# Analog Optical Links for Wide Bandwidth Radar Receivers

**Sean Morris & Brian Potts**

**MQP Presentation**

**Group 33**

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# Motivation

- **Replace coaxial transmission line in radar receiver with analog optical link to:**
  - **Receive full bandwidth signal at the control center**
  - **Improve accessibility of receiver hardware**
  - **Allow remoting of radar back-end hardware**

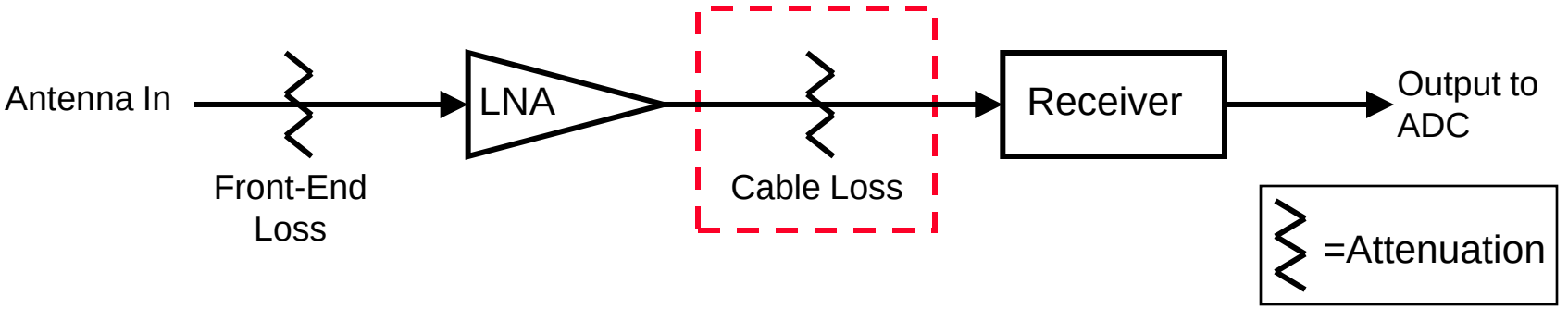
**Example instrumentation radar system**

# Goals & Objectives

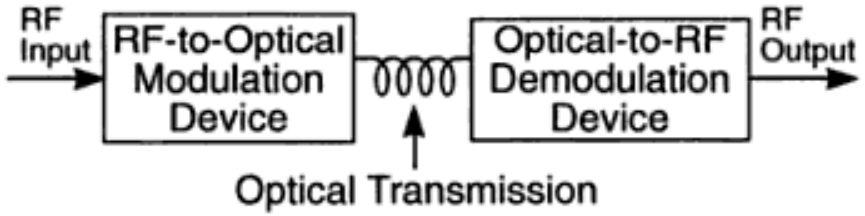
- **Goal**
  - Determine feasibility of using an analog optical link for transmission of a received radar signal
- **Objectives**
  - Conduct a cost-benefit analysis of coaxial cable vs. analog optical links
  - Create tools that model the performance of the receiver side of a radar system
  - Become familiar with a commercial analog optical link
  - Determine if a design can be realized with a currently available commercial analog optical link

# Technical Overview

- **Receiver Side of Radar System**



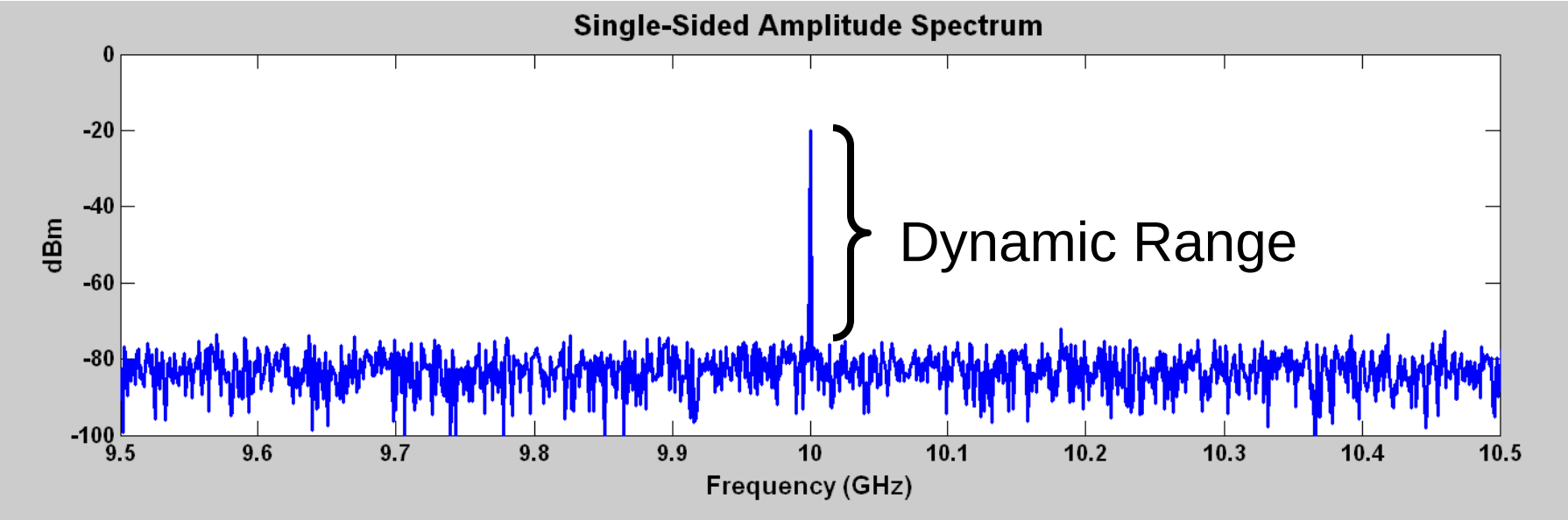

- **Analog Optical Link**




Source: C. H. Cox, *Analog Optic Links: Theory and Practice.* Cambridge, UK: Cambridge University Press, 2004, pp. 288.

