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Revising Taiwan's frequency usage fee regulation

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Abstract

Radio frequency usage fees were first charged in Taiwan in 1997. Since then, spectrum-efficient radio technologies have been making rapid progress, and many new innovative wireless services are demanding allocation of spectrum bandwidth. Therefore, frequency usage fees need to be revised in order to better meet society's needs, and to improve the efficiency and effectiveness of radio spectrum utilization. This research studied the characteristics of frequency usage fee structures of some selected countries, including the UK, Canada, Australia, Korea, Singapore, France, and Israel. A survey of local frequency users concerning their complaints and expectations was also conducted. With future frequency needs in mind, a revision of Taiwan's frequency usage fee system was recommended. The Taiwan Directory General of Telecommunications has fully adopted this revision and made it effective starting 2001.

Keywords: Frequency usage fee; Telecommunications regulation; Spectrum pricing

1. Research background

In the past frequency usage fees in Taiwan were low and did not give frequency users any incentive to invest in spectrum-efficient technologies. In addition, because frequency usage fees were low compared to leased line tariffs, users have typically preferred microwave to wire line transmission. This has led to inefficiency in spectrum usage and congestion in the microwave band. To facilitate fair access and efficient use of frequency, the current frequency usage fee structure needs to be reexamined and revised.

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Emerging new mobile communication services as well as new digital broadcasting services such as digital audio broadcasting and digital terrestrial television all generate new demand for spectrum. Given that the spectrum is a scarce public resource, demand will always exceed supply. Evaluating the economic and/or social impact of radio applications can be criteria in assigning spectra to contending users. Setting a price for using frequency can constitute a mechanism for controlling the demand for it. Radio services that generate high revenues can afford to pay high frequency usage fees. Consequently, commercial radio services that meet customers' demand and have high economic value would be more likely to secure access to the spectrum. To ensure order and avoid interference in spectrum use, the radio regulatory authority needs to constantly monitor radio waves. Another of the rationales for collecting frequency usage fees from spectrum users is to be sure that the investment and the operations expenses for spectrum monitoring and management are borne by spectrum users.

This research reviews the Taiwanese frequency usage fee structure with reference to practices of other countries, including the UK, Canada, Australia, Korea, Singapore, France, and Israel, while also taking into consideration the existing domestic frequency congestion situation, anticipated future spectrum needs of emerging new services, and the complaints of existing frequency users.

The paper is organized as follows: Section 1 describes the research background; Section 2 explains the design philosophy and principles of a frequency usage charging system; Section 3 analyzes the frequency usage fee structures of other countries; Section 4 explains the revision of the Taiwan frequency usage fee system; and Section 5 offers conclusions and recommendations.

2. Principles of designing a frequency usage fee system

2.1. Purposes of charging for spectrum use

Frequency usage fees could be used to establish a 'managed' spectrum environment or to increase national fiscal income, and this varies in different countries. Some governments are interested in generating government fiscal income, while others merely want to recover the cost of managing the spectrum. In general, governments that charge low frequency usage fees focus only on recovering the cost of spectrum management, while others charging high frequency usage fees focus on generating income for the government.

2.2. Philosophies of charging for spectrum use

Formulation of a frequency usage charging system may involve considerations from technical, economic and government policy aspects. Technical considerations include radio emission power, frequency band, and bandwidth. Economic considerations include radio services revenues, number of radio users, population within the radio coverage area, spectrum management costs, and the balance of supply and demand. Government policy considerations include national security, social welfare, encouragement of spectrum-efficient usage, foreign regulations, and international standards, etc. In the past, spectrum pricing systems were mostly established based upon government policies. However, as telecommunications industries liberalize and commercial wireless service markets mature, some countries start employing the market mechanism to reflect

the true value of the radio spectrum. Instead of charging frequency usage fees, frequency administrators may also auction blocks of frequency to contending users.

Zsoka (1994) compared the advantages and disadvantages of different spectrum pricing principles, including management cost, revenue, opportunity cost, and shadow price models. As the basis of the frequency pricing system changes from cost-based to market-oriented, the role of spectrum administration has changed from supervising to managing.

