

Chapter 1

Review & Introduction

1.4 Spectrum Allocation

Office Hours:

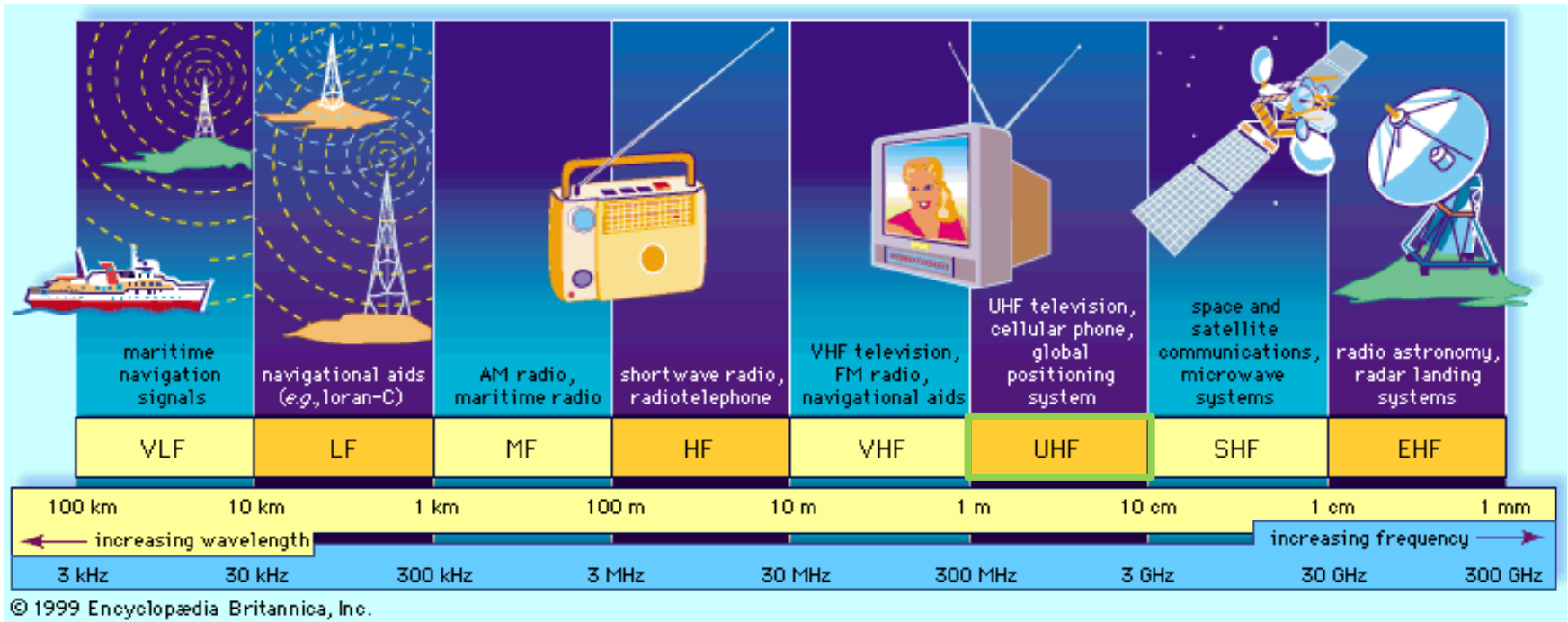
BKD 3601-7

Tuesday 10:00-11:30

Thursday 9:30-11:30

Radio-frequency spectrum

- Commercially exploited bands



$$c = f \lambda$$

3×10^8 m/s

Wavelength

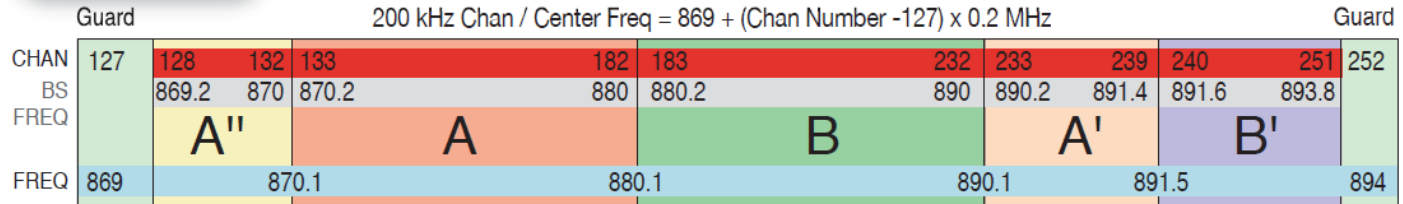
Frequency

Cellular Bands

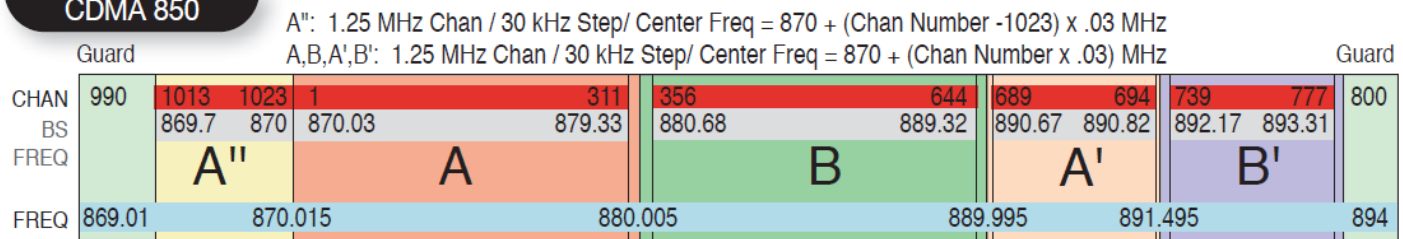
- All cellular phone networks worldwide use a portion of the radio frequency spectrum designated as **ultra high frequency (UHF)** (300 MHz to 3 GHz)
 - The UHF band is also used for television, Wi-Fi and Bluetooth transmission.
 - Due to historical reasons, radio frequencies used for cellular networks differ in the Americas, Europe, and Asia.
- Frequency bands recommended by ITU-R (in June 2003) for terrestrial Mobile telecommunication IMT-2000:
 - 806-960 MHz
 - 1710-2025 MHz
 - 2110-2200 MHz
 - 2500-2690 MHz

Forward link (BS to MS) Frequencies and Channelization (1)

