Spectrum Management of 5G Mobile Technology: A Case Study of Thailand

Settapong Malisuwan, Dithdanai Milindavanij, Jesada Sivaraks, and Noppadol Tiamnara

***Abstract*—Spectrum is used in extremely diverse fields either in businesses, for public interest or national security including mobile communications, radio communications for aviation, maritime navigation, or for emergency response. The increased demand for spectrum require efficient management to avoid interference among high numbers of simultaneous users of the same spectrum. While certain applications would require highly robust performance over a long distance (a characteristic of lower frequencies), other applications would need very high throughput over shorter distances (a characteristic of higher frequencies). These aspects could be optimally achieved by mobile operators having access to a variety of bands to provide a full 5G service. Therefore, overcoming spectrum management's challenging 5G requirements is a critical issue for the Thai's telecommunications regulator to maximize the socio-economic benefits for the country. The main objective of spectrum management is to ensure that the highest social and public benefits can be obtained from these radio frequencies through the most efficient way of using them with acceptable levels of signal interference. This paper aims to introduce key principles of spectrum management and provide a guideline of spectrum management for 5G technology. A specific case study of 5G spectrum management in Thailand is discussed Recommendations to improve the efficiency of spectrum management for transitioning to 5G technology are also provided in this research. Therefore, to promote 5G technology development in Thailand, it is essential that efforts be made to improve and amend the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services, B.E. 2553 (2010). Creating flexible and soft legal frameworks, so that the most suitable, efficient and demand-oriented technologies are selected.**

***Index Terms*—Spectrum, management, 5G, mobile, Thailand.**

I. Introduction

For a long time in the past, spectrum allotment was strictly regulated to prevent mutual signal interference with nearby frequencies or users, a reason particularly relevant in term of national security. But in the current decade, a key development has emerged in the principle of managing huge numbers of spectrum, as well as gradual practical changes in spectrum management and related guidelines [1].

Most current and past spectrum management guidelines are blamed as a key factor contributing to delays in modernizing technologies and related services that could otherwise benefit the general public as well as inflating costs of using them due to unnecessary scarcity of available spectrum. A simultaneous dramatic surge of spectrum demand has required more efficient spectrum management to prevent its shortage which may emerge in the near future.

For clarity and proper understanding, the paper explains definitions of technical terms used in spectrum management before going into further details.

1) Spectrum allocation refers to the setting of work specifications for each range or band of spectrum.
2) Spectrum allotment refers to designation of operating spectrum ranges for each particular band under specific regulations and conditions.
3) Spectrum assignment refers to awarding of operating right of specific spectrum and spectrum slots under specific regulations and conditions.

In the long past, access and utilization of radio spectrum were strictly regulated by supervisory agencies to prevent mutual frequency interference. But in the last 10 years, this traditional practice has changed due to innovations and key new practices gradually adopted for regulating spectrum. But it has been concluded that this slow gradual approach has delayed benefits that the general public could have gained as it has failed to keep pace with faster changes in technology.

Hence it has given rise to the idea of striving for a balance between strict government supervision and a more flexible approach through which regulations and supervision would be relaxed and market mechanism given a greater role. Either approach has pros and cons, and for a country to choose one would require studies and research to determine levels of regional cooperation, different national regulatory frameworks, market-based spectrum assignment, development of secondary market, and follow-up on spectrum utilization. But one should not lose sight of the main overall objective of spectrum management is to ensure its most efficient exploitation and prevention of frequency interference [2].

In Thailand, management of spectrum and national communication resources in radio, television and telecom sectors under the legal framework stipulated in the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services, B.E. 2553 (2010) [3], in the best public interest on national, provincial and local levels, as well as in educational and cultural fields, and for promoting state security and other public interest in line with the principles of free and fair market competition, adequate and equitable sharing of benefits among all members of society while taking into account proper exploitation of available national communication resources.

To achieve the most efficient spectrum management with the best economic results, there is a need to prioritize re-allocation and re-assignment of spectrum. Within the telecommunications sector, priority should be given to spectrum for the mobile phone industry namely for 3G, 4G

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The authors are with the National Broadcasting and Telecommunications Commission (NBTC), Thailand (e-mail: settapong.m@nbtc.go.th, dithdanai.m@nbtc.go.th, jesada.s@nbtc.go.th).

and 5G technologies as well as bands serving amateur radio, as these are producing a big impact on national development economically, socially and the public in general as demonstrated by results of academic studies around the world.

