Lecture 1

of

EEE307

Electronics for Communications

Department of Electrical & Electronic Engineering

Xi'an Jiaotong-Liverpool University (XJTLU)

Friday, 6th September 2019

- **Introduction**
  - about the module leader
  - about the module
    - textbook, assessment
- **Communication Systems**
  - quick overview

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About the Module Leader

(Sang Lam)

- E-mail address: *s.lam@xjtlu.edu.cn*
- Office: **EE326**, EE Building
- Technical background: **Electronic Engineering** and **Physics**
- Research interests: **semiconductor electronics and photonics** (spanning from 30 MHz to 300 THz in the EM spectrum)
- Others (e.g. H&S, Student-Staff Liaison)

XJTLU FIND A PROGRAMME STUDY WITH US DEPARTMENTS RESEARCH LIFE AT XJTLU ABOUT ALUMNI NEWS EVENTS

SANG LAM PH.D.

Associate Professor

PROFILE

Sang Lam studied electronic engineering at the Hong Kong University of Science and Technology (HKUST) where he graduated with a Bachelor of Engineering degree. In his final year project, he worked on a gigahertz low-noise amplifier and downconversion mixer realised using a 0.5-micron CMOS process. Then he carried out research in silicon CMOS devices for radio-frequency (RF) integrated circuits (ICs) and received his Master of Philosophy degree in Electrical and Electronic Engineering. He also earned a Master of Science degree in Physics from HKUST. After working for a few years in Hong Kong, he went to the UK to pursue doctoral research on semiconductor photonics at the nanometre scale. Participating a multi-university and interdisciplinary project funded by EPSRC of the UK, he worked on photonic crystal cavities with embedded quantum dots (QDs) at the University of Sheffield. On completion of his PhD research, Dr. Lam returned to Hong Kong to co-found a start-up company. After building the foundation of the start-up, he worked as an R&D engineer for Hong Kong Applied Science and Technology Research Institute Company Limited (ASTRI), an R&D organization established by the Hong Kong Government. Prior to joining Xi'an Jiaotong-Liverpool University (XJTLU) as an academic staff member of the Department of Electrical and Electronic Engineering (EEE), he worked on a PEM fuel cell project at ASTRI. Besides, he also assisted in R&D projects on

(URL: **http://www.xjtlu.edu.cn/en/departments/academic-departments/electrical-and-electronic-engineering/staff/sang-lam**)

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About the Module EEE307

(teaching delivery)

- Level 3; 2.5 credits
- 26 hours of **lectures**
  - 2 hours/week (for 13 weeks)
- 4 hours of assessed **demonstration**
  - circuit construction & video
  - tentatively in week 13
- no official **lab session**
  - possible help from teaching assistant
- 45 hours of private study
  - about 3 to 4 hours/week
  - i.e. about 0.5 hour/day (assuming no work on weekends)

Module Title	Electronics for Communications
Module Code	EEE307
Originating Department	Electrical and Electronic Engineering
Module Level[1]	3 (FHEQ level 6)
Module Credits *(normally 5)*	2.5
Pre-requisites *(including Year 1)*	EEE103 AND EEE109 AND EEE211
Shared Programme(s) *(please name all)*	BEng Electrical Engineering BEng Electronic Science and Technology BEng Telecommunications Engineering

Mode of Delivery and Hours

	Lectures	Seminars	Tutorials	Lab / Practicals	Fieldwork / Placement	Other *(Private study)*	Total
Hours / Semester	26			4		45	75
Delivery Pattern	2			4			

Description

Aims and Fit of Module*(i.e. relationship to programme)*
To give students an solid understanding of the applications, function, analysis and design of electronic circuits used in communication systems
Learning Outcomes*(for accreditation and other reasons,sub-headings could be added to this section)* *Students completing the module successfully should be able to:*
A. Demonstrate knowledge and understanding of operation principles and applications building-block electronic circuits in communication systems. B. Demonstrate familiarity with common designs of radio-frequency (RF) amplifiers, mixers, oscillators, power amplifiers and phase-locked loops. C. Design and analyse building-block electronic circuits in a modern communication system. D. Construct and test electronic circuits of RF amplifiers, RF filters, mixers, oscillators, and power amplifiers for meeting certain specifications.

(**http://ebridge.xjtlu.edu.cn/**)

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About the Module EEE307

(topics)

- **Overview of communication systems & basic concepts**
  - frequencies for wireless and optical-fibre communication systems; signal power in dBm; lumped circuits
- **Radio-Frequency (RF) Amplifiers & Mixers**
  - LNA, RF filters, transimpedance amplifiers
- **Oscillators: VCO**
  - ring oscillators; passive resonant circuits in LC oscillators
- Phase-locked loops (PLLs)
- **Power Amplifiers**
- Transceiver architectures

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About the Module EEE307

("prerequisite" modules)

- **EEE109 Electronic Circuits**
  - semiconductor materials & properties
  - diodes & transistors (MOSFETs)
  - amplifiers & circuit analysis
- EEE218 RF Engineering & Applied Electromagnetics
  - introduction to RF systems & engineering
  - transmission lines & matching network
- Knowledge from these modules would be helpful.

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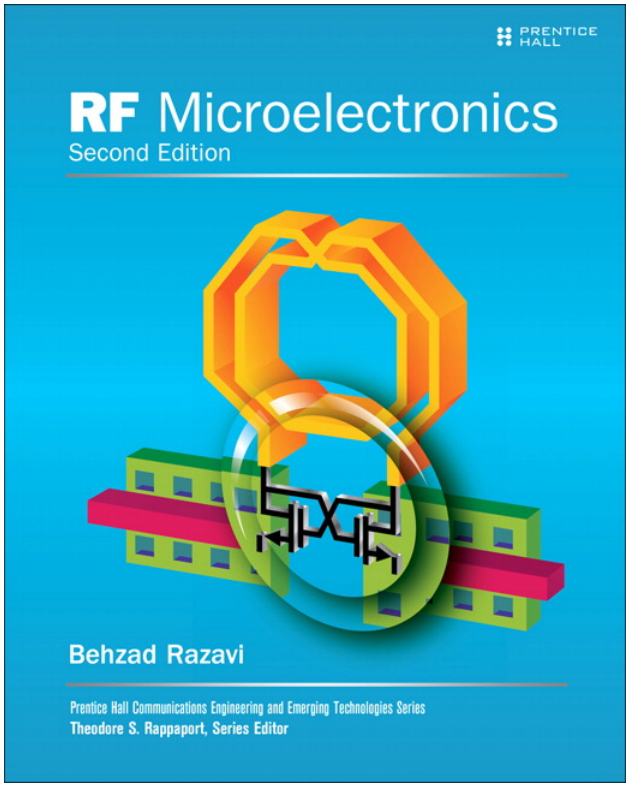
About the Module EEE307

(textbook but not mandatory)

- **RF Microelectronics**
  - by **Behzad Razavi**, a prolific UCLA professor who also has written a few other good textbooks on IC design
  - 2nd edition, 2012
  - published by Pearson
  - thorough contents
  - equip RFIC engineers
- previous edition
  - 1st edition, 1998
  - published by Prentice Hall
  - fewer contents
  - less thorough