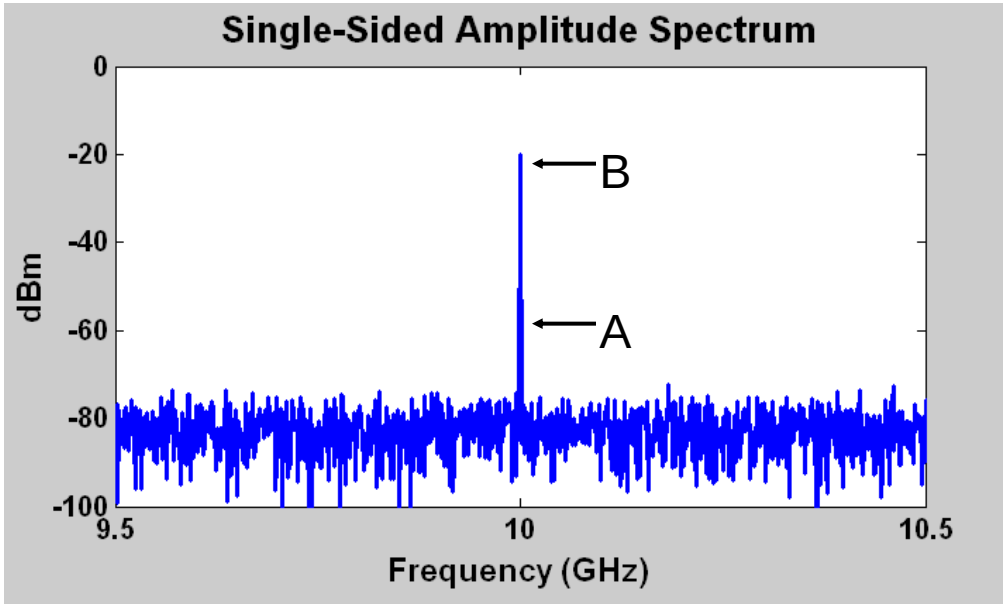
# Specifications to Meet

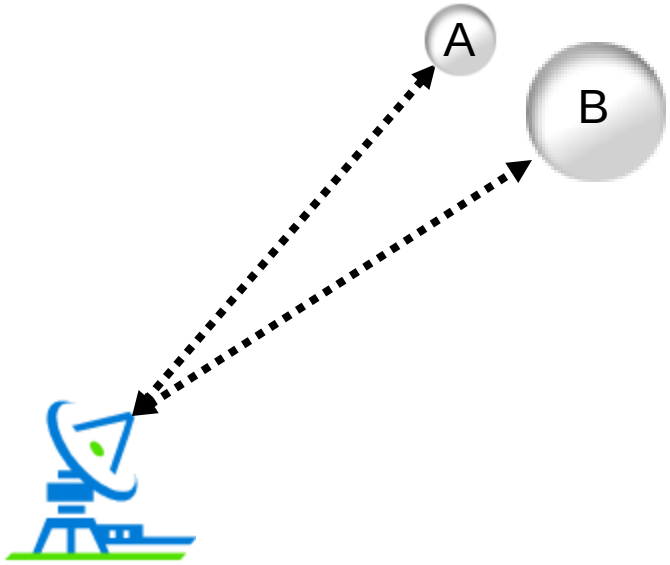
- **Instantaneous Dynamic Range (50 dB)**
  - **Saturation**
  - **Noise Figure**



# Specifications to Meet

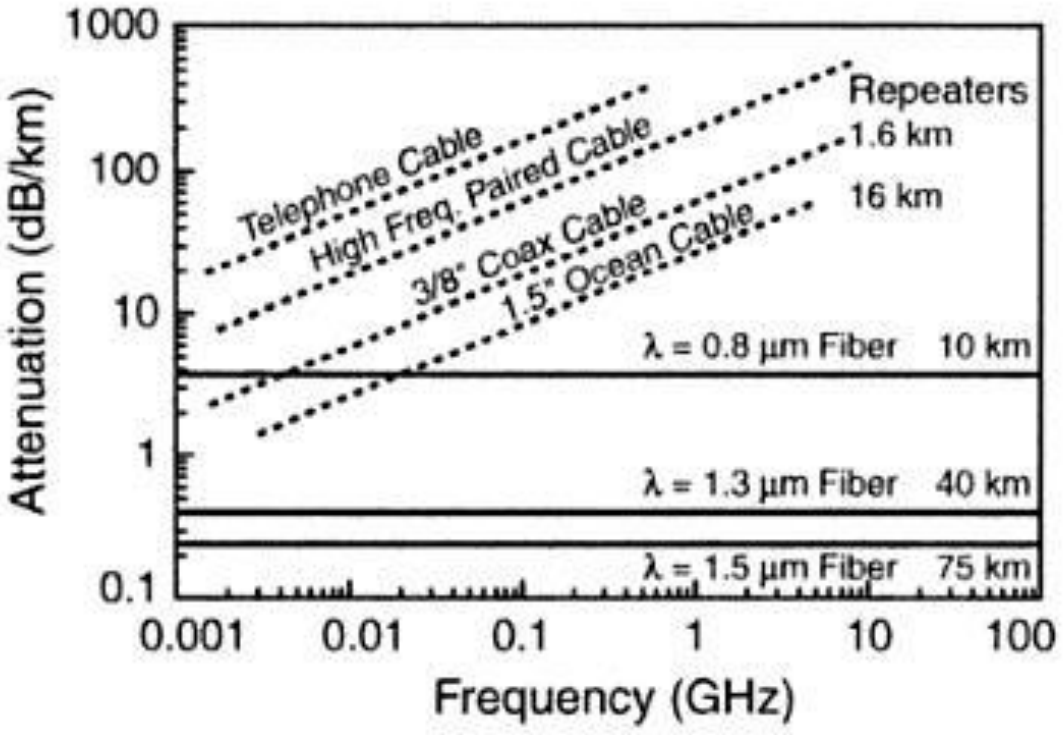
- Instantaneous Dynamic Range (50 dB)
  - Saturation
  - Noise Figure
- **Sensitivity (30 dB signal-to-noise ratio (SNR) for 1m$^2$ target at distance of 1000 km)**
  - **Noise Figure**



# Coax vs. Analog Optical Links

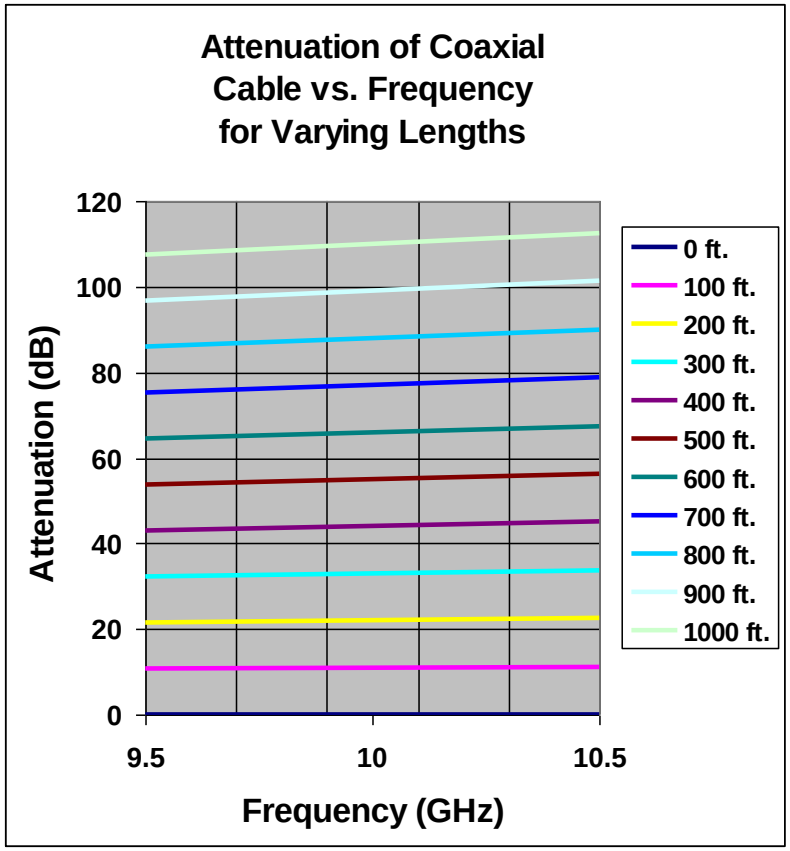
- **Performance Analysis**
  - **Attenuation**