2.3. Principles of charging for spectrum use

Based on an ITU Recommendation (ITU, 1993), the principles constituting a frequency usage fee system include:

(1) All spectrum users should pay and the fees collected should be used to benefit frequency users.
(2) The fee calculation base should be fair, e.g. the charges for the identical usage of spectrum resources should be the same.
(3) The fee should be proportional to the bandwidth of spectrum used.
(4) The fee should reflect the value of the spectrum to the public, e.g., frequency used for public services should be charged less because of its greater social value.
(5) Spectrum management expenses should not become a financial burden to the government.
(6) Inputs from the frequency user community should be surveyed when establishing or revising the frequency usage fee structure.
(7) The frequency usage fees should not become an impediment to the public in accessing radio frequencies nor for service providers to deploy wireless services.
(8) The pricing structure should be clear, concise, and comprehensible without unnecessarily prolonging the frequency licensing process.
(9) The price should reflect the scarcity of frequency availability as well as the level of demand for frequencies in different spectrum bands. Nevertheless, a frequency shortage should not be caused by insufficient allocation or poor management of spectrum by regulators.
(10) The frequency usage fees should be levied on the basis of recovering spectrum management expenses, not for optimizing government fiscal incomes.
(11) Legal bases of charging frequency usage fees should exist, and a mission statement should be established to serve as the guideline for implementing the charging procedures.

2.4. Components of spectrum usage charging

Analyzing and comparing the frequency usage fee structures of different countries has revealed that the following ten components are generally considered: frequency bandwidth, emission power, coverage area, frequency band, dedicated use vs. shared use, time of use, transmit vs. receive-only use, application/service type, supply vs. demand, and special purpose. Explanation of these components follows:

(1) *Frequency bandwidth*: the width of the frequency spectrum used by a radio station: in principle, the wider the bandwidth, the more resource is used, and hence the higher the fee should be.
(2) *Emission power*: the strength of the power emitted from a radio station: the higher the power is, the more extensive the radio coverage area. More people in this area would be excluded

from using the same frequency. Hence, the frequency usage fee should be charged in proportion to the emission power.

(3) *Coverage area*: the area covered by radio wave from a radio station: the frequency usage fee should reflect the population density and income of the people in the radio coverage area. The higher the population density and average income, the more valuable the radio frequency becomes, so a higher frequency usage fee should be charged.
(4) *Frequency band*: the spectrum band in which the frequency resides: frequencies in higher bands attenuate more than frequencies in lower bands. In order to encourage using frequencies in the higher band and releasing frequencies in the more congested lower band, the usage fees of frequencies in the higher band should be less than those of frequencies in the lower band.
(5) *Dedicated use vs. shared use*: the use of a spectrum may be dedicated to a single user or shared by multiple users: if multiple users share use of a certain frequency, the frequency usage fee should be lower because this frequency is being used more effectively than being used by a dedicated user.
(6) *Time of use*: the use of a spectrum may be full-time or part-time: the frequency usage fee should vary according to full-time/part-time usage and peak/off peak usage.
(7) *Transmit vs. receive-only use*: a radio station may perform transmit/receive functions or receive-only functions: the frequency usage fee is generally charged based on the number of transmitting stations, and receive-only stations are generally left charge-free.
(8) *Application/service type*: the type of radio applications or public radio services: frequency usage fees should reflect the commercial values of the applications or the service types that use the frequency.
(9) *Supply vs. demand*: the level of demand and the availability of spectrum: popular frequency bands with high demand should be charged accordingly.
(10) *Special purpose use*: the use of spectrum for public safety or common interest: frequencies used for defense, education, scientific research, emergency rescue, or life-preserving purposes should receive special discounts.

Frequency pricing structures of different countries: The characteristics of the frequency usage fee structures of different countries will now be summarized, and the formulation and parameters will be used as references for reviewing the frequency pricing regulation in Taiwan.

2.5. Canadian frequency usage fees

The principle of Canadian frequency usage fees (Industry Canada, 1994, 1996) takes into account spectrum consumption by users and spectrum scarcity in different areas. The same structure applies to all frequency users in any geographical area, a practice that guarantees uniformity, fairness, and simplicity in pricing.

2.6. Spectrum consumption

Users who consume more spectra are charged proportionally more. Frequency bandwidth, coverage area, and exclusivity are the three components used in calculating spectrum

consumption. Transmitting stations and receive-only stations are both deemed frequency consumers.

2.7. Spectrum saturation

The spectrum consumption of a certain frequency band in a certain area determines the saturation of such frequencies. The higher the saturation, the less available are the frequencies.

2.8. Unit frequency pricing in each geographic square

The unit pricing ($/kHz) of frequencies in each geographic square is defined based on the spectrum saturation status within that geographic square.

2.9. Calculation of frequency usage fee

Given the transmitter site, the frequency band and the emission power, a computer program can depict the coverage area in each geographic square within Canada and calculate the total frequency usage fees associated with that transmitting station.