(Image taken from Pearson; available at https://www.pearson.com/us/higher-education/program/Razavi-RF-Microelectronics-2nd-Edition/PGM173335.html)



(Image taken from Pearson; available at https://www.pearson.com/us/higher-education/product/Razavi-RF-Microelectronics/9780138875718.html)

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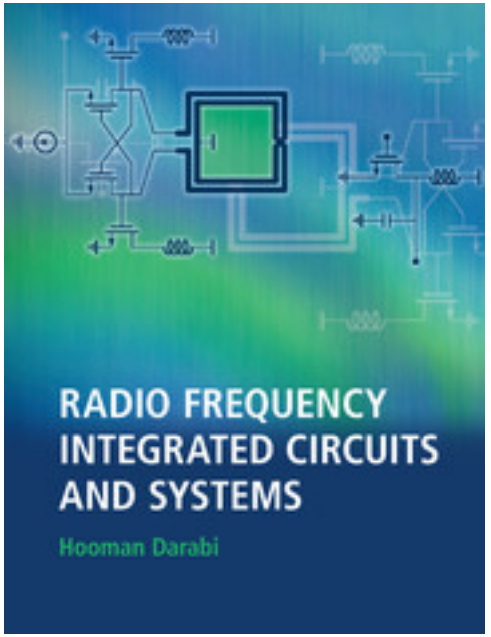
Other Useful Books

(recommended but optional)

- **Radio Frequency Integrated Circuits and Systems**
  - by Hooman Darabi
  - 2015; published by Cambridge University Press
  - covers key topics of electronic circuits & systems for wireless communication
  - contains detailed mathematical analyses
  - more suitable for graduate students who work on RFIC research or RFIC design engineers



(Image taken from Cambridge University Press; available at: http://admin.cambridge.org/academic/subjects/engineering/circuits-and-systems/radio-frequency-integrated-circuits-and-systems)

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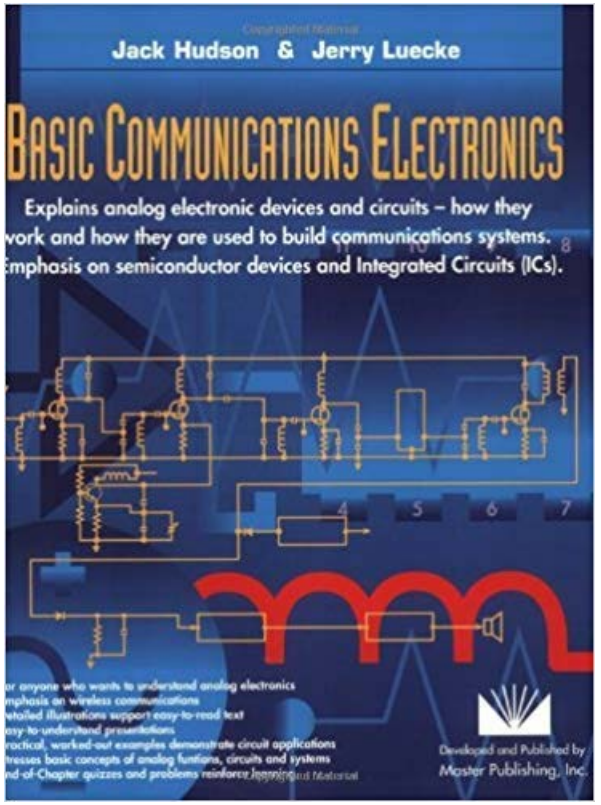
Other Useful Books

(recommended but optional)

- **Basic Communications Electronics**, (1999)
  - by Jack Hudson & Jerry Luecke
  - published by Master Publishing
  - a handy easy book to understand the basics of communication electronics (only about 230 pages)
  - suitable for even electronics hobbyists with no degree-level training in electronic engineering
  - Unfortunately, it is out of print and University's Library does not have a copy.



(Image taken from Amazon.com; available at https://www.amazon.com/Basic-Communications-Electronics-Jack-Hudson/dp/094505324X)

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About the Module EEE307

(**assessment**)

- No mid-term exam (0%); class participation (0%)
- Final Exam (70%)
  - Questions will test more on understanding rather than memorisation of knowledge.
- In-class **Quizzes** (10%) - continuous assessment
  - tentatively at least 10 in-class quizzes (≈ 5-10 min)
  - Each quiz consists of only quick questions, expecting only short answers to be submitted through ICE ⇒ bring your mobile devices so that you can access ICE
- Circuit Construction & Demonstration (20%) – work in pairs
  - produce a video of 2-3 minutes to explain & demonstrate a constructed circuit; with intermediate work (e.g. design schematic, component lists, slides) *assessed* beforehand
  - *assessed* demonstration in week 13/14

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Related News

(plagiarism)

- glossary
  - **plagiarism**

    an act of plagiarizing something; something that has been plagiarized

    plagiarize: to copy another person's ideas, words or work and pretend that they are your own
  - **strip of**
  - **verdict**
  - **deception; deceive**

(Source: ***Oxford Advanced Learner's Dictionary***; available online at: http://oald8.oxfordlearnersdictionaries.com/dictionary/plagiarisms)

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5 February 2013 Last updated at 23:47 GMT

2.4K Share

German minister Annette Schavan stripped of doctorate

The education minister, on a five-day visit to South Africa, is to appeal against the decision

A German university has voted to strip Education Minister Annette Schavan of her doctorate after an investigation into plagiarism allegations.

The University of Duesseldorf's philosophy faculty decided on Tuesday that she had carried out "a deliberate deception through plagiarism".

The minister has denied the claims and said she will appeal.

An earlier plagiarism row brought an end to the political career of Germany's defence minister in 2011.

Large parts of Karl-Theodor zu Guttenberg's 2006 legal dissertations were found by Bayreuth University to have been copied and he stood down before it issued its damning verdict in May 2011.

Using the same words as Duesseldorf's Heinrich Heine University, it concluded that he had "deliberately deceived".

When Ms Schavan became the second minister in Chancellor Angela Merkel's government to be accused of copying her doctorate, in this case by an anonymous blogger, she insisted she had never "knowingly falsely cited any sources" and promised to respond to the accusations.

Related Stories

- German minister denies plagiarism
- Europe's 'plague of plagiarism'
- Ex-German minister 'plagiarised'

(Taken from BBC News; available at http://www.bbc.co.uk/news/world-europe-21347510)

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Related News

(data fabrication)

- glossary

(Source: ***Oxford Advanced Learner's Dictionary***; available online at: http://www.oxfordlearnersdictionaries.com/definition/english/fabricate)

  - **fabrication**

    false information that is invented in order to trick people; the act of inventing such information

    fabricate: *make up*; to invent false information in order to trick people

Stem cells: Scientist asks for research to be withdrawn

By James Gallagher
Health and science reporter, BBC News

10 March 2014 | Health

Share

A Japanese scientist behind a seemingly groundbreaking stem cell study says the findings should be withdrawn amid doubts over its quality.

It **was reported in January** that dipping cells in acid could cheaply and quickly convert them into stem cells.