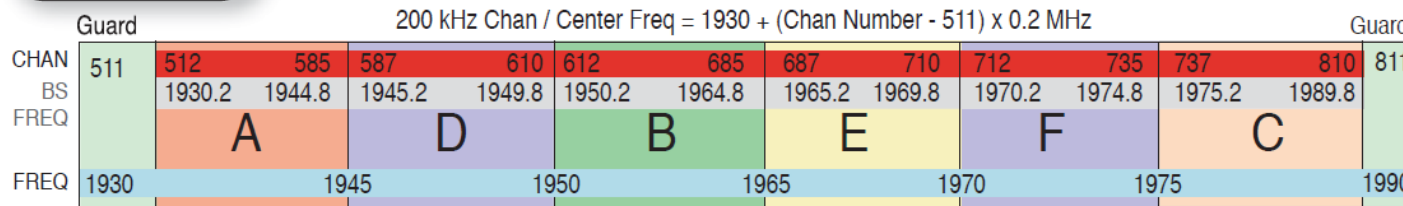
GSM 850



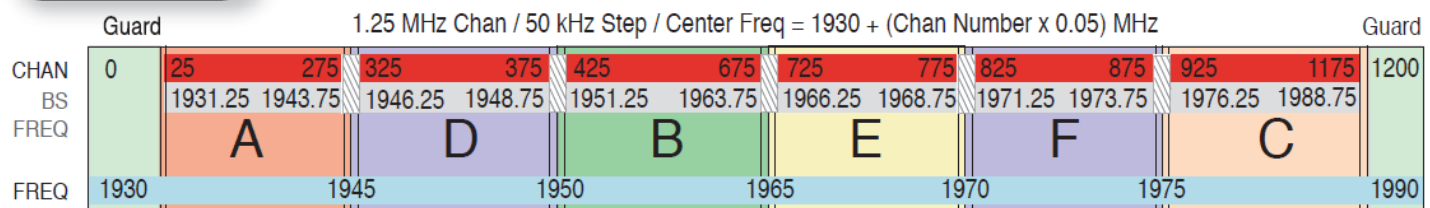
CDMA 850



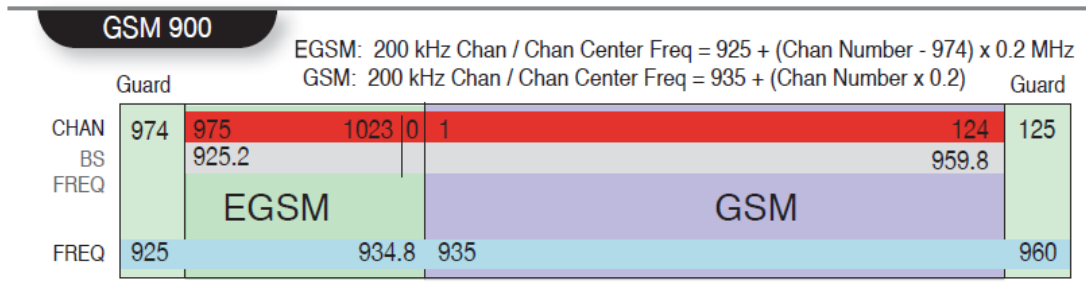
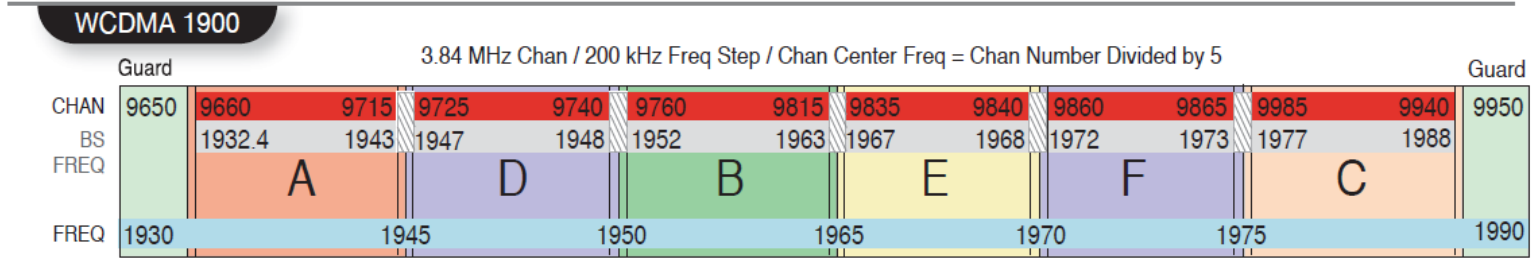
GSM 1900