2.10. Korean frequency usage fees

The Korean frequency usage fees (Korean Ministry of Information and Communication, 2000) are calculated based on the following formulation:

$$\text{Frequency usage fee} = \text{BFP} \times (\sqrt{W}+\text{BW}) \times \text{PP} \times \text{SUP} \times \text{SPP}.$$

Explanations:

BFP	base Fee Parameter is 2000 Korean Yen (less than $2)
W	antenna emission power (Watts) Taking the square root of the emission power to reflect the reach of radio coverage
BW	bandwidth (kHz)
PP	preferential parameter. It varies with different frequency bands. The parameters are higher for congested frequency bands. In order to encourage developing radio applications in the high frequency bands, the parameters will be relatively low
SUP	shared use parameter. The parameters will be higher for exclusive use of frequencies; and less for shared use of frequencies
SPP	special purpose parameter. There are different parameters for different radio service types. Frequencies used for public services should have a small parameter value

2.11. Singaporean frequency usage fees

The Singaporean frequency pricing structure (Telecommunication Authority of Singapore, 1995) is quite concise. The frequency usage fees are simply determined by the consumed bandwidth (Table 1).

Table 1
Singaporean frequency usage fee structure

Bandwidth	Annual fee
Bandwidth <1 MHz	300 Singapore dollar per 25 kHz
Bandwidth $\geqslant 1$ MHz	12,000 Singapore dollar for the first MHz, an extra 300 Singapore dollar for each additional MHz
	3500 Singapore dollar for frequency band <20 MHz
	6200 Singapore dollar for frequency band $\geqslant 20$ MHz

Reference: Spectrum pricing regulation of Singapore.

2.12. Australian frequency usage fees

The frequency usage fees of Australia (Australian Communications Authority, 1999) are calculated based on the following equation:

$$\text{Frequency usage fee} = K \times (\text{Si}, \text{Gi}) \times \text{Bi} \times \text{Ai}.$$

The parameters are explained below:

K base fee parameter
Si spectrum location

The central frequency (f_0) of a radio station could fall into one of the following eight bands: $f_0 \leqslant 30$ MHz, $30\text{ MHz} < f_0 \leqslant 70$ MHz, $70\text{ MHz}, f_0 \leqslant 960$ MHz, $960\text{ MHz} < f_0 \leqslant 2.69$ GHz, $2.69\text{ GHz} < f_0 \leqslant 5.0$ GHz, $5.0\text{ GHz} < f_0 \leqslant 8.5$ GHz, $8.5\text{ GHz} < f_0 \leqslant 31.3$ GHz, or $31.3\text{ GHz} < f_0$.

Gi geographic location,
Bi bandwidth
Ai area of coverage

The geographic location of a radio license/station is characterized by one of four categories: all of Australia, high-density areas (Sydney/Wollongong, Melbourne/Geelong and Brisbane/Gold Coast), moderate-density areas (Adelaide, Perth and Newcastle), and low-density areas (elsewhere). The higher the population density in a geographic area, the greater the demand for radio frequencies; hence, the fees for frequency usage should be higher.

2.13. French frequency usage fees

The frequency usage fees of France (French National Frequency Agency, 2000) are levied differently according to the user types: the government users, the public service providers, and the private users.

2.14. Frequency usage fees of government radio networks

$$\text{Fee} = a \times \Delta f, \text{ if } 29.7\,\text{MHz} \leqslant f_0 \leqslant 960\,\text{MHz}, \tag{1}$$

$$\text{Fee} = a \times \Delta f \times 0.96, \text{ if } 960\,\text{MHz} \leqslant f_0 \leqslant 65\,\text{GHz} \tag{2}$$

in which, f_0 = central frequency, a = 7.6 million Euro Dollar/GHz, Δf = bandwidth.

2.15. Frequency usage fees of public radio networks

GSM mobile service providers pay an annual management fee of 152,000 Euro dollars. The frequency usage fee is proportional to the coverage areas. For instance, if coverage is smaller than 20% of France, the frequency usage fee of each 25 kHz channel is 12,000 Euro dollars. For nationwide coverage of GSM service, the frequency usage fee for each 25 kHz channel is 120,000 Euro dollars. Assuming a nationwide GSM operator with 40 25 kHz channels, the total frequency usage fee charged per year is around 4,800,000 Euro dollars.