But questions were raised about the images used in the scientific report and other research groups have failed to reproduce the results.

Author Prof Teruhiko Wakayama said: "It is no longer clear what is right."

The future of regenerative medicine is pinned on stem cells, which can transform into any other type of tissue. They are being investigated for restoring sight to the blind and repairing the damage caused by a heart attack.

(Taken from BBC News; available at http://www.bbc.com/news/health-26516458)

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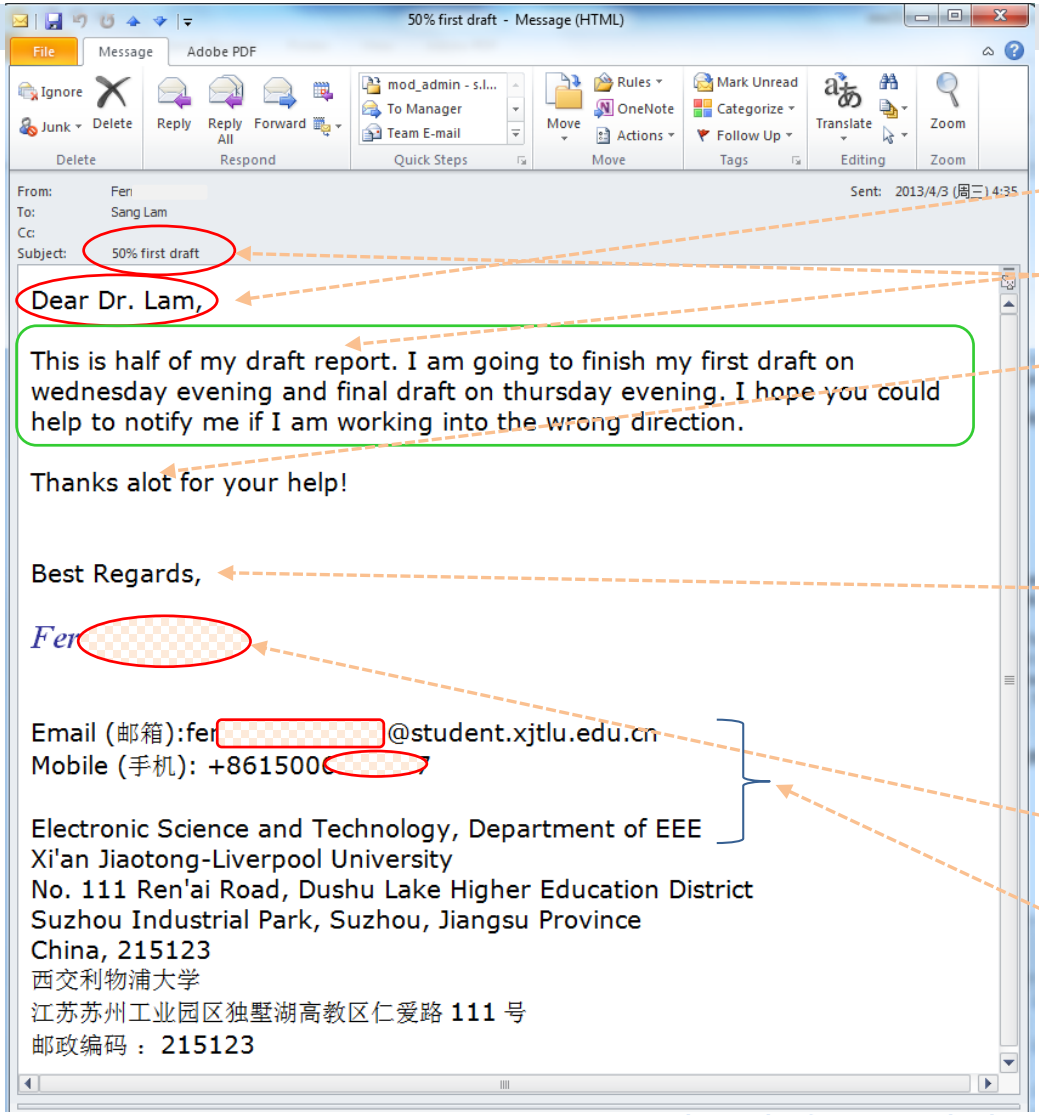
E-mail Communication

(an example e-mail)



- Include a courteous greeting
- Get to the subject
- Use proper English and check your spelling
- Close with "Regards, Sincerely, etc."
- Identify yourself
- Extra information

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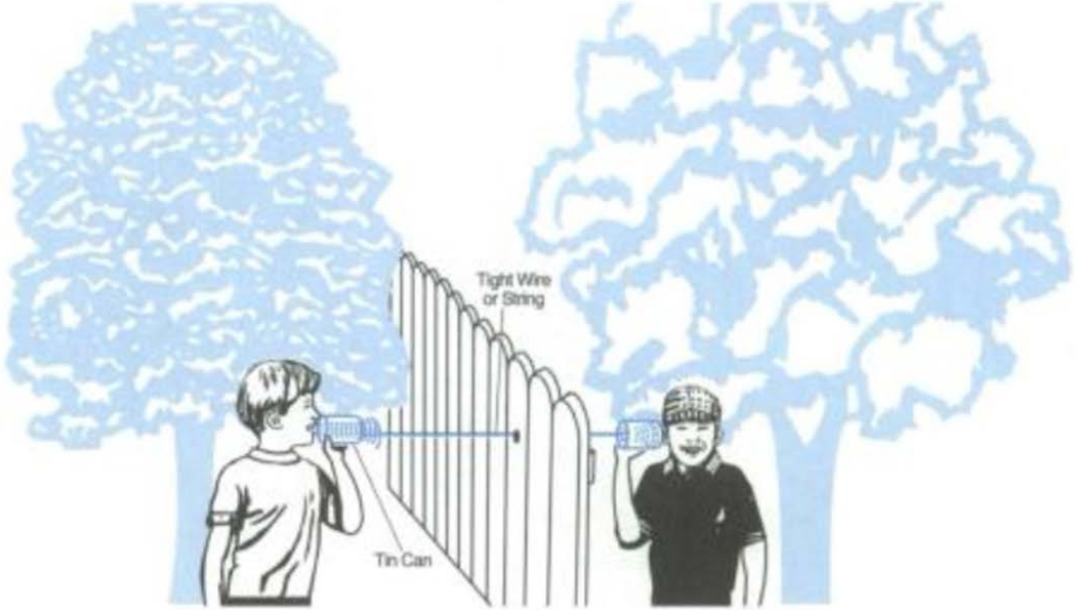
Communication

(exchange information/messages)

- **What is the essence of communication?**
  - **Communication** is the activity or process of ***exchanging information*** (including thoughts & feelings of people).
  - Information can be exchanged through voice and text written or printed on paper (e.g. mails).



- Examples of communication involving no electronics
- What are the limitations of such ways of communication?

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From: Jack Hudson & Jerry Luecke, *Basic Communications Electronics* © 1999 Master Publishing, USA.

