RF Communication System

EE 172
Systems Group Presentation
RF System Outline

- Transmitter Components
- Receiver Components
- Noise Figure
- Link Budget
- Test Equipment
- System Success
- Design Remedy
Transmitter Components

- Audio Transducer
- Oscillator
- Modulator
- Band Pass Filter
- Power Amplifier
- Low Pass Filter
- Antenna
Receiver Components

- Antenna
- Evanescent Mode Filter
- Low Noise Amplifier
- Oscillator
- Demodulator
- Band Pass Filter
- Speaker
System Block Diagram

Transmitter

Audio
Modulator
Filter
Oscillator
Filter
PA
PA
Filter
Antenna

Receiver

Speaker
Filter
Demodulator
LNA
Filter
Antenna
Noise Figure

- The Noise Figure (NF) is the increase of noise power from the input to the output of a network.
- “White noise”, or noise power, is constant in RF and microwave frequencies.
- Noise is mainly important on the receiver end due to the low signal strength.
Noise Figure (LNA example)

- Noise Figure is the ratio of the signal to noise power going into a device compared to the signal to noise ratio coming out.
- Noise Figure of a passive device, such as a filter, is equal to its attenuation.
Link Budget - Expected

\[ P_T = \text{Transmitter power (dBm)} \quad 30 \text{ dBm} \]
\[ G_T = \text{Transmitter antenna gain (dB)} \quad 3 \text{ dB} \]
\[ G_R = \text{Receiver antenna gain (dB)} \quad 10 \text{ dB} \]
\[ P_L = \text{Path Loss (dB)} \quad -154 \text{ dB} \]
\[ T_P = P_T + G_T + G_R + P_L \quad -111 \text{ dBm} \]

*Path loss is an estimated value. Propagation engineers would be responsible for this value.*
### Link Budget - Calculations

<table>
<thead>
<tr>
<th>Parameters &amp; Calculations</th>
<th>Transmitter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Modulator (oscillator terminated)</td>
</tr>
<tr>
<td>S11 (dB)</td>
<td>-6.01</td>
</tr>
<tr>
<td>S12 (dB)</td>
<td>-39.50</td>
</tr>
<tr>
<td>S21 (dB)</td>
<td>-40.30</td>
</tr>
<tr>
<td>S22 (dB)</td>
<td>-2.48</td>
</tr>
<tr>
<td>( \rho )</td>
<td>0.50</td>
</tr>
<tr>
<td>Return Loss (dB)</td>
<td>-6.01</td>
</tr>
<tr>
<td>Insertion Loss (dB)</td>
<td>-39.50</td>
</tr>
<tr>
<td>SWR</td>
<td>3.00</td>
</tr>
<tr>
<td>P reflected</td>
<td>25%</td>
</tr>
<tr>
<td>P transmitted</td>
<td>75%</td>
</tr>
</tbody>
</table>
# Link Budget - Calculations

<table>
<thead>
<tr>
<th>Parameters &amp; Calculations</th>
<th>Receiver</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amplifier</td>
</tr>
<tr>
<td>S11 (dB)</td>
<td>-11.10</td>
</tr>
<tr>
<td>S12 (dB)</td>
<td>-47.00</td>
</tr>
<tr>
<td>S21 (dB)</td>
<td>-47.00</td>
</tr>
<tr>
<td>S22 (dB)</td>
<td>-4.70</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.28</td>
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<tr>
<td>Return Loss (dB)</td>
<td>-11.10</td>
</tr>
<tr>
<td>Insertion Loss (dB)</td>
<td>-47.00</td>
</tr>
<tr>
<td>SWR</td>
<td>1.77</td>
</tr>
<tr>
<td>$P_{\text{reflected}}$</td>
<td>8%</td>
</tr>
<tr>
<td>$P_{\text{transmitted}}$</td>
<td>92%</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Transmitter power:</td>
<td>16 dBm</td>
</tr>
<tr>
<td>Transmitter antenna gain:</td>
<td>6 dB</td>
</tr>
<tr>
<td>Free space path loss:</td>
<td>-71 dB</td>
</tr>
<tr>
<td>Obstacle loss:</td>
<td>-20 dB</td>
</tr>
<tr>
<td>Multipath loss:</td>
<td>-20 dB</td>
</tr>
<tr>
<td>Receiver antenna gain:</td>
<td>10 dB</td>
</tr>
<tr>
<td>Received carrier power:</td>
<td>-79 dB</td>
</tr>
<tr>
<td>Thermal noise in 1 MHz</td>
<td>-114 dB</td>
</tr>
<tr>
<td>30 kHz bandwidth correction</td>
<td>-15 dB</td>
</tr>
<tr>
<td>Receiver noise figure:</td>
<td>-6 dB</td>
</tr>
<tr>
<td>Noise floor:</td>
<td>-123 dB</td>
</tr>
<tr>
<td>Carrier to noise ratio:</td>
<td>32 dB</td>
</tr>
</tbody>
</table>
Test Equipment