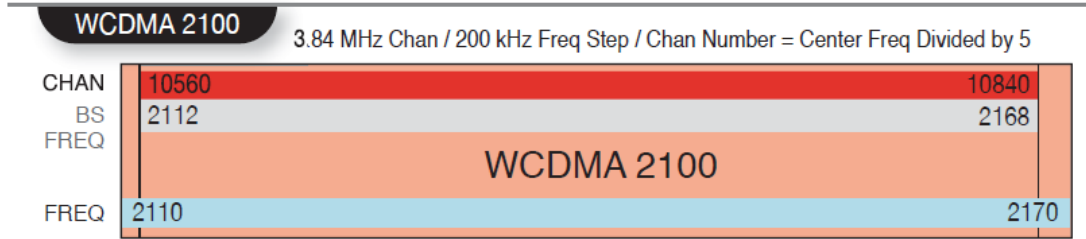
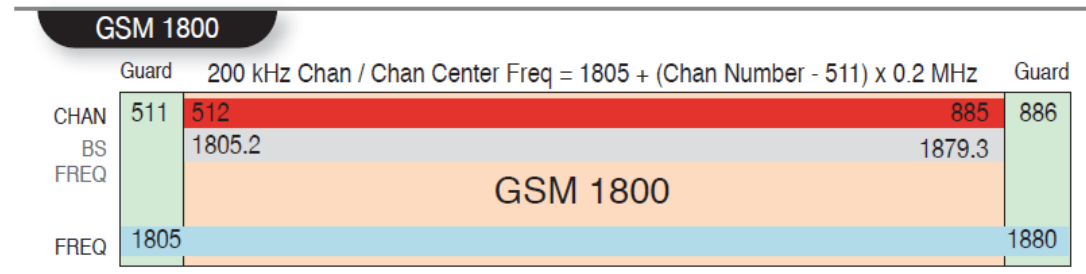
CDMA 1900



Forward link (BS to MS) Frequencies and Channelization (2)



- LEGEND:**
- Valid Center Channels
 - Valid Center Frequencies
 - Full Spectrum Block
 - Conditionally Valid



UNITED STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

- | | | |
|-------------------------------|---------------------------|--|
| AERONAUTICAL MOBILE | INTER-SATELLITE | RADIO ASTRONOMY |
| AERONAUTICAL MOBILE SATELLITE | LAND MOBILE | RADIO DETERMINATION SATELLITE |
| AERONAUTICAL RADIONAVIGATION | LAND MOBILE SATELLITE | RADIOLOCATION |
| AMATEUR | MARITIME MOBILE | RADIOLOCATION/SATELLITE |
| AMATEUR SATELLITE | MARITIME MOBILE SATELLITE | RADIONAVIGATION |
| BROADCASTING | MARITIME RADIONAVIGATION | RADIONAVIGATION SATELLITE |
| BROADCASTING SATELLITE | METEOROLOGICAL AIDS | SPACE OPERATION |
| EARTH/EXPLORATION SATELLITE | METEOROLOGICAL SATELLITE | SPACE RESEARCH |
| FIXED | MOBILE | STANDARD-FREQUENCY AND TIME SIGNAL |
| FIXED SATELLITE | MOBILE SATELLITE | STANDARD-FREQUENCY AND TIME SIGNAL SATELLITE |