Communications

(limitations of primitive ways)

- The basic form of communication in our daily life is verbal communication with two persons speaking to each other.
- But verbal communication have its limitation:
  - how many people the messages can be delivered to
  - the distance the messages can get to
  - how effective in the message delivery (e.g. speed, resources required, amount of messages)
- The similar limitations apply to other primitive ways of communications.
  - sending letters; using smoke signs

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Communication Using Electricity
(telegraph)

- With the development of electricity and magnetism in early 19th century, people discovered the good use of electricity for communication:
  - The battery, invented in 1800 by Alessandro Volta, provides the electricity.
  - Telegraph (with electrical signals transmitted over a wire) was invented in 1830s.
  - Samuel Morse and his assistant developed the Morse code in 1837 for transmitting messages effectively by telegraph.

Telegraph
(electronics)

- Telegraph overcame the limitations of primitive communications over a long distance.
- It in fact revolutionised long distance communication.
  - In 1844, a telegraph line (71 km) was built successfully to link Washington D.C. to Baltimore, Maryland in the US.
  - In 1866, a telegraph line across Atlantic Ocean was built, linking the US and Europe.
- With telegraph for sending or receiving messages over a long distance at faster speed, not much electronics was needed.

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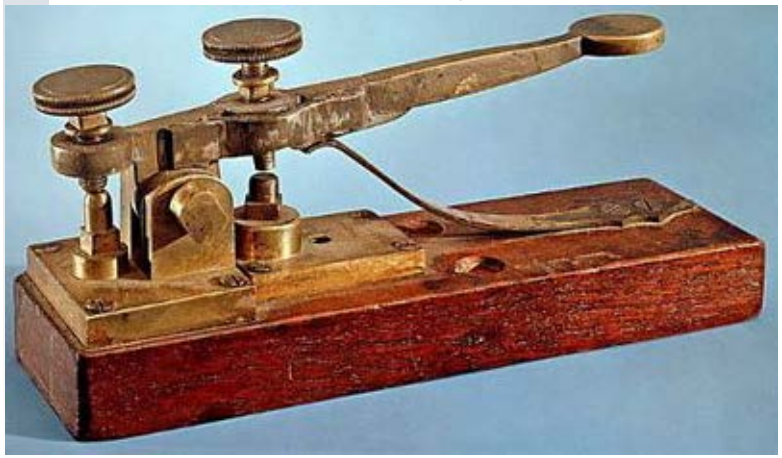
Telegraph
(electronics)

- The equipment used for **telegraph** was not sophisticated:
  - wires (including cable infrastructure)
  - power sources (which can be as simple as a **battery**)
  - telegraph key

(Image taken from Smithsonian Institution; available at http://americanhistory.si.edu/blog/2012/05/samuel-finley-breese-morse-artist-and-inventor.html)



- The technology involved no complicated theory of **electronics**:
  - **voltage** & **current** over a wire
  - mechanical devices

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Wireless Telegraph

(communication using radio waves)

- With the development of **electromagnetic** (EM) theory by James Clerk Maxwell in 1865 and the experimental verification by Heinrich Hertz in 1877, **wireless telegraph** was invented by various people (including Guglielmo Marconi) in 1890s with messages transmitted by **radio waves**.
- The equipment used for **wireless telegraph** was still not *sophisticated*.
  - A large **antenna** was needed.
  - Engineering knowledge of **electromagnetics** was essential rather than electronics.

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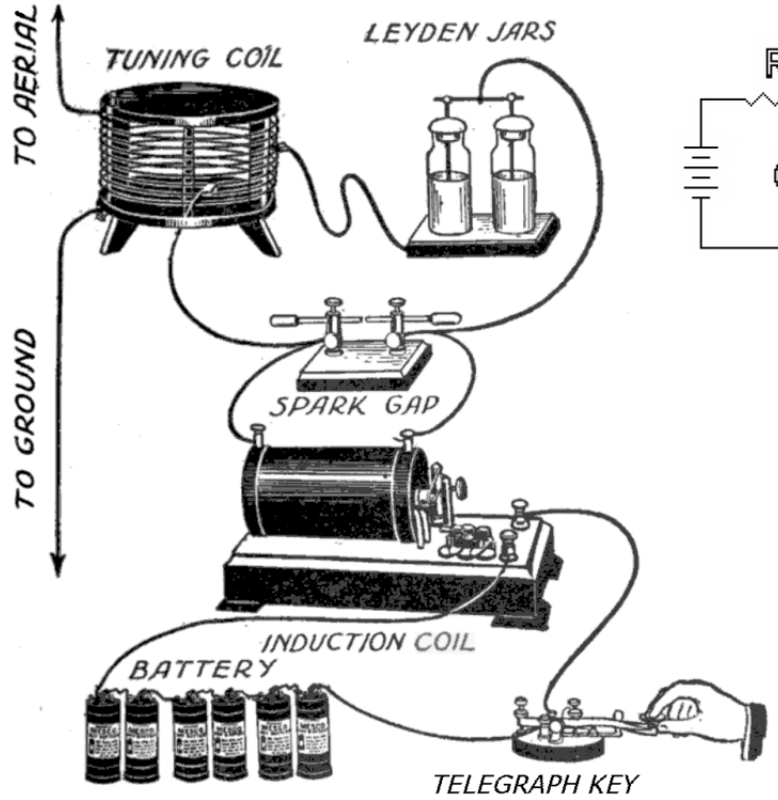
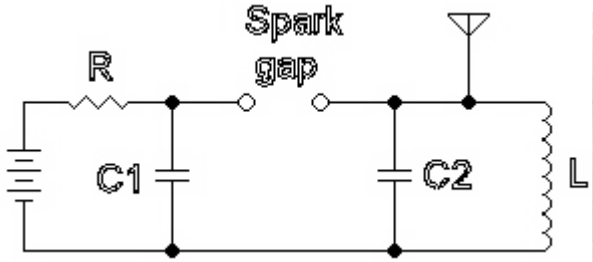
Wireless Telegraph

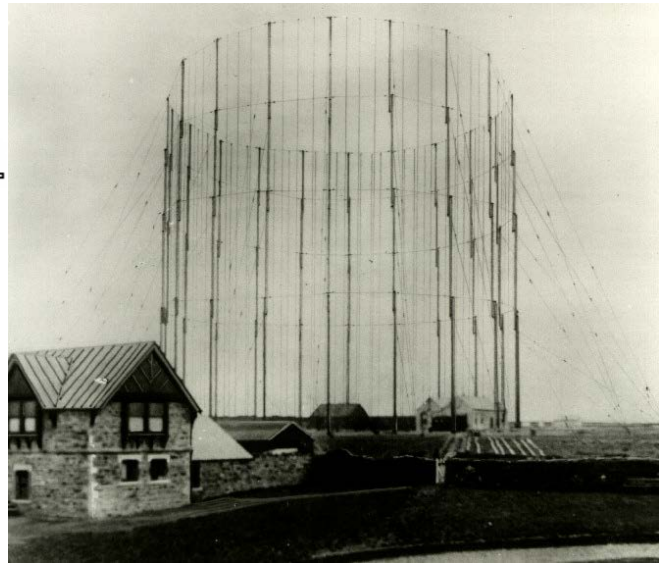
(communication using radio waves)

- The wireless telegraph system is conceptually simple according to today's electronic engineering.