II. Key Principles of Spectrum Management

The Handbook of National Spectrum Management 2005, published by the Radio-Communication Group 1 of the International Telecommunication Union (ITU) [4] stipulates that a successful spectrum management needs to set clear goals and objectives, of which goals must be set to show links and compliance with national policy and related laws, while adequate spectrum must be provided to boost economic growth, produce maximum public and social benefits, as well as exploit spectrum in the most efficient and productive way.

The main principle of spectrum management is to utilize it for maximum public benefits by balancing the needs to comply with government regulations, serve public demand, promote national economic and social interests, based on following internationally accepted principles [5]:

1) Spectrum assignment to achieve most efficient utilization

Spectrum management seeks to achieve maximum public benefits from utilizing radio bands through efficient spectrum assignments and improvement in many other areas including license winners, consumers, communities and various public agencies including those charged with government security.

Regulatory agencies need to undertake research, set regulations and practical guidelines, and promote spectrum utilization to achieve most efficient utilization without undue regulatory interference, as technologies are going through fast changes in line with constant evolving social changes. Accordingly, a flexible regulatory regime can facilitate adoption of proper spectrum technology suitable to market demand.

2) Lowest costs and minimum constraints to achieving policy objectives

The objectives of planning, issuing license process, spectrum assignment, and network standard tests are to minimize costs and operational constraints, and reduce legal complexity so as to ease obstacles facing license holders to help them operate with the most efficiency for the benefit of license owners, consumers and related public agencies.

3) Create opportunities and promote security and flexibility

Regulatory agencies charged with spectrum management need to promote both security and flexibility as license holders need to be confident with regulatory consistency since they are required to invest in equipment, network creation and development, as well as provide services within the license periods for the benefit of the general public by curbing chances of failure. Therefore, licenses should include provision of flexibility for licensees and service subscribers to leave room for changes in spectrum utilization, or selling, auctioning off or sharing the licenses as part of maximizing benefits from the spectrum.

4) Striking a balance between acceptable level of frequency interference and spectrum utilization benefits

Regulatory agencies need to strike a balance between an acceptable level of frequency interference and increased benefits of spectrum utility so as to ensure overall maximum public and national benefits. In general, spectrum utility efficiency can be enhanced by regulatory and rule adjustments regarding acceptable levels of interference which must not be excessively stringent, and it should be recognized that acceptable levels of operational and frequency interference for different services have different levels of acceptability.

III. Improvement of Spectrum Policy in Thailand: Recommendations

Part of the problems and obstacles found in managing spectrum in Thailand stems from legal aspects, mostly related the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services, B.E. 2553 (2010), which stipulated that telecom spectrum assignment be undertaken only through bidding, not through any other process. And it stipulated that assigned spectrum must not be used or shared by any parties other than the specified license holders. These provisions have been regarded as obstacles to the development of the Thai telecom industry, and to efforts of preparing Thailand to accommodate future technological advances.

Therefore Thailand's spectrum utilization policy can be improved by opening it up for more users and making it more consistent with future technological development, so as to maximize efficiency of using it and to rid of obstacles to the country's telecom technology development.

A. Diverse and Balanced Spectrum Policy not Tied to Any Particular Model

Comparing spectrum assignment to distribution of land (owned by the state), if the land is located in a high-value commercial area widely sought after by investors, it is probably advisable to call a bid to get the highest return for the government. But for land plots in remote, rural and undeveloped areas, the state may choose to distribute parts of them for the benefit of the general public, namely for building hospitals, public parks, or schools. Similarly, a singular approach of calling bids for all components of available spectrum may be inappropriate without taking into consideration what commercial bidders want to build on the land. Therefore, a diverse but balanced approach of spectrum assignment is probably the most suitable model based on three internationally accepted practices as follows [6]:

1) Administrative approach undertaken by supervisory agencies imposing annual compensation fees, a minimum median price at the start of the bidding round, and direct spectrum assignment that is set aside for serving public interest.

2) Market approach undertaken through bidding, normal market transactions, or spectrum leases.

3) Spectrum sharing approach through issue of shared licenses to specific groups of operators, as well as spectrum assignment to serve projects for public interest.

The prevailing current worldwide trend of spectrum assignment is biased toward the market approach, such as through bidding or normal spectrum transaction, rather than through a direct administrative approach, based on the principle that market mechanism can help achieve the most

efficient, transparent and prompt management in selecting the best qualified operators to exploit this valuable, much-sought-after resource.