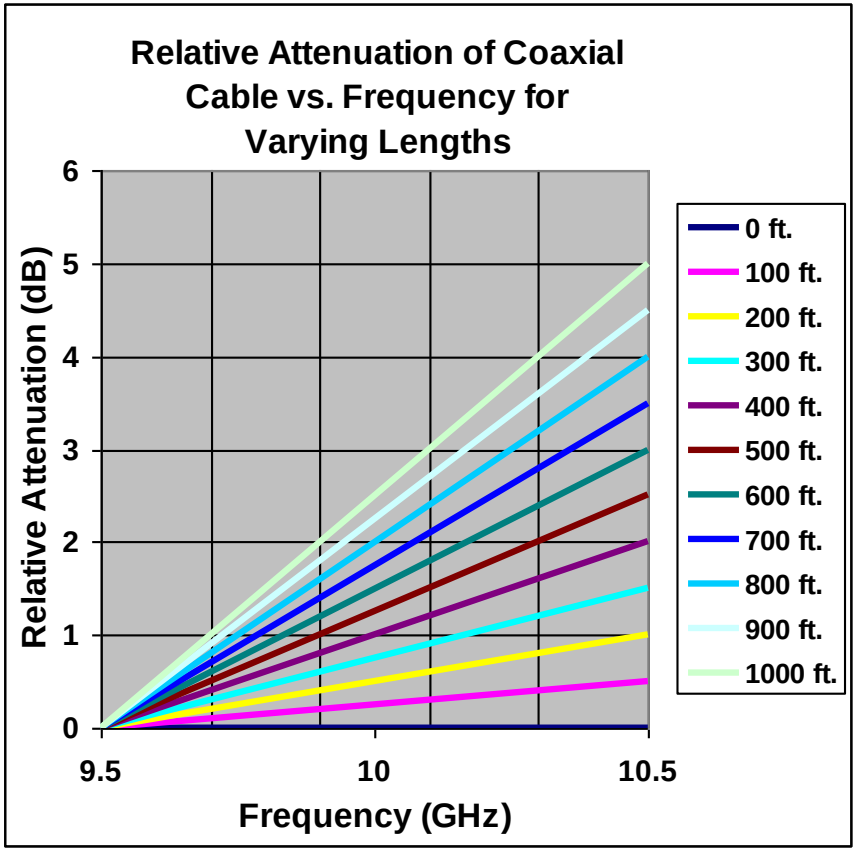

Source: C. H. Cox, *Analog Optic Links: Theory and Practice.* Cambridge, UK: Cambridge University Press, 2004, pp. 288.