(Image taken from Wikipedia; available at https://en.wikipedia.org/wiki/Spark-gap_transmitter)







(Image taken from OldRadio.com; available at https://www.oldradio.com/archives/jurassic/marconi.htm)

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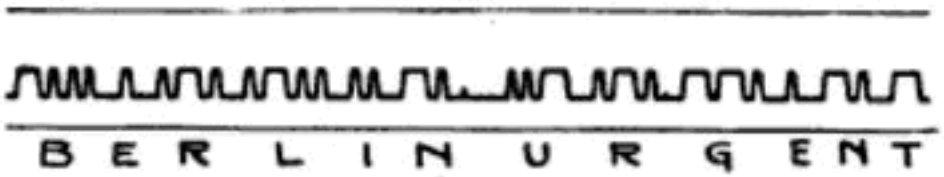
Communication by Radio Waves

(text messages & beyond)

- Although wireless telegraph marked the era of **wireless communication** by **radio waves**, only limited text messages were transmitted (using **Morse code**), the same as telegraph.



(Image taken from Wikipedia; available at https://en.wikipedia.org/wiki/Wireless_telegraphy)

  - The use of the radio spectrum was also very inefficient. Do you know why?

- People desired to ***communicate*** over a long distance not only **text** messages, but **voice/audio** (then later images and videos).

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Electronics for Communications

(vacuum electronics after discovery of electrons)

- The electron was first discovered in 1897 by J.J. Thomson. It marked the birth of **electronics** with the invention and development of **vacuum tubes**.
  - It is called **vacuum electronics** (versus **solid-state electronics** taught in electronic engineering curriculum nowadays).

(cf. P. A. Redhead, "The birth of electronics: Thermionic emission and vacuum," *Journal of Vacuum Science & Technology A* 16, 1394 (1998); available at: https://avs.scitation.org/doi/abs/10.1116/1.581157?journalCode=jva

- **Vacuum tubes** were used in radio receivers for detecting and amplifying electrical signals transmitted by radio waves.
  - vacuum diode (for rectification)
  - vacuum triode (for amplification)

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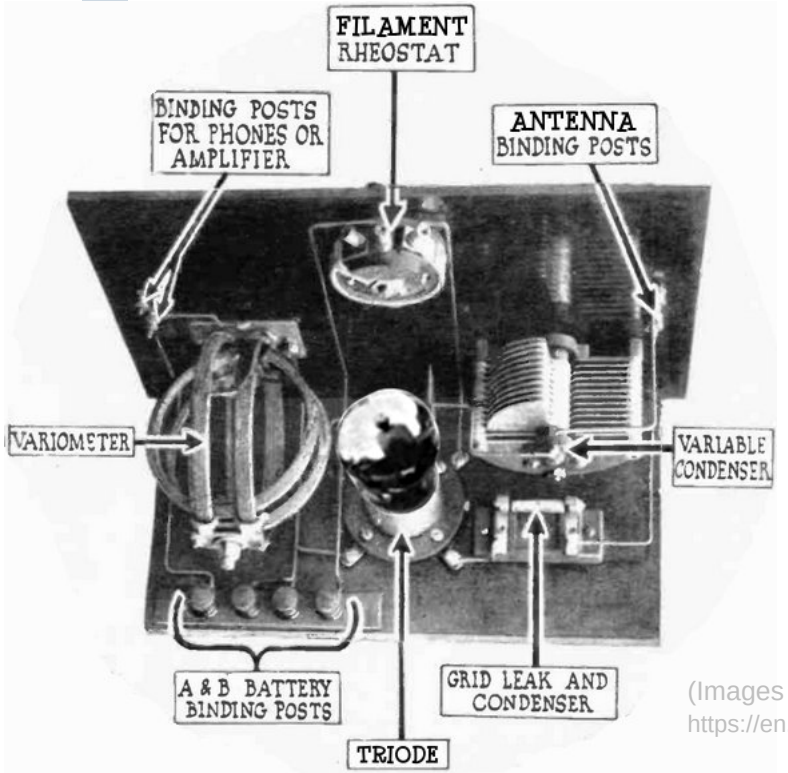
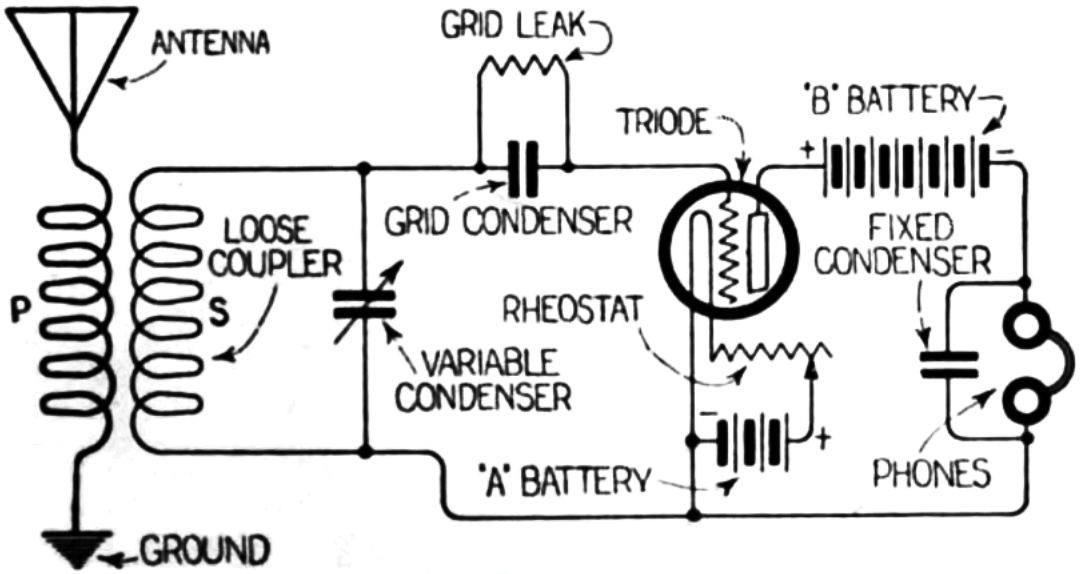
Electronics for Communications

(vacuum tubes in radio receivers)

- Starting from the use of **vacuum tubes** in radio communication, **electronics** has become essential in the development of communication systems.





(Images taken from Wikipedia; available at https://en.wikipedia.org/wiki/Radio_receiver)

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Electronics for Communications

(solid-state electronics)

- With the invention of transistor in 1947, radio communication was revolutionised.
  - Portable radio receivers were developed and radio communication was accessible by ordinary people.
  - Solid-state electronics has come into place.
- With the invention of semiconductor integrated circuits (ICs) in late 1950s, more compact radio transmitters and receivers with even more functionality are developed.
  - Nowadays, the electronic technology even allows the integration of transmitters and receivers (called **transceivers**).

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Electronics for Communications

(wireless communication systems)

- In our modern world, wireless communication systems are pervasive in our daily life.

From: R. C. Jaeger & T. N. Blalock, *Microelectronic Circuit Design*, 4e, © 2010 McGraw-Hill, USA.