- Network Analyzer
  - to retrieve S-parameters for reflection calculations
- Spectrum Analyzer
  - to determine gain, bandwidth, and frequency measurements from components
- Power Supply
  - power up subsystems as needed
System Success

- The RF Communications System did not work 😞
- Major factors for measuring our success includes:
  - power loss across all subsystems
  - gain was nominal versus loss
  - missing components vital for success
  - test yields were astray from specs
System Success

- Overall subsystems are lossy as opposed to ideal conditions
- Amplifier gain was 6 dB versus 15 dB as specs had stated and were missing 2 out of 3 of them.
- The Low Pass Filter had a tested cutoff frequency of 850 MHz versus 940 MHz as specs had stated.
- Demodulator tests showed that the carrier frequency was not removed.
- Systems attempted some remedial tactics.
Design Remedy

- New amplifier was designed that yielded better gain. (with help of Elena from Oscillator group)
- Attempted to design a new low pass filter to remedy cutoff frequency
- Furthermore, the systems group recommends that all the subsystems be matched for the least reflections and loss.
Systems Analysis Team

- Sahel Jalal
- Rizwan Khalid
- Kartik Patel
- Gurvinder Dilawari
- Ankush Mohan

Questions and Answers…
Oscillator

Specifications
Frequency: 915 MHz  Amplitude: 0 dBm  Phase Noise:

Actual Measurements
Frequency: 915.2 MHz  Amplitude: 1.8 dBm  Phase Noise:
Modulator Specifications
Conversion Loss: 10 dB  Spurious: None

Actual Measurements
Conversion Loss: 17 dB  Spurious: 872 MHz, 924 MHz

Transmitter
Band Pass Filter

Specifications
Center Frequency: 915 MHz  Bandwidth: 915 MHz +/- 15%
Insertion Loss: 10 dB

Actual Measurements
Center Frequency: 1.2 GHz  Bandwidth: 200 Mhz
Insertion Loss: 46 dB @ 915 MHz
Power Amplifier

Specifications
- Frequency: 915 MHz
- Gain: 15 dB
- Saturation: 28 V

Actual Measurements
- Frequency: 915 MHz
- Gain: 6 dB
- Saturation: 22 V
Low Pass Filter

Specifications
Cutoff Frequency: 940 MHz
Insertion Loss: 10 dB

Actual Measurements
Cutoff Frequency: 850 MHz
Insertion Loss: 4.7 dB
Antenna Specifications
Gain: 3 dB  Frequency Range: 910 MHz to 920 MHz

Actual Measurements
Gain: 6 dB  Frequency Range: 910 MHz to 920 MHz
Antenna Specifications

- Gain: 10 dB
- Frequency Range: 910 MHz to 920 MHz

Actual Measurements

- Gain: 9-12 dB
- Frequency Range: 910 MHz to 920 MHz
Evanescent Mode Filter

Specifications
- Center Frequency: 915 MHz
- Bandwidth: 140 MHz
- Insertion Loss: 10 dB

Actual Measurements
- Center Frequency: 915 MHz
- Bandwidth: 140 MHz
- Insertion Loss: 14 dB
Low Noise Amplifier

Specifications
Gain: 15 dB  Frequency: 915 MHz

Actual Measurements
Missing originally, systems designed
Gain: 20 dB  Frequency: 915 MHz
Demodulator

Specifications
Conversion Loss: 10 dB  Spurious: None

Actual Measurements
Conversion Loss: 17 dB  Spurious: 875 MHz, 928 MHz
Band Pass Filter

Specifications
Conversion Loss: 10 dB
Bandwidth: 915 MHz +/-15%
Spurious: None

Actual Measurements
Conversion Loss: 8.1 dB
Bandwidth: 873 MHz to 960 MHz
Spurious: None

Receiver