# Coax vs. Analog Optical Links

- **Performance Analysis**
  - Attenuation
  - **Coax Attenuation Slope**



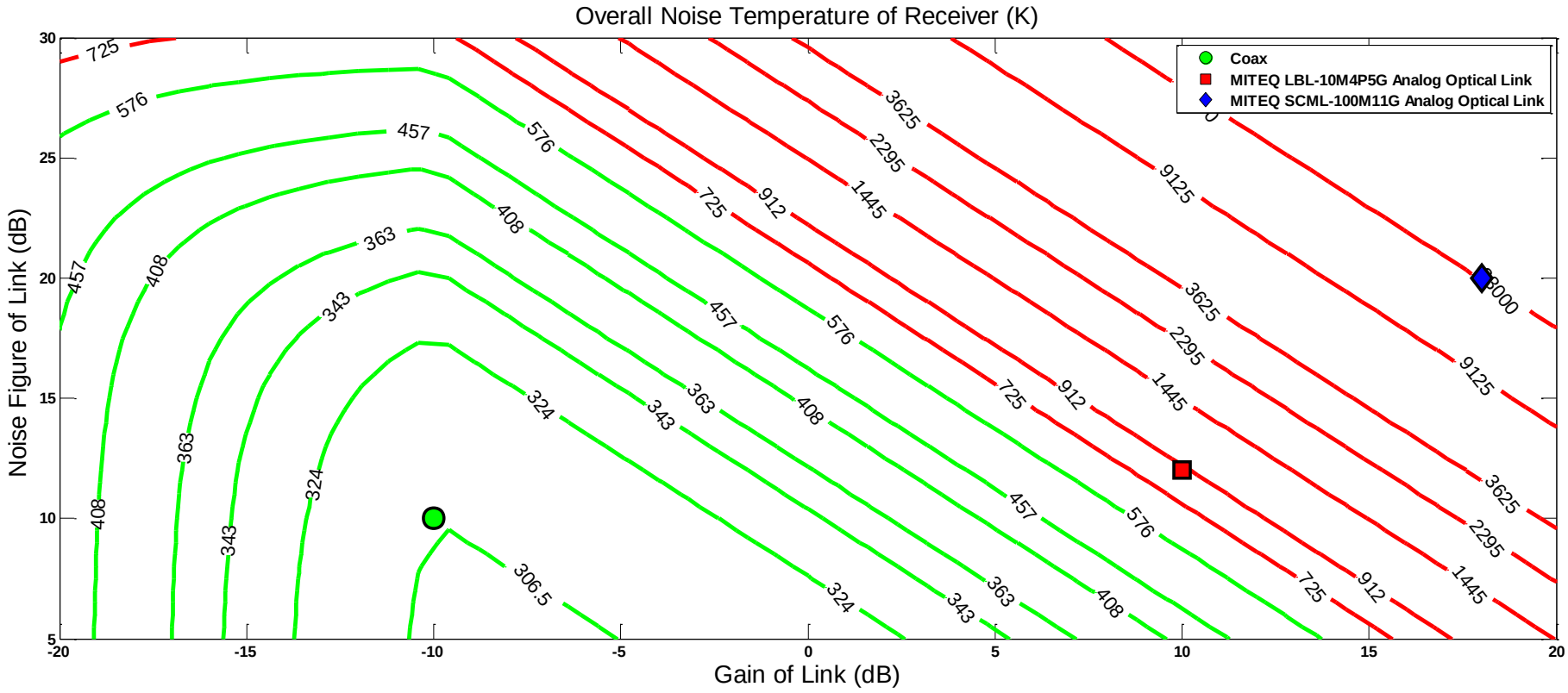

*Approximation of data provided by IW Microwave for IW4806 Cable




*Approximation of data provided by IW Microwave for IW4806 Cable

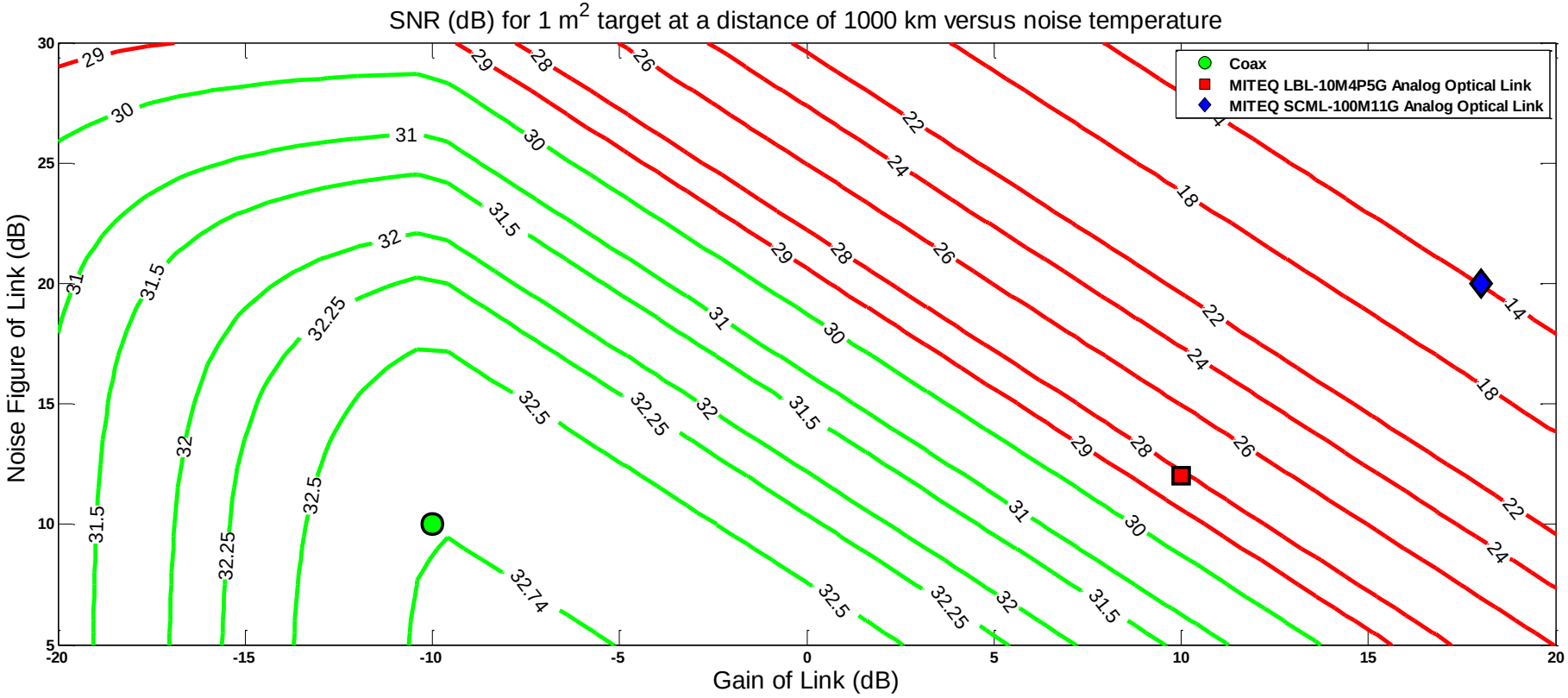
# Coax vs. Analog Optical Links

- **Performance Analysis**
  - Attenuation
  - Coax Attenuation Slope
  - **Noise Temperature**



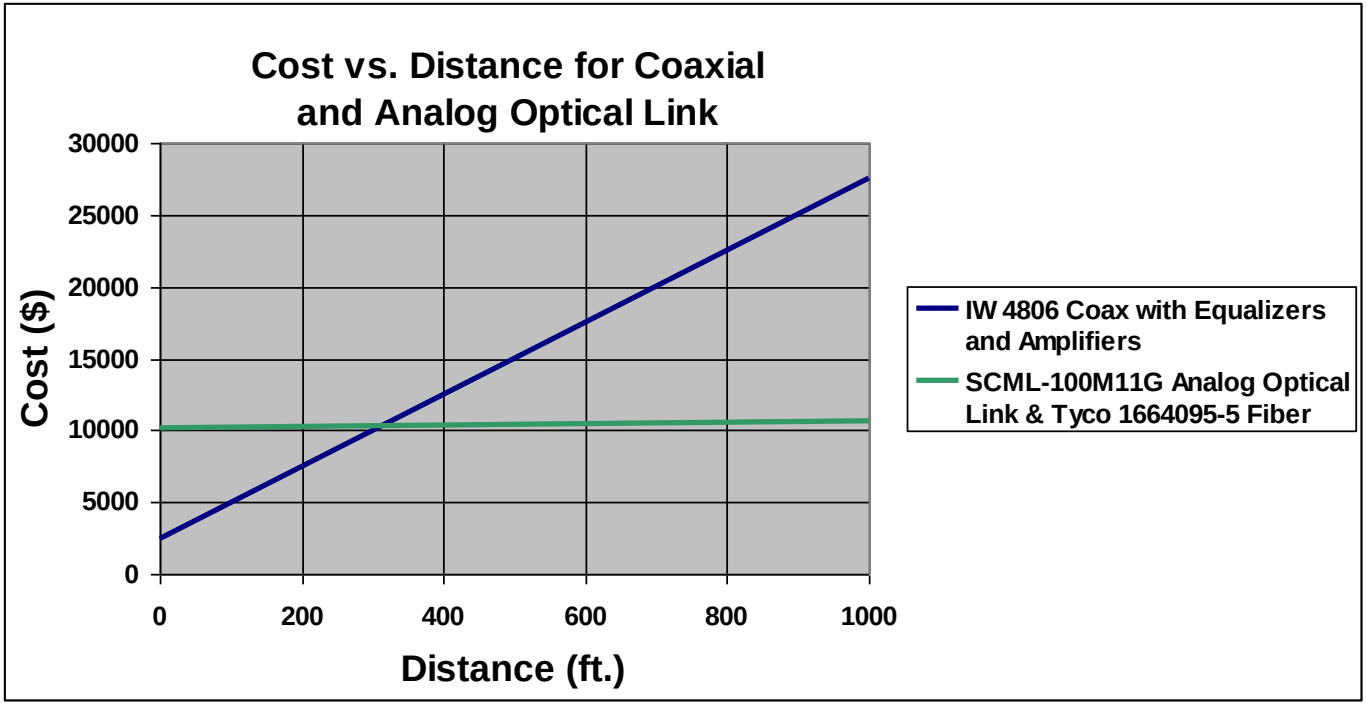
# Coax vs. Analog Optical Links

- **Performance Analysis**
  - Attenuation
  - Coax Attenuation Slope
  - **Noise Temperature**