From: Jack Hudson & Jerry Luecke, *Basic Communications Electronics* © 1999 Master Publishing, USA.

(Image taken from IEEE GlobalSpec; available at: https://www.globalspec.com/learnmore/communications_networking/networking_equipment/satellite_network_components)

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Electronics for Communications

(wireless communication among people)

- Not only text messages are transmitted but also voice/audio, images and videos.
  - Distance is no longer the limitation in exchanging information, particularly in the digital format, known as digital data.
  - To individuals or big groups of people.
- As the **internet-of-things** (**IoT**) emerges, wireless communications take place among not only people, but also electronic gadgets & appliances.
  - smart-home with sensing and actuating gadgets sending data to a control panel
  - wireless sensor networks

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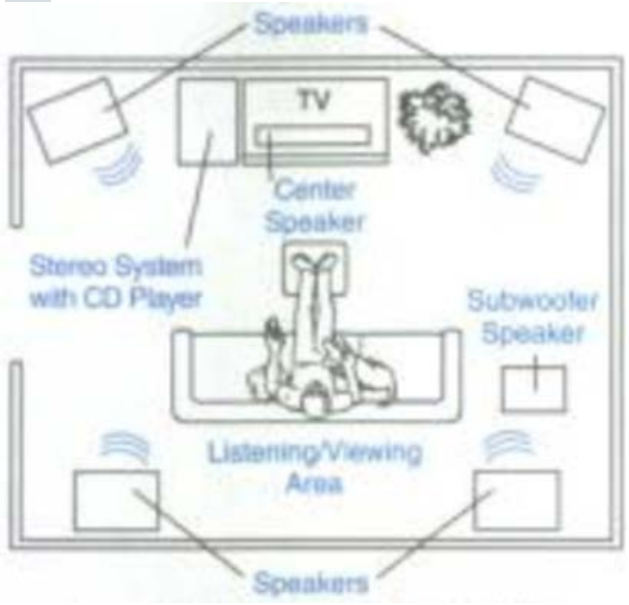
Electronics for Communications

(internet-of-things (IoT))

- Examples of wireless communication between electronic gadgets or appliances are common:
  - aerial imaging – sending image/videos
  - wireless speakers – sending audio data
  - wireless keyboards, computer mice

(Image taken from Gearbest.com; available at: https://www.gearbest.com/speakers/pp_642717.html)

(Image taken from DJI corporate website; available at: https://www.dji.com/phantom-4-pro-v2?site=brandsite&from=nav)



From: Jack Hudson & Jerry Luecke, *Basic Communications Electronics* © 1999 Master Publishing, USA.

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Electronics for Communications

(optical fibre communication)

- Apart from wireless communications using radio waves, **optical fibre communication** is also very important in our modern world for transmitting data at very high speed, especially for long distance.
  - The backbone of the internet is an optical fibre network.
  - Optical-fibre communication among servers in data centres.
- **Electronics** is needed, in addition to **photonic** components, to make circuits for **optical fibre communication**.
  - TIA

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Electronics for Communications

(circuits for communication systems)

- Knowledge of **electronics** (as well as **electromagnetics**) is indispensable to understand and develop solid-state circuits for wireless communication systems.
- The electronics industry would be in much need of engineers who have solid understanding of electronic circuits for communications and skills to design and make them.
  - Studying EEE307 well will help equip you to become competent electronic engineers.

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Electronics for Communications

(analogue electronics)

- With **wireless systems** and **optical-fibre communication systems**, information can be transmitted at very high speed, efficiently and at very low cost, compared with the past.
- Although nowadays **information** is so commonly ***represented***, ***processed***, ***stored*** and ***transmitted*** in the ***digital*** format, ***analogue*** **electronics** still plays a very important role in the developing circuits for all types of communication systems.
  - Why analogue electronics for communications?
  - In EEE307, you will learn mainly analogue circuits for processing and transmitting electrical signals transmitted by EM waves.

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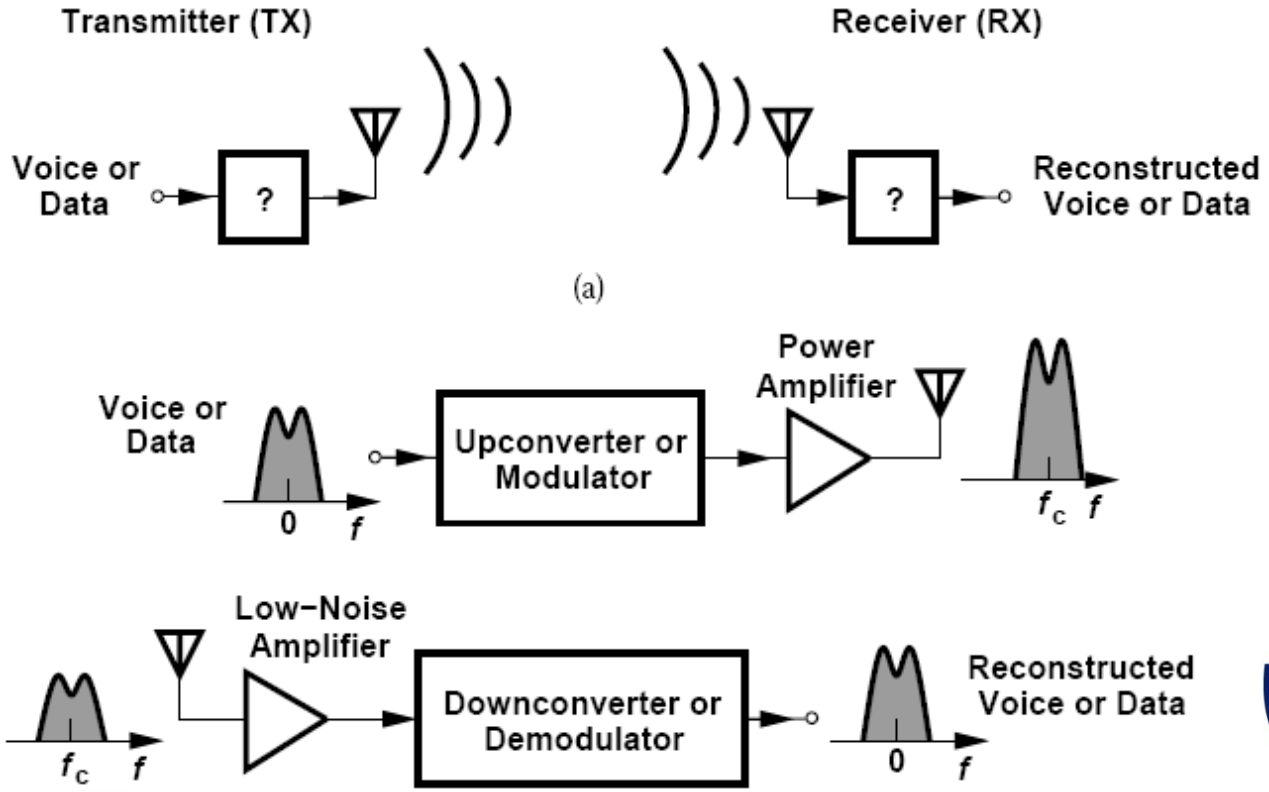
Wireless Communication Systems

(a big picture)

- A typical **wireless communication system** consists of a transmitter and a receiver which are in turn composed of different building blocks.

