Signal Transmission- Modulation Lecture 15

- Signal Transmission
- Radio Spectrum
- Multiple Users
- Duplexing
- Channel Sharing or Multiplexing
- Modulation

Signal Transmission

- In a communications system signals or messages need to be transmitted from one place to another
- We say the <u>signals</u> are passed through a channel (e.g. free space, copper wires, optical fibers)
- We call this signal transmission



- <u>Channels</u> operate <u>only</u> at certain frequencies and suffer from distortion, interference and noise
- In the previous lectures we assumed the channel operated at the frequencies you needed

Radio Waves often form part of the Channel

Radio waves have different frequencies



 The set of all frequencies from OHz to infinity is known as the radio spectrum and is used for many different applications

Some Radio Channels in Hong Kong

AM: 535kHz to 1605kHz; FM: 88MHz to 108MHz Stereo

| | 頻道名稱 | 特高頻/調頻 頻率(MHz) | | | | | | | 中頻/調幅 頻率(kHz) | |
|------------|----------|-------------------|-------|-------|-------|-------|-------|-------|------------------|------|
| 電台名稱 | | 歌賦山 | 九龍坑山 | 青山 | 金山 | 南丫 | 筆架山 | 飛鵝山 | 金山 | 坪洲 |
| 商業電台 | 商業一台 | 88.1 | 88.3 | 88.6 | 88.9 | 89.1 | 89.2 | 89.5 | | |
| | 商業二台 | 90.3 | 90.7 | 91.2 | 90.9 | 91.6 | 91.1 | 92.1 | | |
| | 商業英文台 | | | | | | | | | 864 |
| 香港電台 | 香港電台第一台 | 92.6 | 93.2 | 93.4 | 92.9 | 93.6 | 93.5 | 94.4 | | |
| | 香港電台第二台 | 94.8 | 95.3 | 96.4 | 95.6 | 96.0 | 96.3 | 96.9 | | |
| | 香港電台第三台 | | | | | | | | 567 | |
| | 香港電台第四台 | 97.6 | 97.8 | 98.7 | 98.4 | 98.2 | 98.1 | 98.9 | | |
| | 香港電台第五台 | | | | | | | | 783 | |
| | 香港電台第六台 | | | | | | | | | 675 |
| | 香港電台普通話台 | | | | | | | | 621 | |
| 新城電台 | 新城 997 | 99.7 | 100.0 | 100.4 | 101.6 | 102.1 | 100.5 | 101.8 | | |
| | 精選104 | 104.0 | 104.7 | 102.5 | 105.5 | 104.5 | 102.4 | 106.3 | | |
| | 采訊台 | | | | | | | | | 1044 |
| 有效發射功率(kW) | | 3 | 0.5 | 0.7 | 0.1 | 0.5 | 0.15 | 1 | 20 | 10 |

Radio Spectrum

The radio spectrum is very crowded! ٠



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ALLOCATION USAGE DESIGNATION

RADIO SERVICES COLOR LEGEND

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Sharing and Regulation

- Radio waves travel or propagate through a common channel that everybody shares
- That is for a particular frequency only one person, user or company can use itotherwise there will be interference and chaos!



Hong Kong Mobile Phone Allocations

Three

- 827.5-835/872.5-880MHz
- 897.5-905/942.5-950MHz
- 1765-1770/1860-1865 MHz
- 1964.9 1979.7/2154.9 2169.7 2019.7 - 2024.7 MHz (36)
- 2515-2520 and 2635-2640 MHz
- PCCW Mobile
 - 1775-1789/1870-1875MHz
 - 1920.3 1935.1/2110.3 2125.1/ 1914.9 1919.9 MHz (3G)
 - WLAN and Bluetooth
 - 2.4-2.4835GHz
 - 5.725-5.875GHz
 - GPS/Mobile Satelite



- SmarTone
 - 907.5-915/952.5/960MHz
 - 1745-1750/1840-1845MHz
 (DCS1800)
 - 1950.1 1964.9/2140.1 2154.9/1909.9 1914.9 MHz (36)
 - 2520-2530 and 2640-2650MHz
- CSL
 - 835-842.5/880-887.5MHz
 - · 890-897.5/935-942.5MHz
 - 1725-1730/1820-1825MHz
 - 1735-1740/1830-1835MHz
 - 1935.1 1949.9/ 2125.1 2139.9/ 1904.9 1909.9 MHz (3G)
 - 2535-2540 and 2655-2660MHz
- China Mobile
 - 1755-1760/1850-1855MHz
 - 2530-2535 and 2650-2655MHz

Two-Way Communication Protocols

- Simplex
 - Communication flow can only occur in one direction
- Half Duplex
 - Communication flow can occur in both directions, but not at the same time
- Full Duplex
 - Communication link can support simultaneous twoway communications.