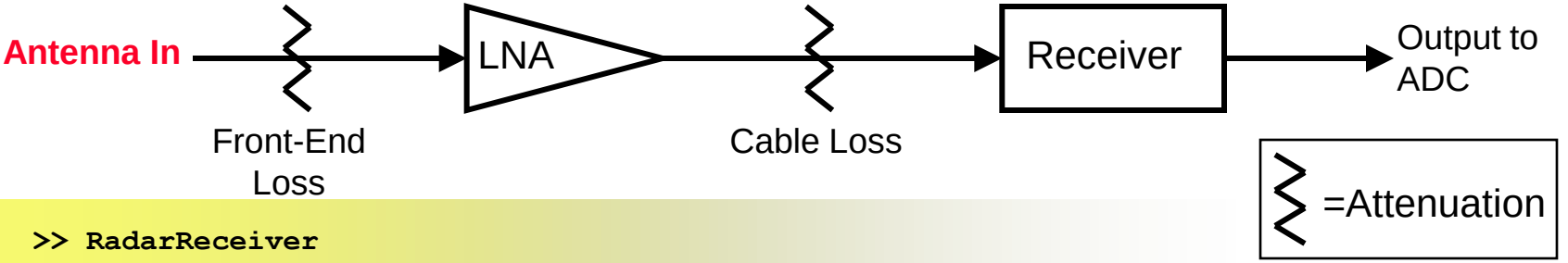


# Coax vs. Analog Optical Links

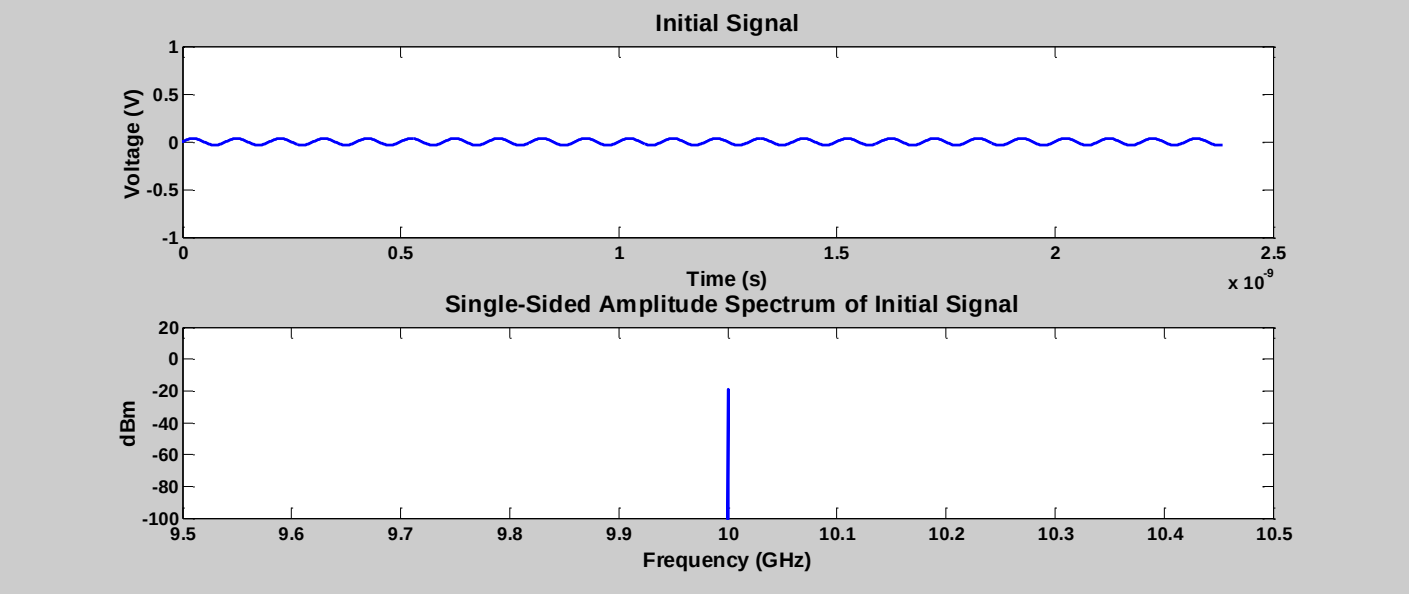
- Performance Analysis
  - Attenuation
  - Coax Attenuation Slope
  - Noise Temperature
- **Economic Analysis**



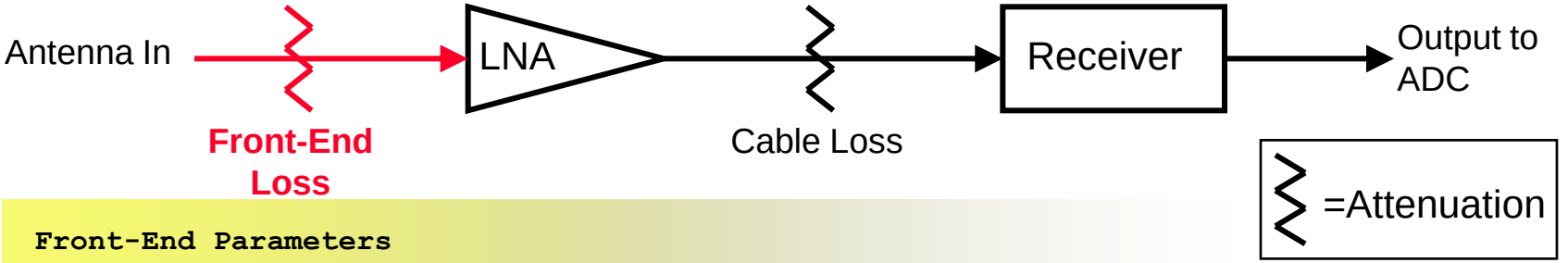
# Modeling



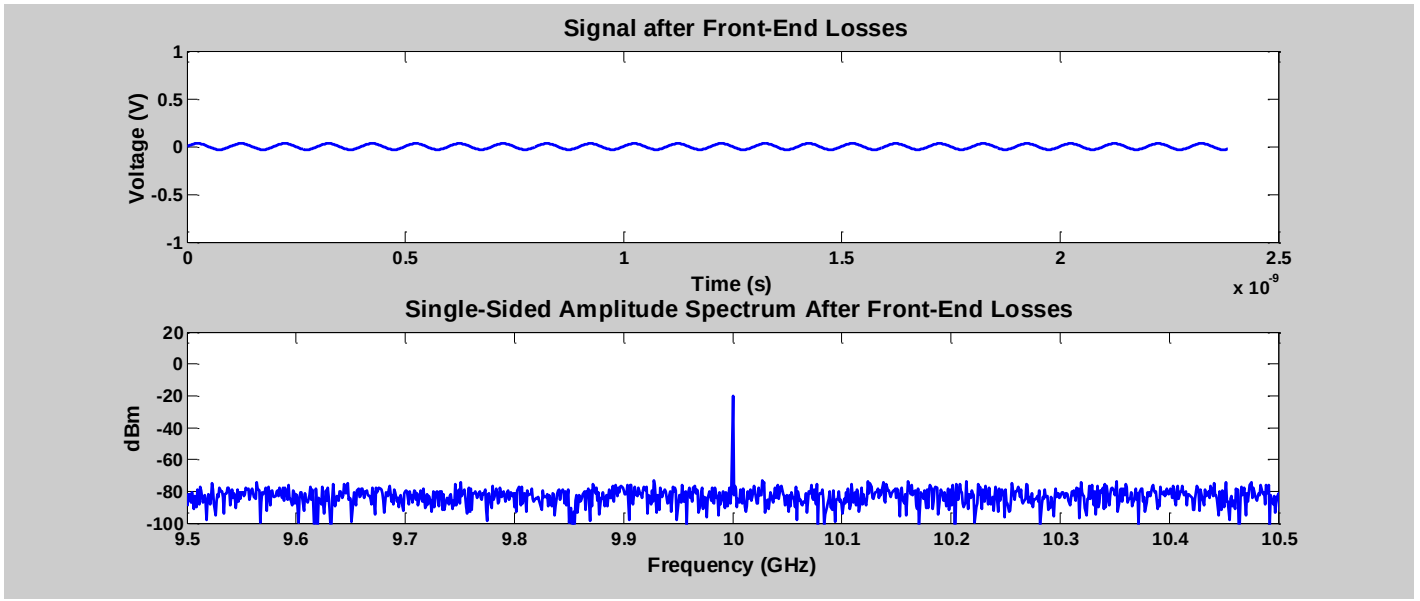

```
>> RadarReceiver
Signal Setup:
  Frequency of Main Signal (GHz): 10
  Average Power of Main Signal (dBm): -19
  System Bandwidth (GHz): 1
Plot signal and amplitude spectrum of initial signal?(y/n): y
```



