number of base stations deployed. Application of prices based on opportunity cost will reduce the sums paid by the mobile operators.

Singapore

The IDA currently has two approaches to charging users for spectrum access: market-based charging (via auctions) and cost-based charging taking into account the occupied bandwidth and the nature of the frequency usage. Cost based charges are paid by all licensees, regardless of whether they are assigned their licences by auction or on an administrative basis. The current cost based charging structure in Singapore has been in place since 1994 when fees were set based on an estimate of future costs.

Radio frequency fees are given in Parts III, IV and V of Telecommunications (Radiocommunication) Regulations, CAP 323, Reg 5, 2002. In addition to these fees, radio users pay station and network fees (Parts I and II of CAP 323) that are related to the number of stations and which are in effect a further payment for spectrum access. Part I of CAP 323 applies to those users who also pay frequency fees while Part II of CAP 323 applies to those users who do not pay frequency fees. The latter mainly comprise users who share spectrum on a non-exclusive basis (e.g. ship, aircraft, experimental and amateur stations).

Fees paid for access to the radio spectrum (radio frequency, station and network fees together) recover many times the IDA's costs of managing the spectrum - radio frequency fees alone recover about twice IDA's costs. Radio frequency fees are currently related to bandwidth and licensed bandwidth has increased while fee levels have remained constant in nominal terms since 1994. The growth in bandwidth licensed has meant that revenues have grown faster than the costs of managing the spectrum.

Focusing on the radio frequency element of the fees, the Singapore Civil Defence Force, broadcasters, Ministry of Defence and the Singapore police force pay cost based frequency fees relative to commercial users who pay fees based on the amount of bandwidth used. A 23% discount is given to the Ministry of Defence as they undertake frequency co-ordination activities. The original intention of adopting such charging principles was to limit the financial impact of the fees that were introduced in 1994.

The radio frequency fees comprise two components. A once-off application and processing fee that is levied each time an assignment is made and a recurrent annual frequency management fee that is intended to recover the costs of frequency planning, co-ordination (national and international), monitoring and interference control.

Annual frequency fees are related to the bandwidth used. In general lower fees are paid for shared versus exclusive use, for permanent versus temporary use and for on site or in-building versus wide area use. Fee levels do not vary by frequency band used.

The IDA's 2008 Radio Spectrum Master Plan refers to the IDA's intention to consider setting fees in frequency bands which are congested or potentially congested according to the opportunity cost of spectrum (i.e. Administrative Incentive Pricing). [63] One reason for this is that rapidly growing demand for spectrum means that congestion is now and will in future be experienced in a number of fixed link frequency bands in Singapore. In some of these bands the IDA uses administrative procedures to determine whether requests for additional assignments are justified or not. The application of these administrative procedures in circumstances where demand for spectrum (at the cost based fees) could outstrip the available supply is problematic. All applicants may have equally valid requests in which case the IDA has little basis on which to choose who should be assigned spectrum. Users who received assignments some time ago have no incentive to economise on their spectrum use or to relinquish spectrum if they know shortages may occur in future. In addition, there is no easy way to reassign spectrum from existing users to those with new demands in circumstances where the latter may be regarded as being of more merit or higher value.

The IDA's decisions concerning revisions to spectrum fees in congested bands so that they reflect opportunity costs have not yet been made public.

Additional countries

Bahrain

The regulator has proposed the following approach for incentive based charges in bands used for fixed links and other fixed access that has not been licensed by auction.[64]

The TRA and the MoT have proposed the following methodology for determining the incentive-based charge, in congested bands:

- Usage of greater frequency bandwidth will be charged more (i.e. ,for example, 2x30KHz charged less than 2x50KHz)
- Usage at the higher bands which have less demand and pose fewer interference problems will be charged less (thus fixed links at 3 GHz will be charged more than fixed links at 11 GHz)
- Usage at higher power will be charged more (especially at lower frequencies) as it reduces ability to reuse the spectrum
- National assignments will be charged at a higher rate than specific location assignments (thus a licensee who takes, say, a 3 GHz fixed link across Bahrain will be charged more than a licensee taking a specific link between two offices).