2.16. Frequency usage fees of private radio networks

The usage fees of microwave or private radio frequencies depend on the bandwidth consumed and the frequency band in which the central frequency resides. The pricing formulation is given below (Table 2).

2.17. UK frequency usage fees

The UK frequency authority (Radio Communications Agency of UK, 1999; Green, 1999) considers the value of a spectrum to be the difference between the marginal utility generated from the spectrum and the marginal cost of obtaining the spectrum. This difference is the users' willingness to pay for the frequency usage fee. At times when demand for frequency is higher than its supply, the frequency usage fee can be measured as the unrealized cost savings resulting from failure to obtain such frequency. It can also be regarded as an opportunity cost, which is the cost difference between using the frequency vs. using other alternatives, like public radio services, different transmission technologies, or using frequencies in different frequency bands.

Frequency usage fees may also be levied in accordance with revenues or profits. However, the frequency usage fees may constitute merely a small part of one user's total revenue while being a large part of another user's revenue. Therefore, associating frequency usage fee with a percentage of a user's revenue is not equitable among all users.

The UK's principles of constituting frequency usage fees are highlighted as follows:

(1) Frequency usage fees should depend on the availability of alternatives to using radio frequency, including subscribing to public radio services instead of constructing private radio systems, sharing use of frequencies with other users, re-using available frequencies, or re-allocating to higher frequency bands to help relieve congestion.
(2) Frequency usage fees should depend on the remaining lifecycle cost of a user's radio equipment. The difference between continually using the existing radio equipment and the

Table 2
Usage fee of microwave frequency of France

Bandwidth	Frequency band		
	$f_0 \leqslant 10$ GHz	10 GHz $< f_0 \leqslant 30$ GHz	30 GHz $< f_0$
3.5 MHz < bandwidth $\leqslant$ 7 MHz	Euro 1920	Euro 1280	Euro 850
7 MHz < bandwidth $\leqslant$ 14 MHz	Euro 2880	Euro 1920	Euro 1280

Frequencies used by local government offering emergency services are discounted by 50%.

cost of using alternatives is the marginal value of a radio spectrum. The marginal value of a radio spectrum is different for different mobile radio services. By averaging among the marginal values of all mobile radio services, the UK Radio Communications Agency has set up an average frequency usage fee of 1.65 pounds for each MHz bandwidth consumed in each square kilometers of coverage area for mobile radio services.

(3) Usage fees for private use of radio frequencies are charged by bandwidth, coverage area, and the number of shared users. Since frequency use is congested in certain parts of the country, location of use should also be taken into consideration in calculating the frequency usage fee. In the UK, London is the most crowded frequency usage area, followed by Birmingham, Manchester, and Liverpool, while the remaining areas are unsaturated.

(4) In addition to the considerations mentioned above for frequency usage fees, other factors are considered as well, e.g., the level of demand for frequencies, the existence/non-existence of alternatives, the quality or importance of the radio services, and the characteristics of frequency bands, e.g., frequencies above 1 GHz attenuate more quickly than frequencies below 1 GHz.

2.18. Israeli frequency usage fees

The Israeli Ministry of Communications (2000) divided the spectrum for fixed radio services into six frequency bands with charges for lower frequency bands higher than those for higher frequency bands. Within each frequency band, the frequency usage fee is proportional to the distance of communication. The frequency usage fee for point-to-multipoint Wireless Local Loop depends on the bandwidth consumed and counts the farthest distance between the hub and the customers' premises. The frequency usage fee for radio and TV services is charged according to the number of radio or TV channels together with the emitting power. For mobile radio services, the frequency usage fees are levied in terms of MHz of bandwidth used and increase as the number of years of operation lengthens.

3. Revision of the Taiwanese frequency usage fees

The Taiwanese frequency usage fee regulation, first approved in 1997 (Ministry of Transportation and Communications), has classified frequency uses in six service categories: (1) Fixed Radio Communications services; (2) Private Mobile Communications Services; (3) AM/FM and Terrestrial Broadcast TV Services; (4) Satellite Communications Services; (5) Public Mobile Communications Services; and (6) Frequency uses for Educational, Research, or Experimental Purposes.

The principles upon which the charge for frequency usage fees described in Section 2 together with the pricing structures and formulae employed by countries described in Section 3 were taken as references and guidelines for revision of Taiwan's first version frequency usage fees. In addition, the Taiwan frequency regulator's policies on spectrum management and current frequency users' complaints have also been taken into consideration. In the following, the revision of Taiwan's frequency usage fees is summarized, and the rationales and advantages are also explained. Note that all frequency usage fees are levied annually and the currency for all base fee parameters have been converted from NT dollars to US dollars at an exchange rate of 35:1.