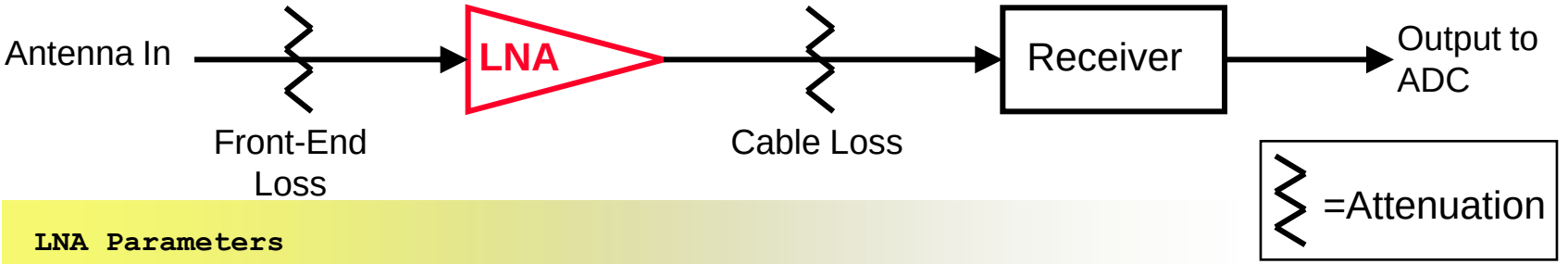
# Modeling



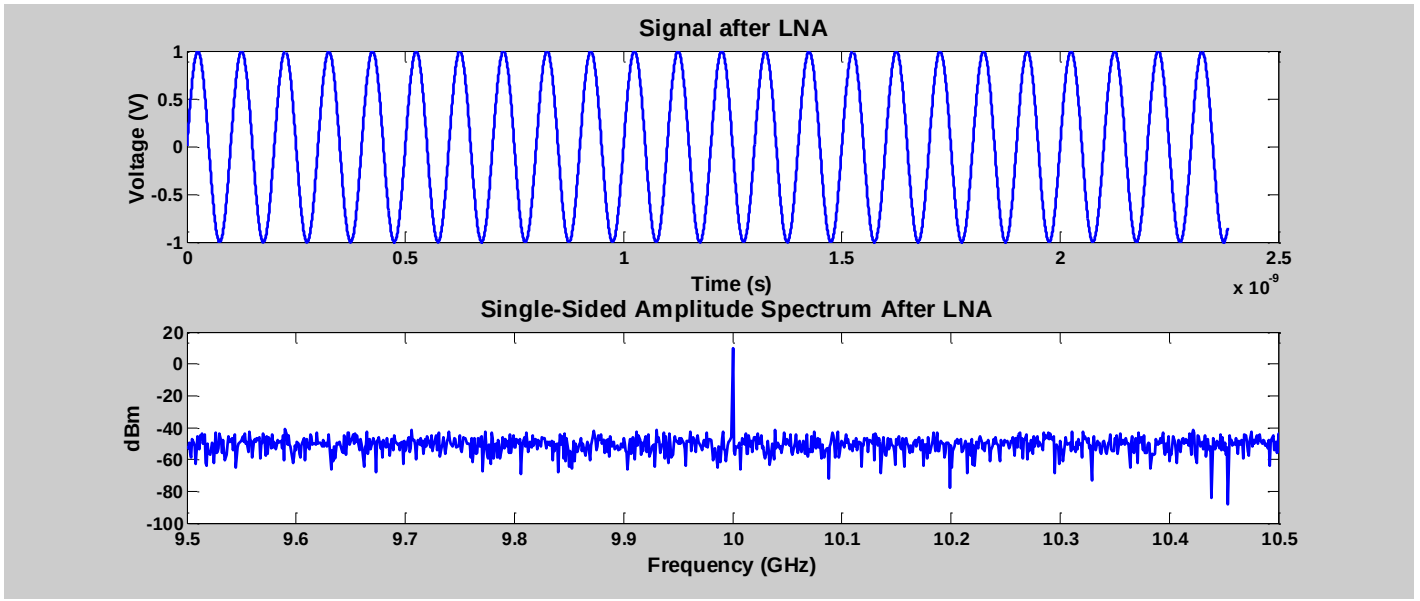

```
Front-End Parameters
  Gain of Front-End (dB): -1
  Noise Figure of Front-End (dB): 1
  System Bandwidth (GHz): 1
Plot signal and amplitude spectrum of current signal?(y/n): y
```



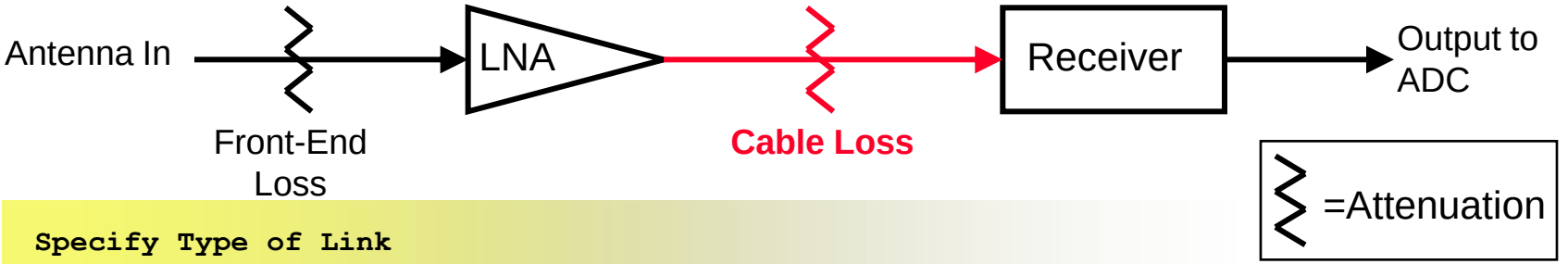
# Modeling



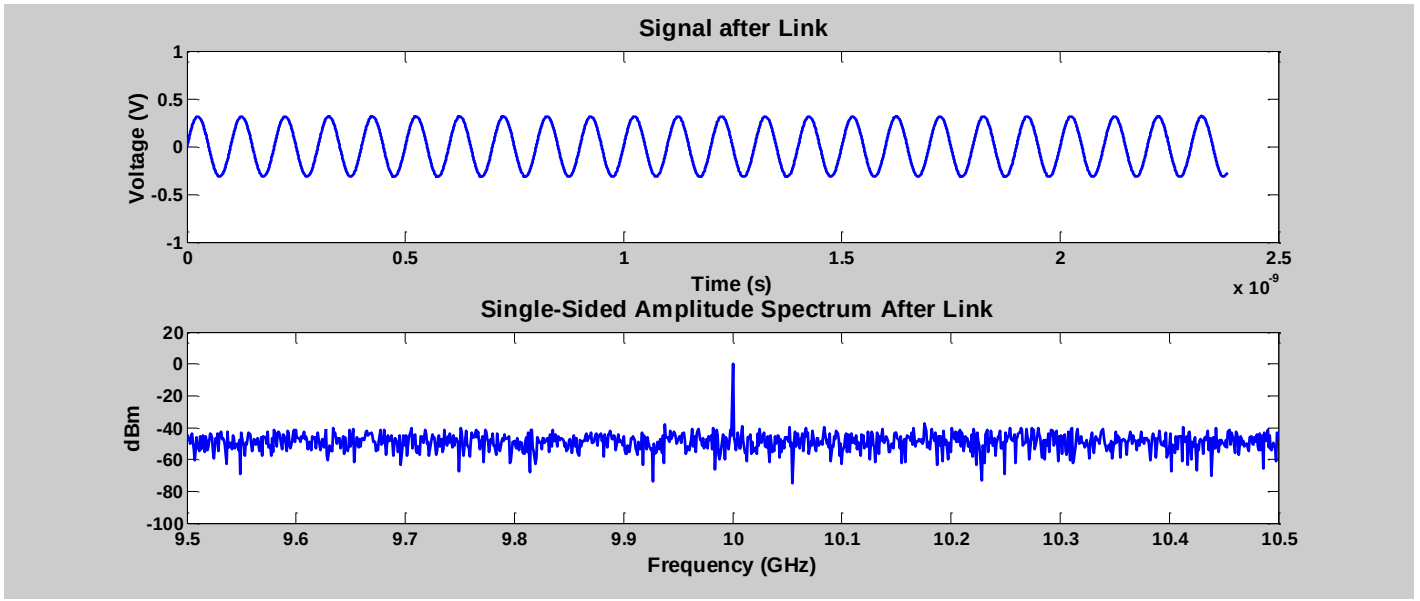

```
LNA Parameters
  Gain of LNA (dB): 30
  Output P1dB of LNA (dBm): 10
  Noise Figure of LNA (dB): 2
  System Bandwidth (GHz): 1
Plot signal and amplitude spectrum of current signal?(y/n): y
```



