Study Unit Overview

Main topics:
- Introduction to RF/Microwave Systems
- RF Performance Parameters
- Transceiver Architectures
- Frequency Synthesizers
- Transmission Lines
- Matching Networks

Assignments:
- Develop a Matlab® code to design L-Section Matching Networks
- Design and Implementation of an all Digital Phase Locked Loop

Exam 80%
Assignments 20%
Historical Perspective

- Wireless technology came to existence when in 1901, Guglielmo Marconi successfully transmitted radio signals across the Atlantic Ocean.

- The consequences and prospects of replacing telegraph and telephone communications with wave transmission through air portrayed a promising future.

- Two-way wireless communication did materialise in military applications but in daily life applications transmission remained limited to one-way radio and television broadcast.

- Ordinary two-way phone conversations would still go over wires for many decades.
Historical Perspective

- The invention of the transistor, the development of Shannon’s information theory and the conception of the cellular system (all at Bell Labs) paved the way for affordable mobile communications.

- But why the sudden surge in wireless systems?

- E.g. demand in the mobile phone industry motivated competitive manufacturers to provide phone sets with increasingly higher performance, functionality and lower cost.

- Multi-standard technology
The Frequency Spectrum

GPS: 1176.45 - 1575.42 MHz

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 GHZ - 300 GHZ</td>
<td>extremely high frequency</td>
</tr>
<tr>
<td>3 GHZ - 30 GHZ</td>
<td>superhigh frequency</td>
</tr>
<tr>
<td>300 MHz - 3 GHZ</td>
<td>ultrahigh frequency</td>
</tr>
<tr>
<td>30 MHZ - 300 MHZ</td>
<td>very high frequency</td>
</tr>
<tr>
<td>30 KHZ - 300 KHZ</td>
<td>high frequency</td>
</tr>
<tr>
<td>3 KHZ - 30 KHZ</td>
<td>medium frequency</td>
</tr>
<tr>
<td>300 Hz - 3 KHZ</td>
<td>low frequency</td>
</tr>
<tr>
<td>Up to 300 Hz</td>
<td>extremely low frequency</td>
</tr>
</tbody>
</table>

Simplified IEEE Frequency Spectrum

GSM: 900 MHz

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RF Design Considerations

- Today’s mobile devices contain more than 1 million transistors, with only a small fraction operating in the RF range and the rest performing low-frequency “base-band” analog and digital signal processing.

- The RF section is still the design bottleneck of the entire system:
  - Multidisciplinary Field
  - RF Design Hexagon
  - Design Tools
Disciplines required in RF Design

- Traditional wireless system design has been carried out at somewhat disjointed levels of abstraction.

- As the industry moves toward higher integration and lower cost, RF and wireless design demands increasingly more concurrent engineering.
RF and μwave Design Hexagon

- Noise
- Power
- Linearity
- RF and Microwave Design
- Supply Voltage
- Operating Frequency
- Gain
Design Tools (CAD)

- Computer-aided analysis and synthesis tools for RF systems are still in their infancy: designer experience, intuition or inefficient simulation techniques.

- E.g. nonlinearity, time variance and noise in RF systems usually require studying the spectrum of signals, but the standard ac analysis uses only linear, time-invariant models.

- So systems (or circuits) are simulated in time to include non-linear effects and then translated in the frequency domain – time consuming + special techniques.

- What about external components to the system? First order approximations. E.g. Surface Acoustic Wave filters
Analog Wireless Transceivers

- In the transmit path, the signal generated by the mic modulates a high-frequency carrier, and the result is amplified and buffered so as to drive the antenna.

- In the receive path, the signal is amplified by an LNA, the spectrum is translated to a lower frequency by a down-converter (mixer) to facilitate demodulation and baseband processing to finally drive the speaker.
Digital Wireless Transceivers

In the digital case, the voice is first digitized by an ADC and compressed to reduce the bit rate and hence the bandwidth.

Next, the data undergoes “coding” and “interleaving”. These functions format the data such that the receiver can detect and minimize errors by performing the reverse operations.

Since rectangular pulses are usually not optimum for modulation, the data is “shaped” before applying it to the modulator and PA.
Transceiver Performance

- The performance of these transceivers can be quantified in terms of the maximum distance across which they operate while providing satisfactory reception.

- Power delivered to the antenna and the sensitivity of the receiver, particularly the noise of the LNA and the type of modulation/demodulation scheme.

- In a real environment, many different transceivers operate together and near to each other, thereby interfering with each other.

- The communication medium is also quite complex: reflections from buildings and other obstacles can result in destructive interference at a given point, suppressing the received signal strength to undetectable levels.

- In such an environment, signal processing in the digital transceiver achieves a higher performance than that of the analog system.
Books / References

- RF Microelectronics by Behzad Razavi.