3.1. Revised frequency usage fees for fixed radio communications

3.1.1. Directions for improvement

The following are major improvements made on the usage fees for frequencies used for fixed radio communications:

For frequency use in the lower frequency band, bandwidths of 3 and 12.5 kHz are the basic units for charging. For frequency use in the higher frequency bands, bandwidth of 1 MHz is the basic unit for charging. These bandwidth units are the common channel sizes in the respective spectrum bands.

In all frequency bands, the frequency usage fee should be calculated in direct proportion to the actual bandwidth consumed.

In all frequency bands, the frequency usage fee should be calculated in proportion to the power of the transmitter.

Usage fees for frequencies in higher frequency bands should be charged less than frequencies in lower frequency bands.

There should be significant discounts on frequency uses for public services such as police, fire, ambulance, emergency rescue, etc.

The microwave band has limited bandwidth while demand for it has always been very high. Before frequency usage fees were charged in 1997, microwave frequencies were carelessly over-used. Because wired transmission technologies such as copper wire, coaxial cable, and optical fiber are all viable substitutes for microwaves, the Taiwan Directory General of Telecommunications (DGT) has a policy to raising the usage fees for microwave frequencies to a level comparable to the leased line tariff in order to encourage the use of wired technologies instead of microwave. AM/FM and terrestrial broadcast TV provide free to the air services to the public. Their broadcast stations are generally located on top of mountains where it is difficult to install wired transmission lines. Therefore, their use of microwave frequencies should be granted with special discounts.

The Revised Formulation If $f_0 < 30$ MHz:

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{3\,\text{kHz}} \right) \times \left(\frac{W}{25\,\text{W}} \right) \times \$57 \right\} \times d.$$

If 30 MHz $< f_0 <$ 1GHz:

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{12.5\,\text{kHz}} \right) \times \left(\frac{W}{25\,\text{W}} \right) \times \$286 \right\} \times d.$$

If $1\,\text{GHz} < f_0 < 3\,\text{GHz}$:

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{1\,\text{MHz}} \right) \times \left(\frac{W}{1\,\text{W}} \right) \times \$457 \right\} \times d.$$

If $3\,\text{GHz} < f_0 < 12\,\text{GHz}$:

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{1\,\text{MHz}} \right) \times \left(\frac{W}{1\,\text{W}} \right) \times \$400 \right\} \times d.$$

If $12\,\text{GHz} < f_0 < 23\,\text{GHz}$:

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{1\,\text{MHz}} \right) \times \left(\frac{W}{1\,\text{W}} \right) \times \$343 \right\} \times d.$$

If $23\,\text{GHz} < f_0 < 31\,\text{GHz}$:

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{1\,\text{MHz}} \right) \times \left(\frac{W}{1\,\text{W}} \right) \times \$229 \right\} \times d.$$

If $31\,\text{GHz} < f_0$:

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{1\,\text{MHz}} \right) \times \left(\frac{W}{1\,\text{W}} \right) \times \$143 \right\} \times d.$$

Note that:

BW bandwidth (The maximum accountable bandwidth used by non-profit government organizations is 20 MHz, while that for commercial use is 56 MHz)

W the power of the transmitter (Watts (W)). (Minimum accountable power is 0.5 W, and maximum accountable power is 100 W)

D Discount factor:

By public radio service providers	$d = 1.0$
By public-service government organizations, e.g., police, fire department, ambulance, etc.	$d = 0.1$
By non-profit government organizations	$d = 0.3$
By non-public-service organizations	$d = 1.0$
By commercial AM/FM stations	$d = 0.2$
By non-commercial AM/FM stations	$d = 0.1$
By commercial TV stations	$d = 0.4$
By non-commercial TV stations	$d = 0.1$

3.2. Revised frequency usage fees for private mobile communications

3.2.1. Directions for improvement

In all frequency bands, the frequency usage fee should be calculated in direct proportion to the actual bandwidth used. In all frequency bands, the frequency usage fee should be calculated in proportion to the power of the transmitter. In the first version of the frequency usage fee regulation, a special fee table was designed for the eastern rural part of Taiwan and offshore

islands. Actually, the same fee structure could be used but with different discount factors. Because public mobile radio services are viable options for private mobile radio users, it is also a policy of Taiwan DGT to encourage subscription to public mobile radio services instead of constructing private mobile radio networks. Therefore, the usage fees of frequencies used for private mobile radio should rise. The private mobile radio networks of the police department, fire department, ambulance, and rescue organizations have significant importance for the well-being of the people and deserve special discounts on the use of frequencies for such purposes.