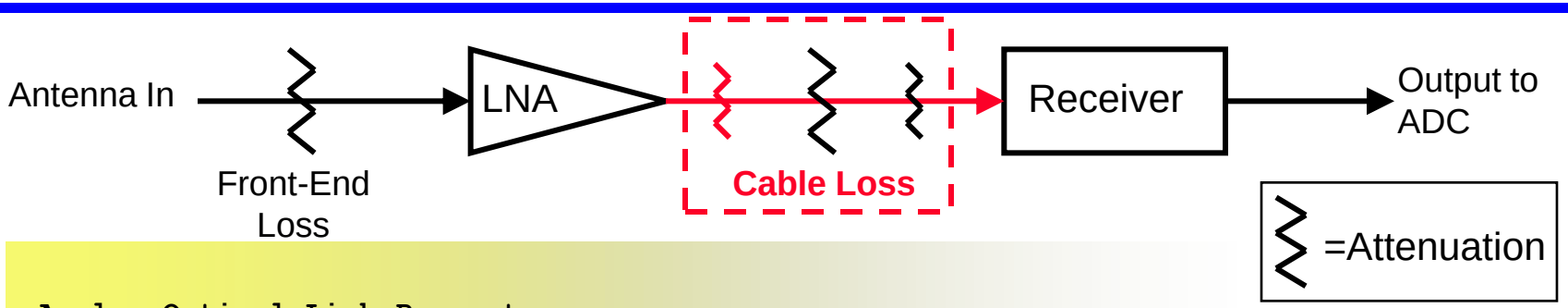
# Modeling



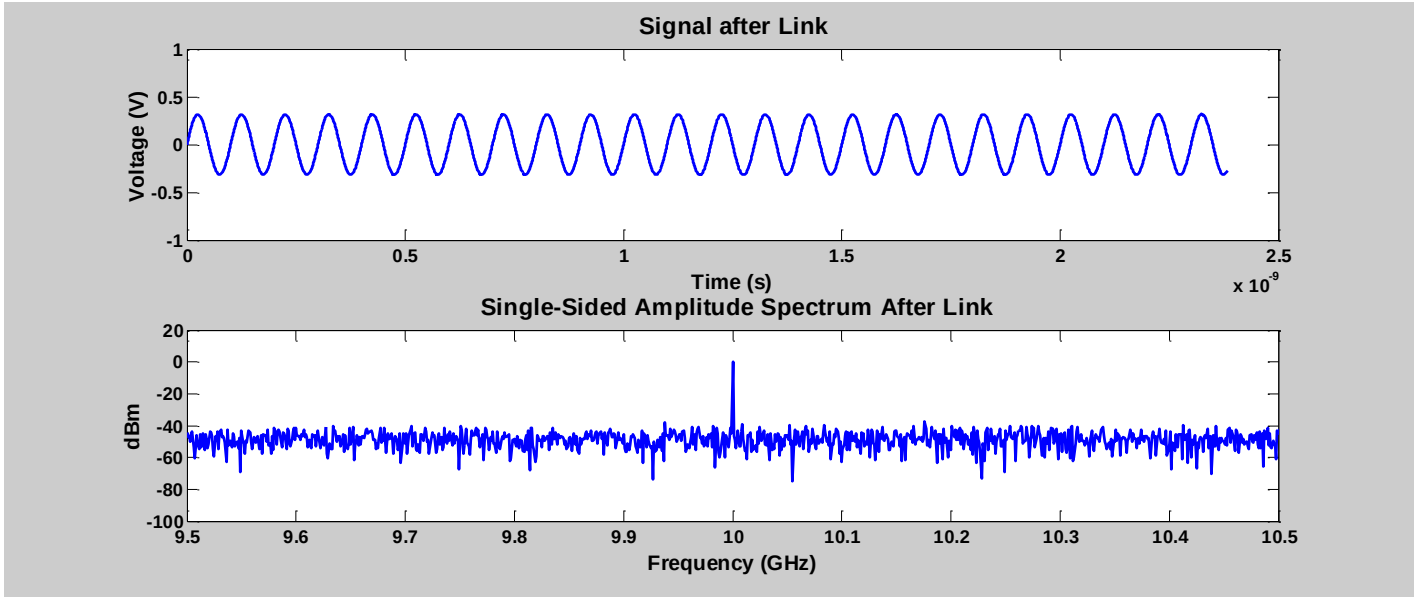

```
Specify Type of Link
  1) Coaxial
  2) Analog Optical (Component Level - External Modulation)
  3) Analog Optical (Component Level - Direct Modulation)
  4) Analog Optical (Link Level)
Enter #: 4
```