This has been expressed as a formula:

Charge = Bandwidth x (Frequency, Geography) x Power x Constant

Where:

- *Bandwidth*: reflects the amount of bandwidth used (e.g. frequency band/25KHz)
- *Frequency*: values vary across the spectrum - higher values for the most congested parts
- *Geography*: national vs. specific location assignment

[63] Radio Spectrum Master Plan, April 2008, IDA

[64] This approach has been proposed in Bahrain and is reportedly used in France, Greece, Italy and Malaysia. See p45 of Spectrum Policy and Planning, TRA and Ministry of Transportation, Bahrain, November 2005

- *Power*: used to reflect level of interference caused to other users
- *Constant*: will be used to calibrate the result to acceptable levels for Bahrain; based on local operating conditions and cost

These proposals have not yet been implemented.

Canada

Industry Canada (the regulator) sets spectrum fees according to the following five guiding principles:[65]

- the fee structure should be simple and equitable
- The more of the spectrum resource used, the higher the licence fee should be
- Where the spectrum resource is relatively scarce, the licence fee should be higher
- The fee structure should be flexible and independent of the licensing process
- Any significant change to user fees should be announced promptly and should be implemented over a reasonable period.

The amount of the spectrum resource used is defined in terms of bandwidth, denial area and exclusivity. The level of fees in areas where spectrum is scarce are set higher than licence fees but there does not appear to be a clear method for setting the level.[66]

France

Some users of telecoms services (PMR and PAMR, fixed links, WLL) and some satellite users have to pay spectrum-related charges.

All users, be they public sector or private, would have been subject to charges based on the amount of spectrum used under a May 1997 Decree which, however, has never been signed.

The French regulatory bodies are working to simplify existing fees and charges and to base them on sound technical and economic principles. Particularly, the implementation of a general base fee for all spectrum users, public or private, is being considered in order to promote efficient spectrum use. In fact, ANFr is trying to implement the 1997 Decree even though it is not currently in effect. Non-commercial activities are supposed to be charged with a spectrum-related fee based on the bandwidth and the frequency.

- When the band is between 29.7 MHz and 960 MHz, the fee is calculated as follows: Fee = a x ΔF with a being fixed by the Budget Ministry below 50 million EUR and ΔF the bandwidth
- When the band is between 0.96 GHz and 65 GHz, the fee is calculated as follows: Fee = a x ΔF x 0.96/F

Broadcasting and radio astronomy activities are still totally exempted.

Spain

Spain has developed a generic formula which it applies to all radio services, namely:

Annual fee = surface area in km² x Bandwidth (kHz) x C1 x C2 x C3 x C4 x C5)] / €166.386.

[65] Spectrum management through economic and other incentives, Mike Connolly,Industry Canada, 2006

[66] See chapter 4 in Towards More Flexible Spectrum Management, WIK, December 2005

The five parameters C1 – C5 are set for each service and take into account:

- The level of occupancy and demand for that service in the frequency band.(C1)
- The type of networks that use the spectrum e.g. whether they provide public services as in the case of broadcasting (C2).
- Whether the spectrum is awarded on an exclusive basis or shared. Also services that are deployed in non-standardised bands are charged a premium.(C3)
- The type of technology deployed and whether it uses the spectrum efficiently (C4)
- The social relevance of the services and the relevant economic interest or benefit (C5).

This approach is applied to setting fees for both broadcasting and other radiocommunications services and is based on promotion of spectrum efficiency and the intention is to reflect the market value of spectrum when setting spectrum fees. However, although the parameter C5 refers to economic benefit it is unclear how the values were derived or why there are wide variations between different services.

Appendix B: Summary of calculations for 5-10 GHz SUF

Table B-1: Summary of costings

Alternative	FTNS SUF HK$ per MHz per annum	WBLRS SUF HK$ per MHz per annum
Technology (modulation)	-4,045	-528
Higher frequencies / double hop	2,936 (Note 1)	5,086 (Note 1)
Leased line + additional fibre	2,947 (Note 2)	6,464
Satellite link	351,000 – 655,200	351,000 – 655,200
Self provision – fibre / cable	34,662	38,179

Note 1: Least cost value used (see derivation below)