The spectrum license issuing process should evolve in accordance with prevailing market conditions and circumstances. Lately market mechanism has played a bigger role of boosting the efficiency of managing spectrum to produce suitable returns for the government while market competition helps drive up prices [7].

1) Example of economic tools for spectrum management

- If the objective is to boost efficiency from the start of the spectrum licensing process, bidding would be a suitable tool as winners of the bidding or the highest bidders should be ones who put the highest value on the spectrum.
- If the objective is to let spectrum license holders to raise efficiency of utilizing it, the administrative incentive pricing or the lost opportunity tool would be the most appropriate one, as it relies on market mechanism to determine the value of the spectrum. Under this rationale, license holders who fully appreciate the economic value of the spectrum should use it in the most efficient way by not hoarding or wasting any un-used bands.
- If the objective is to speed up and boost efficiency of the spectrum assignment process, especially the un-utilized bands, the administrative incentive pricing option should be adopted with an added provisional right for the supervisory authorities to recall the licensed spectrum for refarming if necessary.

Moreover, a serious review of this issue should reveal that spectrum utilization is not confined only to the mobile phone service. It is being used for all communication services via satellite, short-distance communications like wireless household phones, WIFI and bluetooth. Assigning the entire spectrum only through the bidding process would produce widespread impact. Therefore any improvement for the spectrum sharing option, either through licensing or opening it up for as a public band, would contribute toward further development of an efficient Thai telecom sector, helping it to keep pace with global changes and curb legal constraints [8].

2) Administrative incentive pricing

Administrative incentive pricing, or lost opportunity costs for spectrum utilization. This is a tool designed to discourage hoarding of spectrum rights without using them especially by state agencies holding and wasting large numbers of non-utilized or under-utilized spectrum that should otherwise produce full commercial benefits. This has always been a common supervisory problem worldwide which in the past was attributable to military, scientific, surveillance, telecom or public communication agencies. But once these supervisory bodies were split up into independent agencies, the former failed to hand over the hoarded spectrum, creating a problem of their shortage for subsequent re-assignment to the private sector as witnessed in many countries. For this reason, the administrative incentive pricing has been commissioned as a tool to induce the spectrum turnover.

Under the administrative incentive pricing mechanism, responsible regulatory bodies would use market tools to calculate the lost opportunity costs of the non-utilized or under-utilized spectrum. For example, Ministry A which previously held the non-utilized spectrum might charge annual x-baht fees on the use of the spectrum based partly on expenses incurred by the regulatory bodies which Ministry A agreed to pay in exchange for retaining the rights to the under-utilized spectrum. But by adopting the administrative incentive pricing mechanism, the supervisory bodies would have to compare the returns of re-assigning the spectrum which might be 10 times more than what Ministry A previously used to pay. The difference of the two figures which could amount to multi-million baht is the so-called lost opportunity cost. If Ministry A failed or was not in a position to pay the lost opportunity cost, the new regulatory agencies would seek to acquire the spectrum from Ministry A and re-assign it to the private sector. The regulatory agencies could later use proceeds from the re-assignment to settle any outstanding amount they owed to Ministry A. The United Kingdom was the first to introduce the administrative incentive pricing scheme in 1998, adopting it as part of maximizing benefits derived from OFCOM. A review by OFCOM showed that administrative incentive pricing was only part of a scheme to force delinguishing of the non-utilized spectrum. Even though the number of delinguished spectrum then might not be high, the result was definitely positive for the future [9].

B. Opening up Spectrum Rights

Thailand's law assigning spectrum to specific and exclusive license holders has created problems as follows:

1) Thailand's current ban on sharing spectrum even though such sharing does not affect its license holder runs against a current global trend of giving priority to sharing spectrum in diverse forms as mentioned, especially for 5G technology which has been clearly designed for accommodating spectrum sharing, either with exclusive individual license holders, with assigned groups of shared users, or total opening up spectrum in question for all to use without any license requirement. Even though NBTC has designated the 2.4 GHz band as a shared public spectrum accessible freely by all parties so long as no excessive frequency interference emerges to disrupt other users. But from a legal perspective, the NBTC decision still essentially violates the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services, B.E. 2553 (2010), as mentioned above.

2) The ban on transferring spectrum license rights to other parties. As the law prohibits transfers of spectrum license rights or sale of such licenses, and in the event of existing licensed operators run into problems that prevent them from carrying on their businesses or have no needs to utilize all spectrum under their ownership, they still are not permitted to sell, rent or take any other actions to exploit the idle spectrum other than let their remaining license periods expire. This legal provision blocks new operators from entering the Thai telecom industry, an unfortunate loss of opportunities and an obstacle to national development.