3.2.2. Revised formulation

$$\text{Frequency usage fee} = \left\{ \left(\frac{\text{BW}}{12.5\,\text{kHz}} \right) \times \left(\frac{W}{25\,\text{W}} \right) \times \$229 \right\} \times d.$$

Note that:

BW bandwidth (kHz) (The maximum bandwidth for nonprofit government use is 20 MHz)
W power of transmitter (W) (The minimum power is 0.5 W, and maximum power is 100 W)
D Discount factors:
For public-service government organizations, e.g., police, fire department, ambulance, etc. $d = 0.1$
For other non-profit government organizations $d = 0.3$
For non-public-service organizations $d = 1.0$

The frequency usage fees for mobile radio stations are defined below based on their transmitter power (W):
if $W < 10$ W,\$1.4 per station per year,
if 10 W < 20 W, \$2.9 per station per year,
if 20 W $< W$, \$5.7 per station per year,
if a mobile radio station operating with bandwidth greater than 30 kHz and power greater than or equal to 0.05 W, the frequency usage fee should be charged according to equation above.

3.3. Revised frequency usage fees for AM/FM

3.3.1. Directions for improvement

The frequency usage fee of an AM/FM broadcast station should be based on the number of people within the broadcast coverage area. The assessment of population within a coverage area is improved as follows:

If the radio coverage area covers over two-thirds of a population zone, the total population of this zone is counted.

If the radio coverage area covers over one-third, but less than two-thirds of a population zone, one half of the total population of this zone is counted.

If the radio coverage area covers less than one-third of a population zone, then none of the population of this zone is counted.

3.4. Revised formulation

For each FM station broadcasting at 200 kHz channel:

$$\text{Frequency usage fee} = \text{BFP} \times P \times d.$$

BFP base fee parameter equals \$50 US dollars per 100,000 population covered
P assessed population within broadcast coverage area
D discount factors:

For educational and public broadcasting AM/FM stations, $d = 0.2$.

3.5. Revised frequency usage fees for terrestrial TV

3.5.1. Directions for improvement

All TV companies in Taiwan are awarded two 6 MHz channels to cover the whole island. It should be a TV company's obligation to cover as large a population as possible. Therefore, the frequency usage fee for the two 6 MHz channels assigned to each TV company should be charged on the assumption that it covers the total population of Taiwan. Tedious efforts to assess the population within the broadcast coverage areas of each TV broadcast station could thus be avoided.

Additional TV channels shared by TV broadcasters that re-broadcast signals to hard-to-reach areas should not be burdened with frequency usage fees. One rationale is that the frequency usage fees of the two 6 MHz main channels are already assumed to cover the entire Taiwanese population. Another rationale for waiving the frequency usage fees is to encourage TV broadcasters to make as much use of those re-broadcasting channels as possible in order to expand the broadcast coverage of Taiwan residences.

3.6. Revised formulation

The frequency usage fee of two 6 MHz (VHF or UHF) channels of a TV broadcaster:

$$\text{Frequency usage fee} = \text{BFP} \times P \times d.$$

BFP base fee parameter equals \$1543 US dollars per covered 100,000 people
P total Taiwan population is 22,170,000 people
d discount factors

For educational and public broadcasting TV stations, $d = 0.2$.

3.7. Revised frequency usage fees for public mobile communications

3.7.1. Directions for improvement

Because mobile radio communications are commercial services provided to the public, the associated frequency usage fees should reflect the market values, profitability, and operational

efficiency of their service providers. The frequency usage fee should be calculated in direct proportion to the actual bandwidth used by each service provider.

The frequency usage fee should include an item related to the number of mobile customers. If the actual number of mobile customers is considered in calculating the frequency usage fee of an operator, then operators with more customers will pay more frequency usage fees than operators with fewer customers. This is actually punishing the more efficient operators. Therefore, an industry-wide average number of customers served per MHz of bandwidth can become a benchmark for all operators. Each operator will pay the same portion of frequency usage fee based on this average number of mobile users, irrespective of the actual number of mobile customers that each operator has.