Note 2: Value also referred to in text

Table B-2: Costings for least cost alternative

Cost element	Annualised cost (FTNS case) HK$ per annum	Annualised cost (WBLRS case) HK$ per annum
Equipment for one hop = HK$ 155,000		
Scrapped value of one hop half way through 15 year life = HK$ 77,500 Annualised over 7.5 years at 10%	13,839	13,839
New equipment for two hops = HK$ 310,000 Annualised over 15 years at 10%	37,052	37,052
Additional running costs. 10% of CAPEX	15,500	15,500
New site rental	210,000	210,000
Original licence fees (two at 7 GHz)	-205,334	-8,400
New licence fees (four at 15 GHz)	93,332	16,800
Cost difference (2 x 28 MHz)	164,389	284,791
Cost difference per MHz	**2,936**	**5,086**

Appendix C: Summary of calculations for 10-20 GHz SUF

Table C-1: Summary of costings

Alternative	FTNS SUF HK$ per MHz per annum	WBLRS SUF HK$ per MHz per annum
Technology (modulation)	-1,211	-528
Higher frequencies / double hop	**4,436** (Note 1)	5,086 (Note 1)
Leased line + additional fibre	5,780	6,464
Satellite link	351,000 – 655,200	351,000 – 655,200
Self provision – fibre / cable	37,495	38,179

Note 1: Least cost value used (see derivation below)

Table C-2: Costings for least cost alternative

Cost element	Annualised cost (FTNS case) HK$ per annum	Annualised cost (WBLRS case) HK$ per annum
Equipment for one hop = HK$ 155,000		
Scrapped value of one hop half way through 15 year life = HK$ 77,500 Annualised over 7.5 years at 10%	13,839	13,839
New equipment for two hops = HK$ 310,000 Annualised over 15 years at 10%	37,052	37,052
Additional running costs. 10% of CAPEX	15,500	15,500
New site rental	210,000	210,000
Original licence fees (two at 15 GHz)	-46,666	-8,400
New licence fees (four at 25 GHz)	18,668	16,800
Cost difference (2 x 28 MHz)	248,393	284,791
Cost difference per MHz	**4,436**	**5,086**

Appendix D: Summary of calculations for recalibrated 5-10GHz SUF

Table D-1: Summary of costings

Alternative	FTNS SUF HK$ per MHz per annum	WBLRS SUF HK$ per MHz per annum
Technology (modulation)	-6,981	-5,614
Higher frequencies / double hop	8,872 (Note 2)	10,172
Leased line + additional fibre	**11** (Note 1)	**1,378** (Note 1)
Satellite link	351,000 – 655,200	351,000 – 655,200
Self provision – fibre / cable	31,726	33,093

Note 1: Least cost value used (see derivation below). The value shown here needs to be added to the original 5 – 10 GHz SUF which is assumed to be in place and has been included in the licence fees used to derive this new least cost value.

Note 2: Value also referred to in text.

Table D-2: Costings for least cost alternative

Cost element	Annualised cost (FTNS case) HK$ per annum	Annualised cost (WBLRS case) HK$ per annum
Bidirectional 28 MHz fixed link		
Equipment and installation = HKS 155,000 Annualised over 15 years at 10%	18,526	18,526
Maintenance and running costs per annum 10% of CAPEX	15,500	15,500
Site rental per annum	210,000	210,000
Licence fees (incl SUF) per annum	369,750	293,216
Total	613,776	537,242
Total per MHz	10,960	9,593
100 Mbps leased line		
Tariff (per month per end = HK$ 18,800)	451,200	451,200
Installation (per end = HK$ 12,000) Annualised over 15 years at 10%	2,869	2,869
Total	454,069	465,069
Total per MHz	8,108	8,108
Additional fibre		
Cost of provision per metre (dense urban) = HK$ 2,000 Cost of provision per metre (rural) = HK$ 500 Distance to be provisioned = 2 km Proportion in dense urban environment = one third Amount of bandwidth supported = 83.5 MHz Costs annualised over 15 years at 10%		
Total cost	239,043	239,043
Total cost per MHz	2,863	2,863
Summary calculation		
Fixed link cost per MHz	10,960	9,593
Leased line cost per MHz	8,108	8,108
Additional fibre cost per MHz	2,863	2,863
Leased line and fibre cost per MHz	10,971	10,971
Additional cost of alternative (leased line / fibre) per MHz	**11**	**1,378**