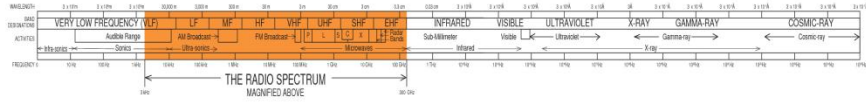
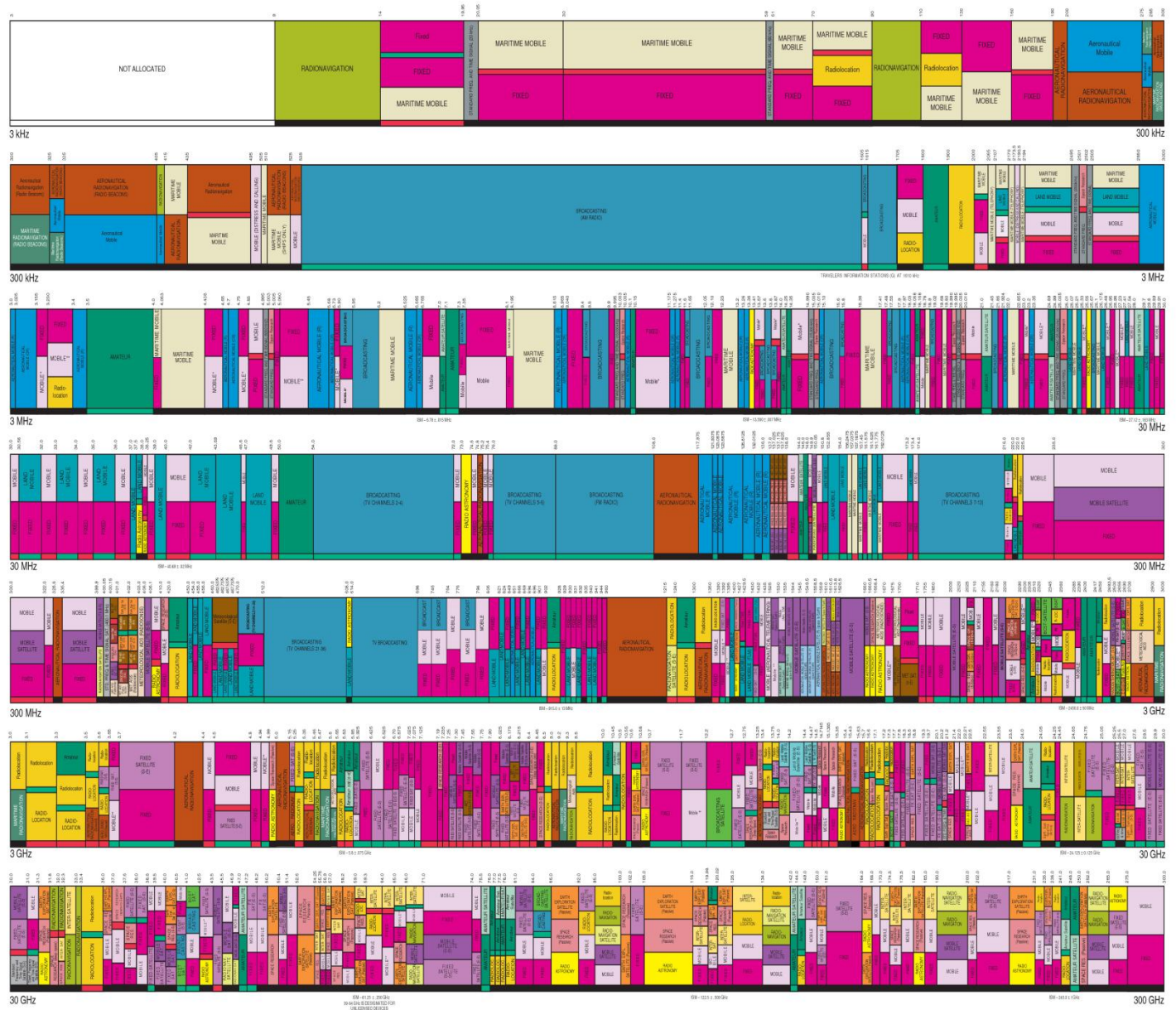
ACTIVITY CODE

- | | |
|--------------------------|----------------------------------|
| GOVERNMENT EXCLUSIVE | GOVERNMENT/NON-GOVERNMENT SHARED |
| NON-GOVERNMENT EXCLUSIVE | |

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	MOBILE	1st Capital with lower case letters

This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC. As such, it does not constitute either an analysis, an estimate and exact changes of the Frequency Allocation. Therefore, for complete information, users should consult the most current issue of the U.S. allocation.