From: Behzad Razavi, *RF Microelectronics*, © 2012 Pearson , USA.



- The TX needs to drive the antenna with high power level.
- The RX needs to sense small signals (amplify with low noise).

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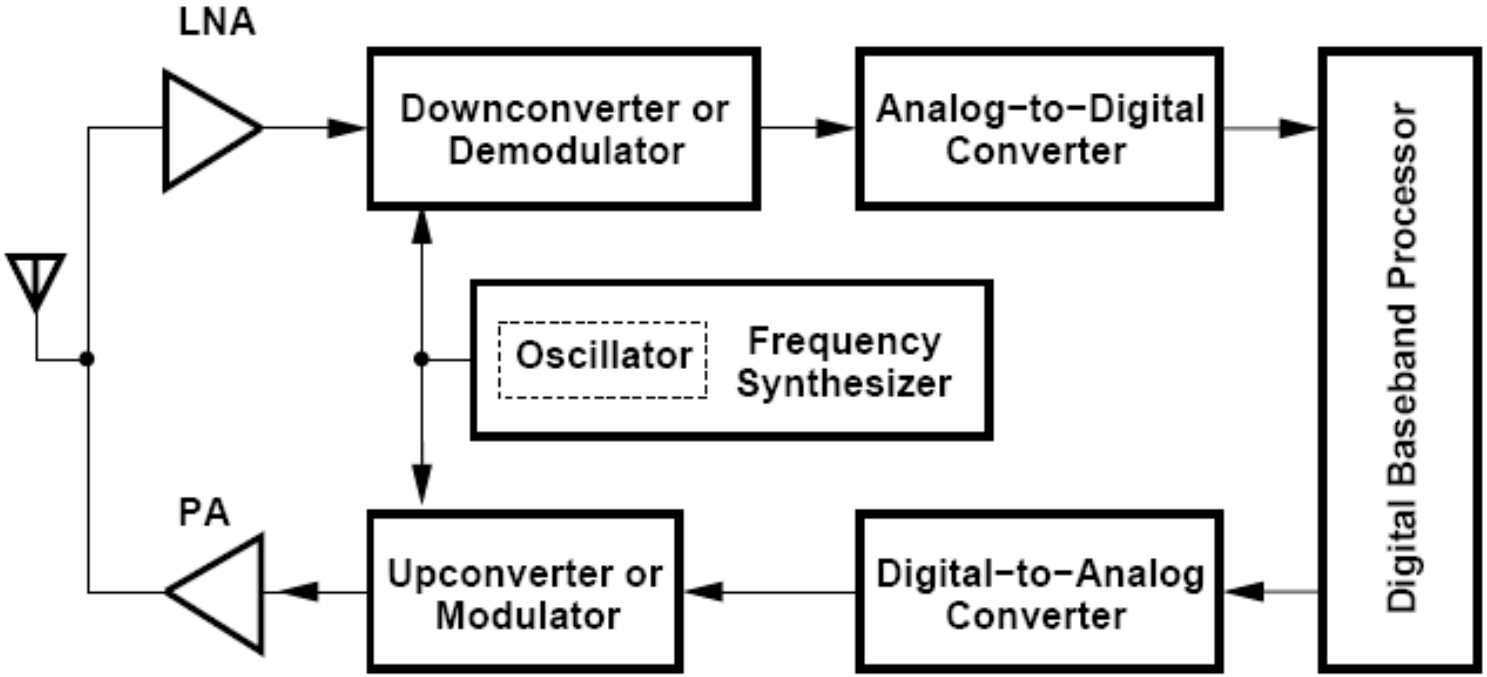
Wireless Communication Systems

(transceiver & building blocks)

- A transmitter and a receiver integrated together is called a transceiver and a generic radio transceiver is shown here.



From: Behzad Razavi, *RF Microelectronics*, © 2012 Pearson , USA.

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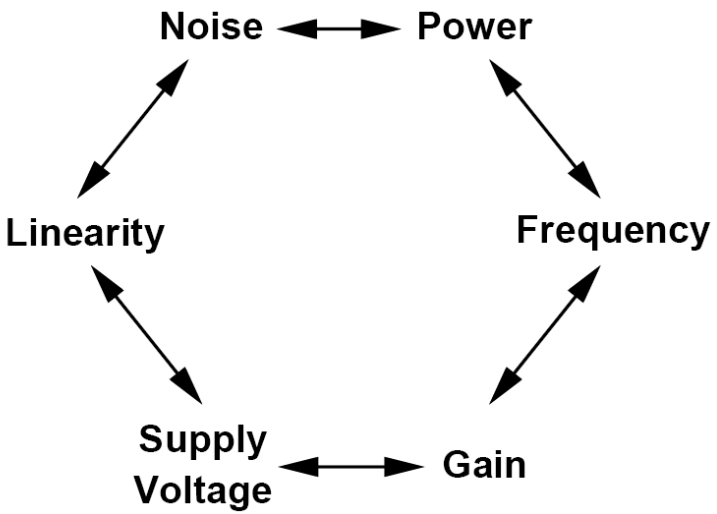
Circuits for Communications

(performance trade-offs)

- In this EEE307 module, you will learn about the design of and the principles behind building-block electronic circuits for wireless communications and some for optical fibre communication.
- There will be performance trade-offs in the circuits.



  - Ideally, we want to have high performance for the radio circuits in all aspects.
  - But the **cost** would be very high (even if it's possible to achieve the ideal).

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From: Behzad Razavi, *RF Microelectronics*, © 2012 Pearson , USA.

Wireless Communications

(generation evolution from 1G to 5G)

- 1st generation (1G): analogue-based (e.g. AMPS)
  - voice only
- 2nd generation (2G): digital-based & cellular network (e.g. GSM)
  - voice and data (text messages)
- 3rd generation (3G): faster data transmission and video transmission allowed in addition to 2G
  - wireless modem
- 4th generation (4G): even faster data transmission and mobile internet connection (e.g. LTE)
- 5th generation (5G): mmwave, IoT