3.7.2. Revised formulation

The following frequency usage fee formula applies to all mobile radio service types, including Mobile Phone Service, Low-tier Mobile Phone Service, Mobile Data Service, Trunking Radio Service, Low-power Mobile Phone Service (CT2), and Paging Service:

$$\text{Frequency usage fee} = \{(\text{BW} \times \text{BFM}) + (\text{BW} \times \text{ANC} \times \text{BFMC})\} \times d.$$

Note that:

BW	bandwidth, in MHz, assigned to a mobile service operator.
BFM	base fee per MHz.
BFMC	base fee for each mobile customer.
ANC	average number of mobile customers serviced per MHz of bandwidth allocated to one mobile service type. (Adding the total number of mobile customers within one mobile service type, and dividing the sum by the total bandwidth assigned to all of the operators of such mobile service type).
D	discount factors for regional service operators: for whole region operator $d = 1.0$ for north region operator $d = 0.45$ for central region operator $d = 0.25$ for south region operator $d = 0.30$

The associated base fee parameters and the average number of customers serviced per MHz of bandwidth for different service types are summarized in the table below (Table 3).

3.8. Revised frequency usage fees for satellite communications

3.8.1. Directions for improvement

Regardless of the size of antenna, the frequency usage fees for fixed earth stations and mobile earth stations (SNG, Fly Away) should both be related to the transmission frequency bandwidth. The reason transmission power is not considered is because power is emitted along a specific beam angle towards the satellite and would not interfere with other users.

Table 3
Base fee parameters for different mobile communications service types in Taiwan

Mobile communications service types	Base Fee/MHz (US Dollar)	Average number of customers served per MHz	Base fee/mobile customer (US Dollar)
Mobile phone	$210,143	83,000	$1.14
Low-tier mobile phone in 1900 MHz (LT)	$136,600	15,000	$0.43
Mobile data	$52,543	29,000	$0.29
Trunking radio	$52,543	2500	$0.29
Low-power mobile phone in 900 MHz (CT2)	$105,086	4500	$0.29
Paging	$52,543	2,000,000	$0.06

Because the number of satellite mobile phones in use is very limited, the frequency usage fee for them could be waived to save administration cost.

Receive-only earth stations are not subject to frequency usage fees.

3.8.2. Revised formulation

$$\text{Frequency usage fee formulation of satellite communication} = \left\{ \left(\frac{\text{BW}}{1\ \text{MHz}} \right) \times \$143 \right\} \times d.$$

Note that:

BW bandwidth (There is a maximum accountable bandwidth of 72 MHz, and a minimum accountable bandwidth of 1 MHz)
D discount factor

3.9. Revised frequency usage fees for educational, experimental or research purposes

3.9.1. Directions for improvement

Frequencies used for these purposes should be charged at a special discount of 1% in order to promote such meaningful causes. The frequency usage fees can be exempted altogether if waived by the Ministry of Transportation and Communications.

4. Conclusions and suggestions

This research has reached the following conclusions.

4.1. Major principles of frequency usage fee pricing

By analyzing the frequency usage fee pricing systems of different countries, it is clear that the trend in administration for spectrum usage has shifted from supervision to management, and the basis for charging a frequency usage fee is changing from a cost-orientated to market-orientated approach. Because the spectrum is a precious public resource that grows in value as demand increases, the market-orientated pricing system can more accurately reflect the true value of spectrum.

A list of key factors that should be considered in frequency usage fee charging include: frequency bandwidth, emission power, usage area, frequency band, dedicated use vs. shared use, time of use, transmission vs. receive-only usage, application/service type, supply vs. demand, and other special considerations. Bandwidth, power, and frequency band are the most commonly considered components.

4.2. Advantages of the revised frequency usage fee structure

The revised frequency usage fee charging system for Taiwan has the following advantages:

For each radio service type and each bracket of frequency band, the frequency usage fees are calculated from several concise equations of consistent structure, which generate fees directly proportional to the bandwidth consumed and power emitted. Instead of looking into over-simplified and discrete rate tables to figure out usage fees, these equations help make the fee pricing system fairer and more easily computerized.

Charging less for frequencies in higher frequency bands than for frequencies in lower frequency bands is simply done by setting descending base fee parameters for the respective fee equations in the ascending frequency bands.

A few categories of usage fees are raised to reflect the true value of certain commercial radio services, such as public mobile phone service, or to relieve congestion in the frequency band of microwave transmission. On the other hand, special discounts are given to public service bureaus such as the police department, fire department, emergency rescue organizations, etc. Educational, experimental, and research use of frequencies are also heavily discounted.