Simplex Broadcast radio or TV

Half Duplex Walkie-Talkies, CB radio



Regulation of Radio Spectrum

- The government effectively owns the radio spectrum and regulates it
- In some cases the government sells the spectrum to a user or company
- The government of different countries must coordinate the regulation of the spectrum



OFCA and the ITU

- In Hong Kong this regulation is performed by the government office of OFCA (The Office of the Communications Authority)
- OFCA web site located at http://www.ofca.gov.hk/ and a lot of useful information is contained there
- Generally you must obtain a license from OFCA to make use of the radio spectrum
- OFCA will also coordinate spectrum with the world authority ITU (International Telecommunications Union)
- $\boldsymbol{\cdot}$ The ITU is an organization under the United Nations
- The ITU is headquartered in Geneva, Switzerland is an international organization within which governments and the private sector coordinate global telecom networks and services.
- Web site http://www.itu.int/



Regulation of Radio Spectrum

- In most countries this process has been performed by auction- the government will sell the spectrum to the highest bidder
- This is thought more efficient since it allows the spectrum to be allocated by the free market
- In Europe 3G spectrum was sold for around HK\$300
 Billion in Germany and UK!
- Considered extremely expensive at the time!
- In 2008 US 700MHz spectrum (old TV band-60MHz BW) was auctioned for HK\$160 Billion
- In 2013 4G bands at 2.6GHz were auctioned in UK for HK\$24 billion
- In 2013 4G bands were auctioned for HK\$1.54B in HK

Channel Sharing

Many users share one common channel •



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Channel Sharing

- To share a single common channel such as the radio spectrum we must work out some method of sharing it
- In essence multiple users share a common channel and it is often known as multiplexing
- The most obvious way is simply to allocate every user a separate frequency band.
- That is users divide the common channel into frequency bands
- Hence we refer to this type of channel sharing as <u>Frequency</u> <u>Division Multiplexing (FDM)</u>
- The key in this is how we translate a <u>baseband signal</u> to a different frequency band and this is known as frequency translation or modulation

Baseband Signals

- When we refer to signals and messages we often use the term "baseband signal"
- This term includes digital data (001100..), voice, video and nearly all signals we deal with
- A typical baseband signal can be pictured as:



Frequency Division Multiplexing (FDM)

• We first translate baseband signal to center frequency fo



• Then translate second message to f_1 so we share the channel (FDM)



Understanding modulation

- The idea of modulation is to multiply (i.e. mix) a baseband signal with a carrier signal
- Modulation concept can be easily seen through the trigonometric formula (product to sum sin and cosine) assuming a sinusoidal signal



A simple example

Consider modulating a 1 Hz sinusoidal signal to a carrier frequency at 10 Hz



Complex exponentials of a signal

- The <u>baseband signal</u> $m(t) = \cos (2\pi f_s t)$ M(f) 1 f_s f
- \cdot This can be verified by knowing Euler's formula

$$e^{j\theta} = \cos \theta + j \sin \theta$$

• m(t) = cos
$$(2\pi f_s t)$$

= $\frac{1}{2}$ (exp $(j2\pi f_s t)$ + exp $(-j2\pi f_s t)$)

$$\int_{-f_s}^{1} M(f)$$

Using complex exponentials & full frequency spectra

- The baseband signal $m(t) = \cos(2\pi f_s t)$
- $= \frac{1}{2} \exp(j2\pi f_{s}t) + \frac{1}{2} \exp(-j2\pi f_{s}t)$

• The carrier
$$c(t) = cos(2\pi f_0 t)$$

= $\frac{1}{2} exp(j2\pi f_0 t) + \frac{1}{2} exp(-j2\pi f_0 t)$



Picture analysis in the frequency domain

 \cdot The message f_s is translated along the frequency axis to $f_0\pm f_s$



• Note that the <u>bandwidth</u> BW of the message is f_s and that of the modulated signal is $2f_s$

Picture analysis in the frequency domain

• A message with continuous spectrum and bandwidth BW is translated along the frequency axis to $f_0 \pm BW$



• The modulated signal has a bandwidth *twice* that of the baseband signal.

Frequency Division Multiplexing (FDM)

• We first translate baseband signal to center frequency fo



• Then translate second message to f_1 so we share the channel (FDM)





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Summary

- Sharing a common channel is very important in communications
- Sharing in Radio channels is regulated because radio channels can be accessed by anyone
- One common way to share channels is Frequency Division Multiplexing (FDM)
- Key parts of FDM are frequency translation and filtering
- Modulation is used for signal transmission
 - Frequency translation to a desirable band
- Modulation is a straightforward process
 - involves multiplication (mixing)