C. Prioritize Spectrum Management

Spectrum in each specific band possesses different specifications, and even spectrum in the same band can be utilized for different diverse purposes. And government supervisory agencies cannot oblige all spectrum applications as doing so may compromise efficiency of spectrum

exploitation in general. It is therefore essential to prioritize licensing spectrum operators as part of the overall spectrum management. There are diverse criteria for prioritizing the licensing subject to policy of responsible supervisory agencies which may focus on issues of promoting economic growth, social development, legal consideration, or just preference to be consistent with an international trend of raising utility efficiency.

IV. Guideline of Spectrum Management for 5G Technology

The 5G technical requirements to support 5G wireless networks (e.g. peak data rate greater than 10 Gbps, cell edge data rate of 100 Mbps and 1 msec end-to-end latency) will utilize a variety of carrier frequencies. The 5G spectrum management techniques need flexible and efficient use of all available non-contiguous spectrum for wildly different network deployment scenarios. Table I lists potential spectrum-related implications of various high-level requirements for future 5G systems [10].

TABLE I: Potential Spectrum-Related Implications of Various 5G Requirements

High-Level Requirement	**Potential Spectrum-Related Implications**
Ultra-high speed radio links	Ultra-wide carrier bandwidths, e.g. 500 MHz Multi-gigabit fronthaul/backhaul
High speed radio links	Wide carrier bandwidths, e.g. 100 MHz Gigabit fronthaul/backhaul
Support for low to high-Doppler environment	Depends on the throughput requirement
Ultra-low latency	Short range implications
Low latency	Mid-short range implications
Ultra-high reliability radio links	Severe impact of rain and other atmospheric effects on link availability in higher frequencies, e.g. mm-wave, for outdoor operations
High reliability radio links	Impact of rain and other atmospheric effects on link availability in higher frequencies, e.g. mm-wave, for outdoor operations
Short range	Higher frequencies, e.g. mm-wave
Long range	Lower frequencies, e.g. sub-3 GHz
Ground/obstacle penetration	Lower frequencies, e.g. sub-1 GHz
Operation in cluttered environment	Diffraction dominated environment in lower frequencies Reflection dominated environment in higher frequencies
Operation near fast moving obstacles	Frequency-selective fading channels
Mesh networking	High-speed distributed wireless backhaul operating in-band or out-ofband

The guideline of spectrum management for 5G technology can be divided into 2 different perspectives:

1) Spectrum management from the perspective of supervisory agencies and

2) Spectrum management from the perspective of licensed spectrum users

A. Spectrum Management from the Perspective of Supervisory Agencies

Fig. 1 shows spectrum management from the perspective of regulatory agencies which comprises two options of stipulating spectrum operating rights and three options of spectrum assignment as follows [11]:

1) Guideline on stipulating collective spectrum user rights on which everyone has an equal access (general authorization)

For the guidelines on spectrum operating rights based on individual authorized assignments, the formats of assignment are

1) For primary users and
2) For LSA-mode shared license access, which in another word can be described as stipulating spectrum operating rights for individual primary users and for shared license users bunched in groups.

2) Guideline on stipulating collective spectrum user rights on which everyone has equal access (general authorization)

Guideline on stipulating collective user rights on which everyone has equal access (general authorization) without a license, or the so-called unlicensed mode.

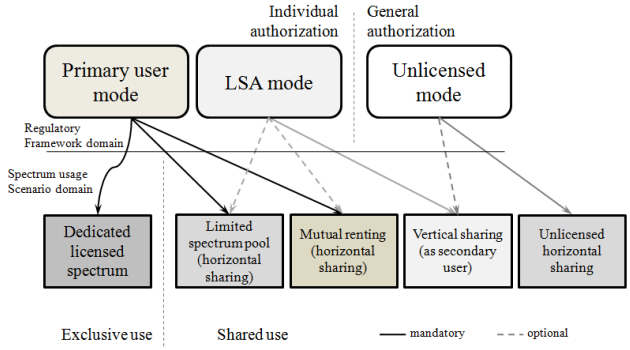

Fig. 1. shows guideline of spectrum assignment for 5G technology from perspectives of regulatory agencies and licensed operators.