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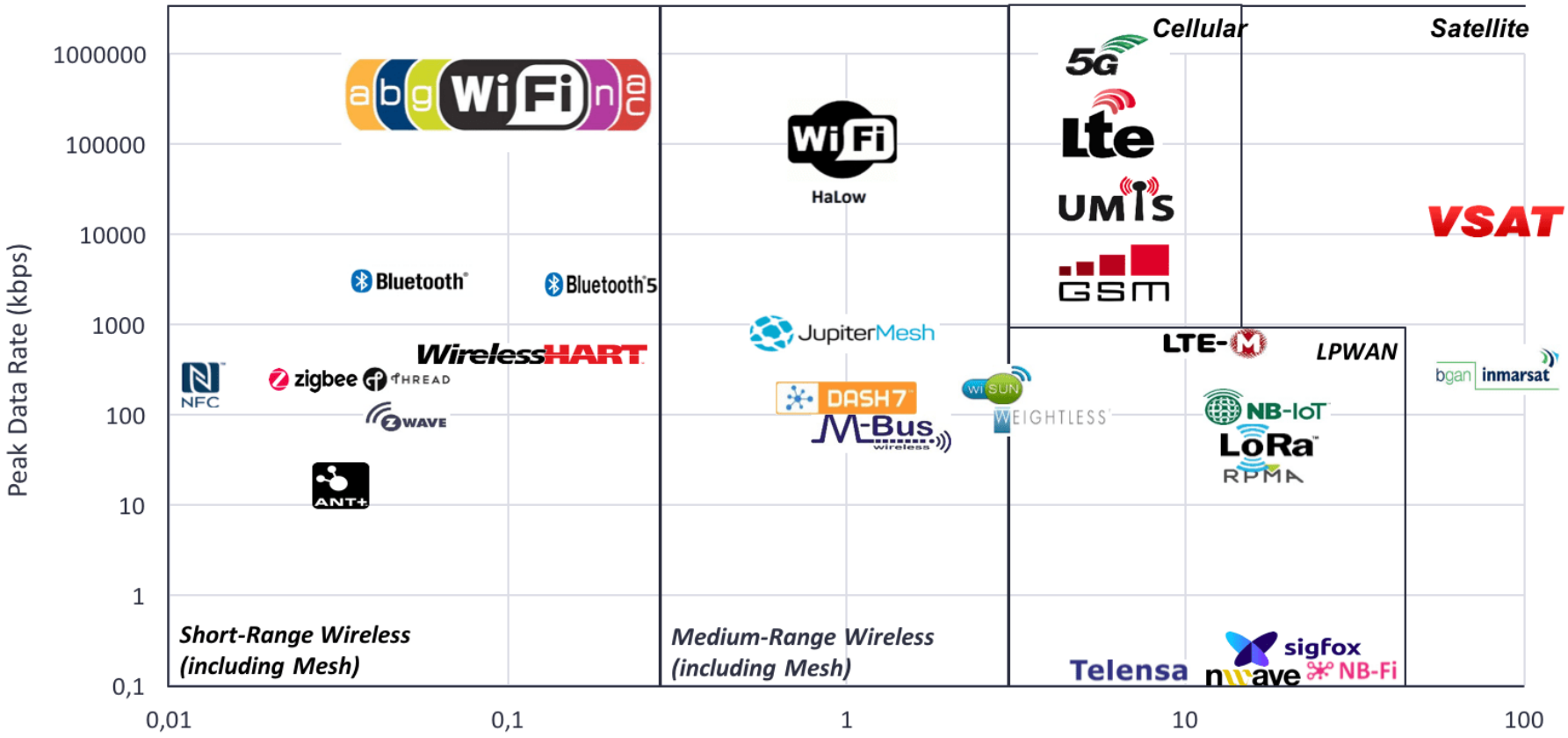
Wireless Technologies

(various data rate & transmission range)



(Chart taken from the IoT Analytics website; available at: https://iot-analytics.com/iot-segments/iot-connectivity/)

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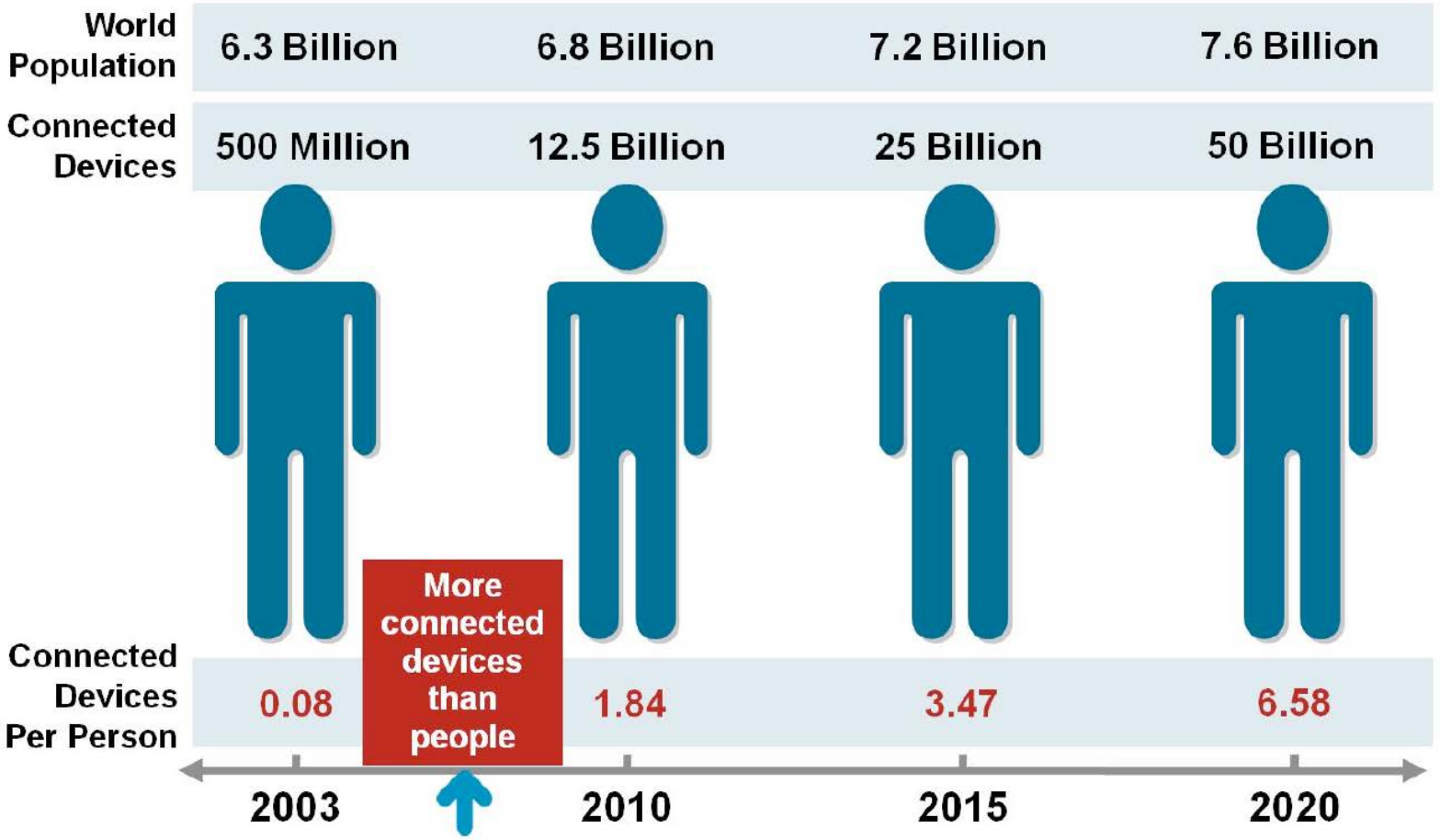
Wireless Connected Devices

(increasing faster than population)



(Chart source: D. Evans, "**The Internet of Things: How the Next Evolution of the Internet Is Changing Everything**," *White Paper by Cisco Internet Business Solutions Group* (*IBSG*), April 2011; available at: https://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf)

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