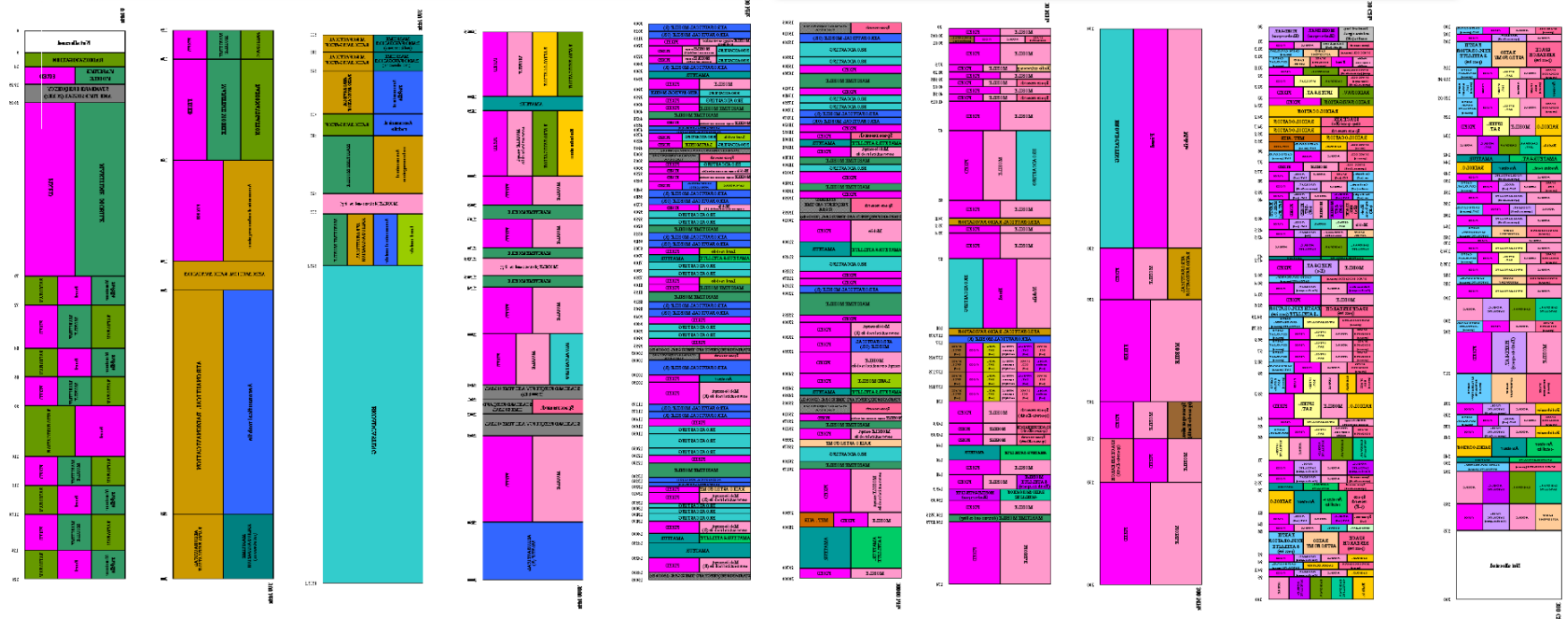


PLEASE NOTE: THE SPACING ALLOTTED TO THE SERVICES IN THE FREQUENCY ALLOCATION TABLE IS ONLY APPROXIMATE AND IS SUBJECT TO THE ACTUAL AMOUNT OF SPECTRUM OCCUPIED.

Thailand Freq. Allocations Chart

RADIO SERVICES COLOR LEGEND			
	Aeronautical mobile		Meteorological aids
	Aeronautical radionavigation		Meteorological-satellite
	Amateur		Mobile
	Amateur-satellite		Mobile-satellite
	Broadcasting		Radio astronomy
	Broadcasting-satellite		Radiodetermination-satellite
	Earth exploration- satellite		Radiolocation

	Fixed		Radionavigation
	Fixed-satellite		Radionavigation- satellite
	Inter-satellite		Space operation
	Land mobile		Space research
	Maritime mobile		Standard frequency and time signal
	Maritime radionavigation		Standard frequency and time signal-satellite



Spectrum Allocation



- Spectral resource is limited.
- Most countries have government agencies responsible for allocating and controlling the use of the radio spectrum.
- Commercial spectral allocation is governed
 - globally by the International Telecommunications Union (**ITU**)
 - ITU Radiocommunication Sector (**ITU-R**) is responsible for radio communication.
 - in the U.S. by the Federal Communications Commission (**FCC**)
 - in Europe by the European Telecommunications Standards Institute (ETSI)
 - in Thailand by the National Telecommunications Commission (**NTC**; สำนักงานคณะกรรมการกิจการโทรคมนาคมแห่งชาติ; กทช.)
- Blocks of spectrum are now commonly assigned through **spectral auctions** to the highest bidder.