B. Spectrum Management from the Perspective of Licensed Spectrum Users

Spectrum assignment based on perspective of licensed users can be further sub-divided into two user guidelines and 4 user formats

1) Spectrum user guideline for exclusive use

This spectrum user guideline is exclusively based and dedicated licensed that is not for sharing with others

2) Guideline on spectrum sharing mode

This spectrum user guideline is extremely interesting from the perspective of new technology development, and which has formats, namely:

- Limited spectrum pool is exclusive spectrum group sharing - many service operators assigned to the same spectrum but a limit is placed on members of the group sharing the same band.
- Mutual renting is a mutual right to rent spectrum from one another, i.e. a spectrum is sub-divided into many smaller blocs of spectrum with each assigned to a single operator who can lease out any sub-spectrum that he does not need, and the leasee also has a right to further lease this sub-block to a third party. Each service operator has a right to lease more than one block of sub-spectrum.

3) Vertical sharing or secondary user

This format of spectrum assignment emerges when a primary user is appointed for a specific spectrum, but if other

service providers could prove that they can share this spectrum without interfering with the operation of the appointed primary user, then they should have a right to lease the sub-blocs, which is the same principle adopted for exploiting satellites and related frequencies on a first-come, first-serve basis. Satellite orbits and amptitudes are resources to be shared by all mankind as they do not belong to any country. Any nation given the right to operate satellites and their amptitudes do not automatically have a right to own or control them. Other nations have a right to share these resources if they have a capability to do so. This is to maximize the benefits of these resources for the betterment of mankind.

4) Unlicensed horizontal sharing

Under this format, the spectrum assignment is based on the view that spectrum is a universal public property to be shared by any party wishing to exploit it so long as in doing so, it is not carried out to such an extreme that prevents others from sharing it, including, for example, the 2.4GHz spectrum currently reserved for this purpose.

C. Obstacles to a New Era of Telecommunication Development in Thailand

As mentioned earlier, the spectrum management undertaken with an objective of accommodating the 5G telecom technology is highly crucial for strengthening the telecom industry so that it generates maximum benefits for the country. However, current practices, standards, regulations, and various legal issues need to be based on thorough understanding of the technical specifications of the spectrum serving the telecom industry. As for Thailand, these practices, standards, regulations, and various legal issues would remain obstacles to exploit the 5G technology if existing misconception persisted.

Spectrum is available for assignment, not for sale only to obtain high returns. In fact, the benefit of spectrum to the country is how to exploit it as much as feasible, the more extensively the more benefits it will generate. If it can be shared with many service operators, its benefits for the country will be even higher. So far our limited technology development has allowed us to exploit only a few hundred megahertz of mostly the UHF band. Additionally, there is still a self-imposed limit that a spectrum band cannot be used or shared simultaneously with other operators. Accordingly, future technology development faces the demand of putting more new bands of spectrum into service and of letting operators to share existing spectrum.

V. Recommendations on the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services, B.E. 2553 (2010)

Article 45 stipulates that operating licenses can be allocated only through bidding, and Article 46 stipulates that spectrum operating licenses offer only exclusive, non-transferable rights to license holders who must themselves operate the telecom business and not delegate wholly or partly their services to other parties to act on their behalf.

The objective of spectrum assignment to secure proceeds from competitive license bidding by private operators seeking exclusive, non-transferable rights to own the spectrum is inconsistent with basic facts of this issue and has created obstacles to introducing new technologies to the industry especially the 5G technology. It has raised following different viewpoints compared with the past:

1) Spectrum assignment should be carried out based on the principle of "Right of Use" and not "Exclusive Ownership", meaning that although successful bidders own the right to use the spectrum, they cannot do so to the extent of obstructing other operators to exercise their usage rights on the same spectrum should future technology allow them to do so, or other operators could prove that their sharing of the spectrum does not interfere with operations of the original successful bidders.

2) It is a fact that the objective of spectrum bidding to help raise the potential value of the spectrum may not necessarily bring the expected benefit for the country. This proved to be the case with the bidding of the 2.1GHz band in England and Germany which attracted high bidding prices. It turned out later that the bid winners failed to secure sufficient funding for building networks to cover all areas to fully serve demand of subscribers at appropriate service charges, which subsequently was responsible for the failure of 3G services in Europe [12]-[14].

In comparison, the 3G services in Japan had carried out long and extensive advance studies on spectrum bidding. It turned out interestingly that Japan decided not to adopt the bidding system. The assignment of 2.1GHZ spectrum in Japan was carried out without imposing any financial fees on service providers who are expected to build sufficient 3G networks to cover all areas and operate services that charge subscribers appropriate fees so that the Japanese public can have sufficient access to 3G technology.