4.3. Compatibility of the frequency revision with the principles

The principle of setting frequency usage fees in Taiwan has changed from supervision to management and its calculation from cost to market-orientation. Before telecommunications liberalization, frequency users in Taiwan were limited to the state-run telecom service monopoly, Chunghwa Telecom, and other government providers. The regulator's role was mainly supervisory to avoid spectrum interference. However, in recent years, advances in radio technologies have made many new wireless services possible, and many new service operators have emerged. Spectrum shortage was a difficult problem to address. Raising frequency usage fees for spectra with high market value or high demand can serve the purpose of selecting the most innovative operators who can offer useful services that

meet consumer demand. Frequencies in lightly used bands can be charged with minimal fees in order to encourage usage.

Frequency usage fee revision in Taiwan followed most of the principles of ITU recommendations described in Section 2.3, except that it was levied so as to recover spectrum management expenses. Increasing government fiscal income was one of its side objectives. The operational principle was akin to taxing the rich and giving to the poor.

The following statistics demonstrate the impact of this new frequency usage fee revision (adopted on 1-1-2001) on frequency usages, fees collected, and its compatibility with the fee collection principles. For the most congested microwave band, frequency usage fees increased significantly, especially in the spectrum between 1 and 12 GHz. The incumbent Chunghwa Telecom has consequently relinquished 1511 microwave licenses, decreasing from 2022 licenses in 2000–511 licenses in 2001. The total microwave licenses of the rest of the users decreased from 1728 in 2000–1292 in 2001. The percentage of Chunghwa Telecom's microwave licenses dropped from 54% in 2000 to 28% in 2001. The objective of forcing Chunghwa Telecom to relinquish microwave licenses was accomplished via the frequency usage fee revision.

Chunghwa Telecom mobile phone service occupied about one third of the total Taiwanese mobile phone market, and as much as half of the total mobile phone spectrum. The average after tax profit margin of all mobile phone operators in Taiwan was 17.2% in 2000. To reflect the high market value of mobile phone service in Taiwan and to place a higher burden on Chunghwa Telecom which has enjoyed more spectrum than other mobile phone operators, the total frequency usage fee for this spectrum was increased six times from about $10 million US dollars in 2000 to $60 million US dollars in 2001. Chunghwa Telecom pays approximately half of it.

Since the revised frequency usage fee structure for all service types and all user groups is based on the same set of principles and the same equation-based calculation logic which is acceptable to all frequency users in Taiwan, the fees generated by these equations are also accepted by the same Taiwanese frequency users without too much disagreement.

4.4. Suggestions

Frequency usage fees should be appraised and amended periodically to reflect the latest status of spectrum use and users' needs. In certain frequency bands, the frequency usage fees may have been intentionally set high to encourage users to move to other frequency bands or to make use of alternative technologies. Once the congestion is removed, the usage fees for frequencies in such bands should be adjusted downwards to relieve the burden of using frequencies in such bands. After all, one of the major objectives in charging frequency usage fees is to promote the effective and efficient use of the radio spectrum.

This equation-based frequency usage fee structure could serve as a reference model for other countries. The base fee parameters and the discount factors should be constructed separately to reflect each individual country's specific spectrum usage situations, the spectrum regulator's policies, and the users' frequency needs.

It is suggested that at least a portion of the frequency usage fee income is invested in automating the fee management system and monitoring the order of spectrum use, so that spectrum regulators can provide better services to spectrum users.

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References

Australian Communications Authority. (1999). Apparatus License Fee Schedule, http://www.aca.gov.au.
French National Frequency Agency. (2000). Spectrum Pricing and Management, http://www.telecom.gouv.fr
Green, L. (1999). The UK Approach to Spectrum Pricing and Auctions. IDEE Telecom Conference: Spectrum Valuation and Pricing, June 11.
Industry Canada. (1994). Guide For Calculating Radio License Fees, October.
Industry Canada. (1996). Consultation On Radio License Fees—Phase 1, http://www.ic.gc.ca.
Israeli Ministry of Communications. (2000). Spectrum Fees, http://www.moc.gov.il.
ITU. (1993). Spectrum Pricing Study.Communication Study Groups, ITU-R SM.2012.
Korean Ministry of Information and Communication. (2000). Principles For Radio Usage Fee System.
Radio Communications Agency of UK. (1999). Implementing the Third Stage and Beyond, http://www.radio.gov.uk.
Telecommunication Authority of Singapore. (1995). Part-II Application and Process Fee for Use of a Frequency, Radio Communication Regulations. http://www.tas.gov.sg.
Zsoka, E. K. (1994). Study On Spectrum, ITU, P.4.