US licensed spectrum

AM Radio	535-1605 KHz
FM Radio	88-108 MHz
Broadcast TV (Channels 2-6)	54-88 MHz
Broadcast TV (Channels 7-13)	174-216 MHz
Broadcast TV (UHF)	470-806 MHz
3G Broadband Wireless	746-764 MHz, 776-794 MHz
3G Broadband Wireless	1.7-1.85 MHz, 2.5-2.69 MHz
1G and 2G Digital Cellular Phones	806-902 MHz
Personal Communications Service (2G Cell Phones)	1.85-1.99 GHz
Wireless Communications Service	2.305-2.32 GHz, 2.345-2.36 GHz
Satellite Digital Radio	2.32-2.325 GHz
Multichannel Multipoint Distribution Service (MMDS)	2.15-2.68 GHz
Digital Broadcast Satellite (Satellite TV)	12.2-12.7 GHz
Local Multipoint Distribution Service (LMDS)	27.5-29.5 GHz, 31-31.3 GHz
Fixed Wireless Services	38.6-40 GHz

Unlicensed bands

- In addition to spectral auctions, spectrum can be set aside in specific frequency bands that are **free to use** with a license according to a specific set of **etiquette rules**.
- The purpose of these unlicensed bands is to encourage innovation and low-cost implementation.
- Many extremely successful wireless systems operate in unlicensed bands, including **wireless LANs, Bluetooth, and cordless phones**.
- A major difficulty is that they can be killed by their own success.
 - If many unlicensed devices in the same band are used in close proximity, they generate much **interference** to each other, which can make the band unusable.

Unlicensed bands (2)

- Unlicensed spectrum is allocated by the governing body within a given country.
- Often countries try to match their frequency allocation for unlicensed use so that technology developed for that spectrum is compatible worldwide.
- The following table shows the unlicensed spectrum allocations in the U.S.

ISM Band I (Cordless phones, 1G WLANs)	902-928 MHz
ISM Band II (Bluetooth, 802.11b WLANs)	2.4-2.4835 GHz
ISM Band III (Wireless PBX)	5.725-5.85 GHz
NII Band I (Indoor systems, 802.11a WLANs)	5.15-5.25 GHz
NII Band II (short outdoor and campus applications)	5.25-5.35 GHz
NII Band III (long outdoor and point-to-point links)	5.725-5.825 GHz

Licensed vs. Unlicensed Spectra

Licensed	Unlicensed
Typically nationwide. Over a period of a few years. From the spectrum regulatory agency.	For experimental systems and to aid development of new wireless technologies.
Bandwidth is very expensive.	Very cheap to transmit on.
No hard constraints on the power transmitted within the licensed spectrum but the power is expected to decay rapidly outside.	There is a maximum power constraint over the entire spectrum.
Provide immunity from any kind of interference outside of the system itself.	Have to deal with interference.

Spectrum Allocation (Final Words)

- Spectrum is a scarce resource.
- Spectrum is allocated in “chunks” in **frequency** domain.
 - “Chunks” are licensed to (cellular/wireless) operators.
- Within a single cellular operator, the chunk is further divided into many **channels**.
 - Each channel has its own band of frequency.
- Mobile networks based on different standards may use the same “frequency chunk”.
 - For example, AMPS, D-AMPS, N-AMPS and IS-95 all use the 800 MHz “frequency chunk”.
 - This is achieved by the use of **different channels**.