And this fact explains why Japan has become a country that has the most advance mobile communication technologies in the world. Another example is the 4G spectrum bidding in the Czech Republic in November 2012 when the responsible agency charged with the bidding expected to receive only hundreds of million euros of bidding fees. But as it turned out, the actual bidding rose to billions of euro, which prompted the responsible Czech agency to cancel the bidding on its expectation that the successful bidders would not have the capacity to build networks essential for serving the general public, and on the ground that with the initially excessive bidding cost, the bid winners would likely try to push the burden to subscribers, which would have defeated the objective of providing people nationwide access to 4G technology [15].

The conclusion of samples above shows that priority should be given to limited spectrum pools, mutual renting, vertical sharing with primary users, and unlicensed horizontal sharing with all parties free of any constraints.

Therefore from the legal perspective, it is virtually impossible for the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services B.E. 2553 (2010), to promote 5G technology development, but which itself has become a main obstacle for Thailand to access the 5G technology. Accordingly, it is essential that efforts be made to improve and amend the Act of the Agency Charged with Assigning

and Supervising Spectrum of Radio, Television and Telecommunications, B.E 2553.

VI. Conclusion

Achieving the most value from spectrum exploitation requires creation of a process with minimum intervention of government regulations, a prospect full of challenges brought by rapid technological changes, changing consumer behaviour and social development, constant changing formats of weighing issue of licenses in accordance with international standards which further complicate these efforts. Nevertheless, these difficult goals are achievable by creating flexible and soft legal frameworks, by adopting a licensing process without any technology bias, so that the most suitable, efficient and demand-oriented technologies are selected. To facilitate achieving that goal, internationally recognized technology standards must be designed and put in place to help a transparent, fair and accountable process of assigning and licensing spectrum with participation of all parties concerned. Additionally, efforts must be made to prevent market monopolies and market domination by creating an atmosphere conducive to open and fair competition.

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Settapong Malisuwan was born on March 24, 1966 in Bangkok, Thailand. He was awarded full scholarship from Thai government for Ph.D. in electrical engineering (telecommunications), specializing in mobile communication systems from Florida Atlantic University (State University System of Florida), Boca Raton in 2000. He received his MSc in electrical engineering in mobile communications system from George Washington University in 1996 and was awarded First Class Honors, Gold Medal Award and Outstanding Cadet Award by the university. He also achieved MSc in electrical engineering in telecommunication engineering from Georgia Institute of Technology in 1992. Furthermore, he achieved military education from Special Warfare Center, Thailand, specializing in Ranger and Airborne Courses in 1989 and 1988 respectively. He is currently the Vice Chairman and Board Commissioner of National Broadcasting and Telecommunications Regulator in Bangkok, Thailand. He was awarded The "Science Towards the Excellence in 2013" by The Senate Standing Committee on Science, Technology, Communications and Telecommunications. His research interests are in electromagnetics, efficient spectrum management and Telecommunications policy and management.

Dithdanai Milindavanij was born in Bangkok, Thailand on February 15, 1981. He received his Master of Political Science in Political Management from Ramkhamhaeng University in 2006. He has been working in National Broadcasting and Telecommunications, Bangkok, Thailand office since 2011 and has been working as an Assistant to Vice Chairman in National Broadcasting and Telecommunications since May 2015. His research interests are in technology management and spectrum management.

Jesada Sivaraks was born on May 12, 1970 in Bangkok, Thailand. He received his MSEE degree from Oklahoma State University in 1996 and BEng from King Mongkut"s Institute of Technology, Thailand. He completed his PhD in electrical engineering at Florida Atlantic University, Boca Raton, FL in 2001. Since 2011, he has been working in National Broadcasting and Telecommunications Commission as the Secretary to the Vice Chairman. His PhD work is on the system aspects of Bluetooth, WLAN and Mobile IP/CDPD. His current research interests are in telecommunication planning and related system analysis and efficient spectrum management. He is a member of Tau Beta Pi, Florida Epsilon and was an Honorary Advisory's Chairman of Science & Technology committee of Parliament in 2009

Noppadol Tiamnara was born on November 12, 1968 in Pah Na Korn Sri Ayuttaya, Thailand. He received his BSc in electrical engineering from Saint John's University, Thailand, 2002. He received his MSc in technology management from Thammasart University, Thailand, 2012. Since 2006, he has been working in National Broadcasting and Telecommunications Commission as Assistant to Secretary of Vice Chairman of National Broadcasting and Telecommunication Commission (NBTC). His research interests include LTE design, wireless systems, microstrip antenna, electromagnetic, technology management and spectrum.