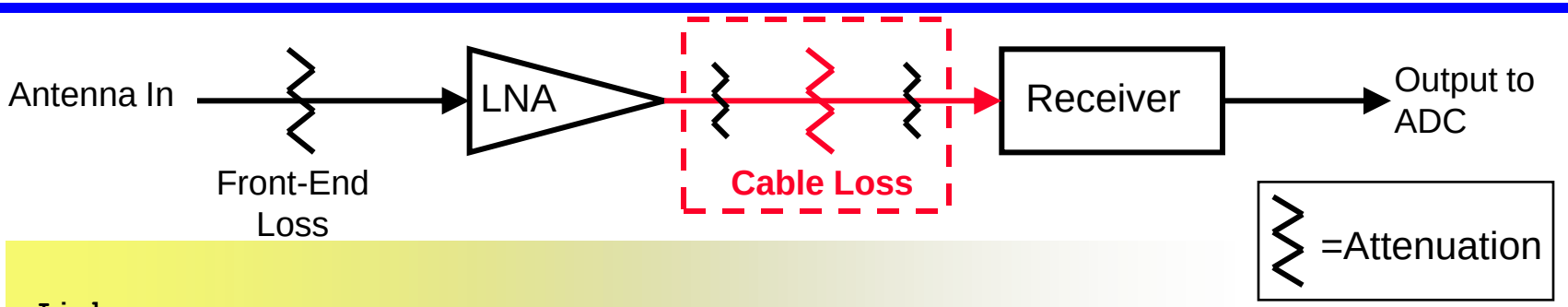
# Modeling



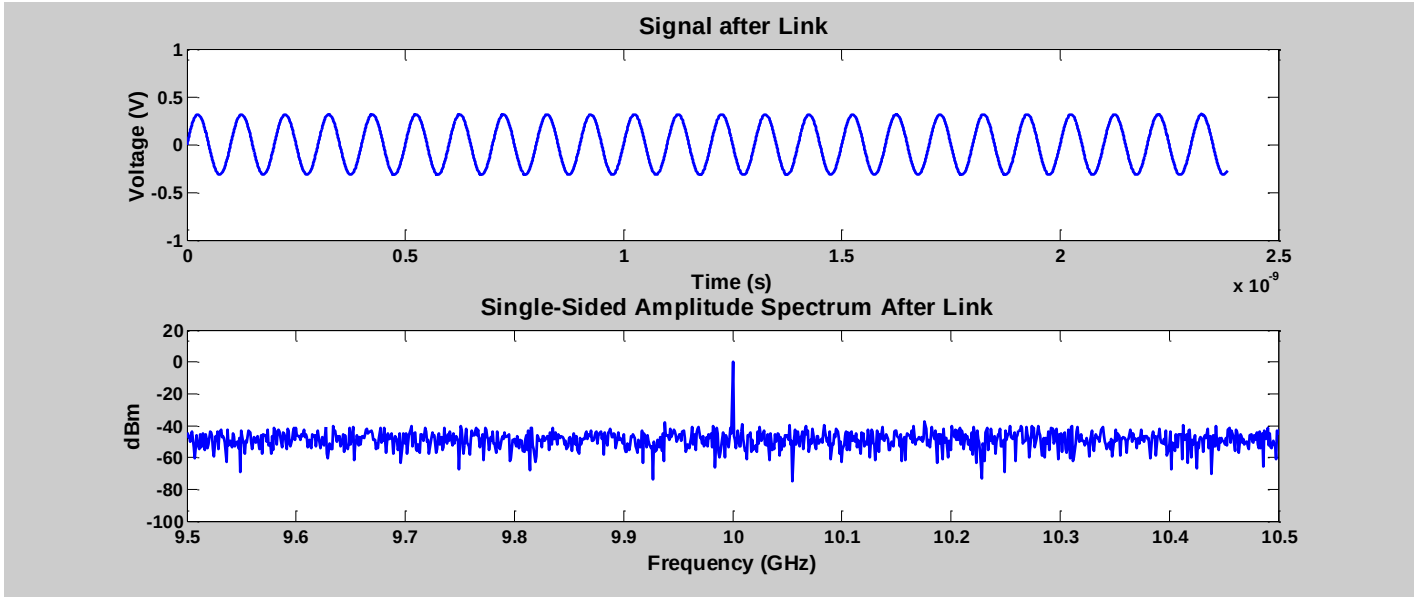

```
Analog Optical Link Parameters
  Attenuation Before Link
    Gain (dB): -24
    Noise Figure (dB): 24
```



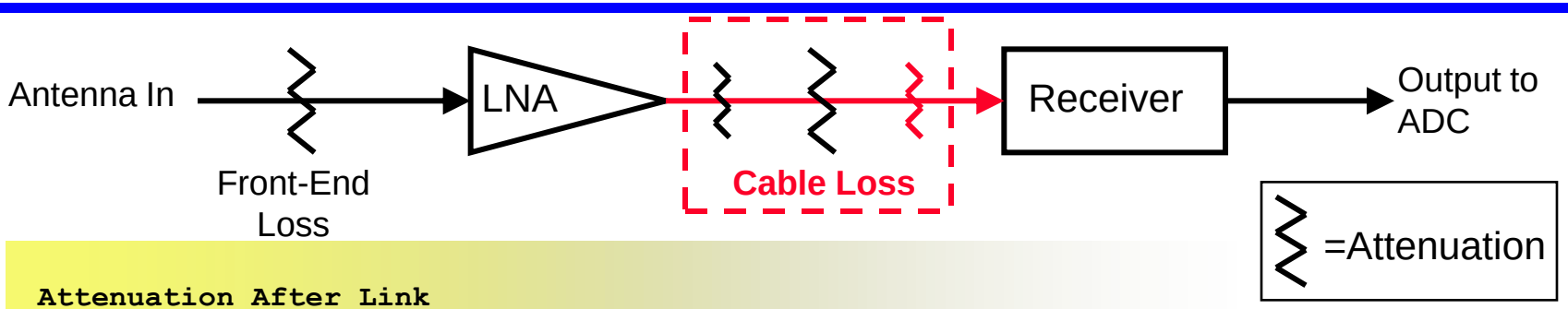
# Modeling



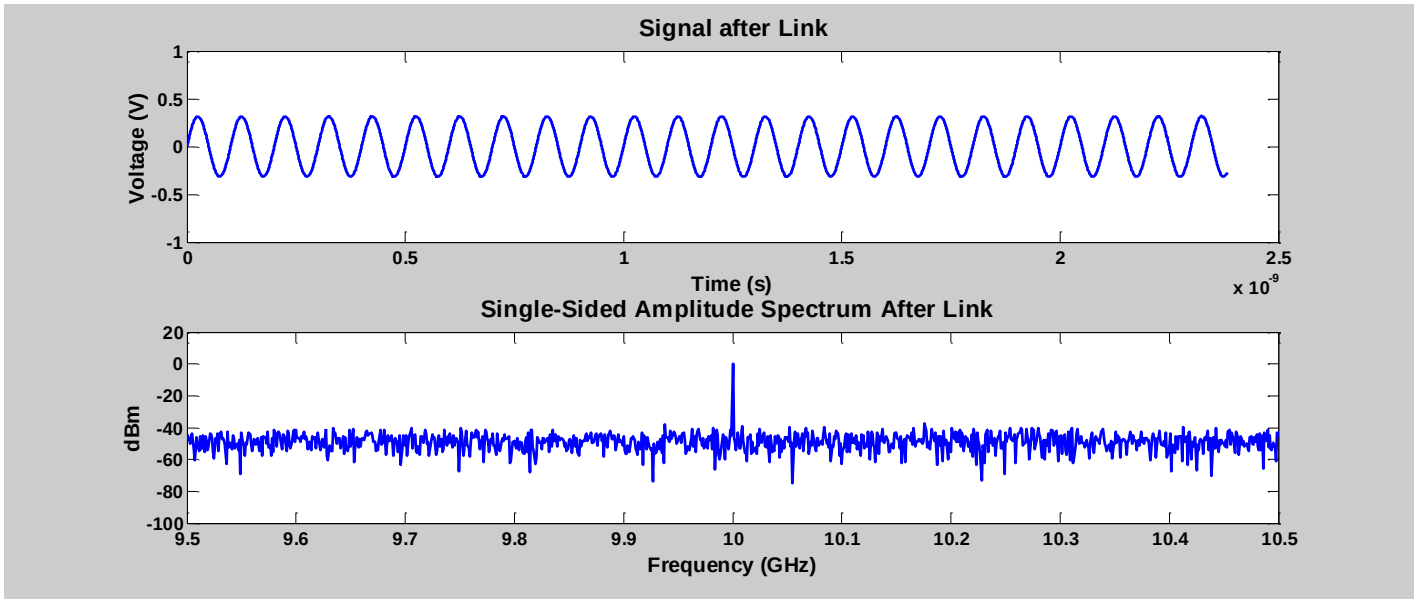

```
Link
     Gain (dB): 18
     Output P1dB (dBm): 4
     Noise Figure (dB): 20
```



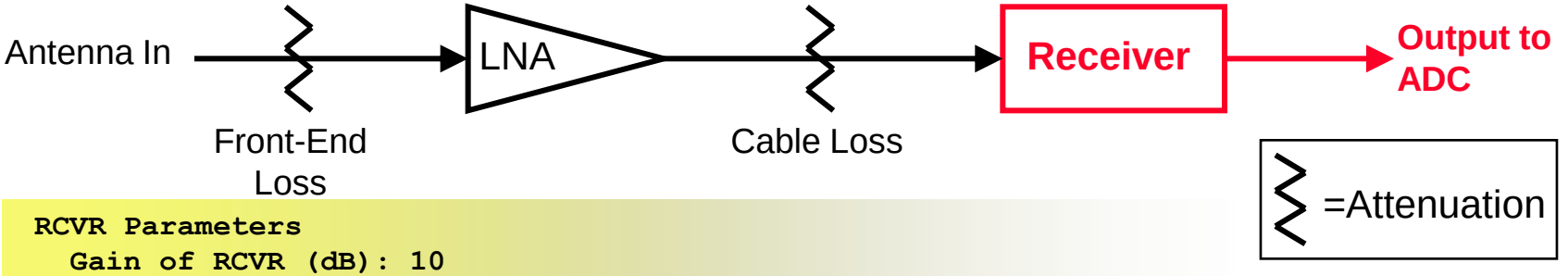
# Modeling



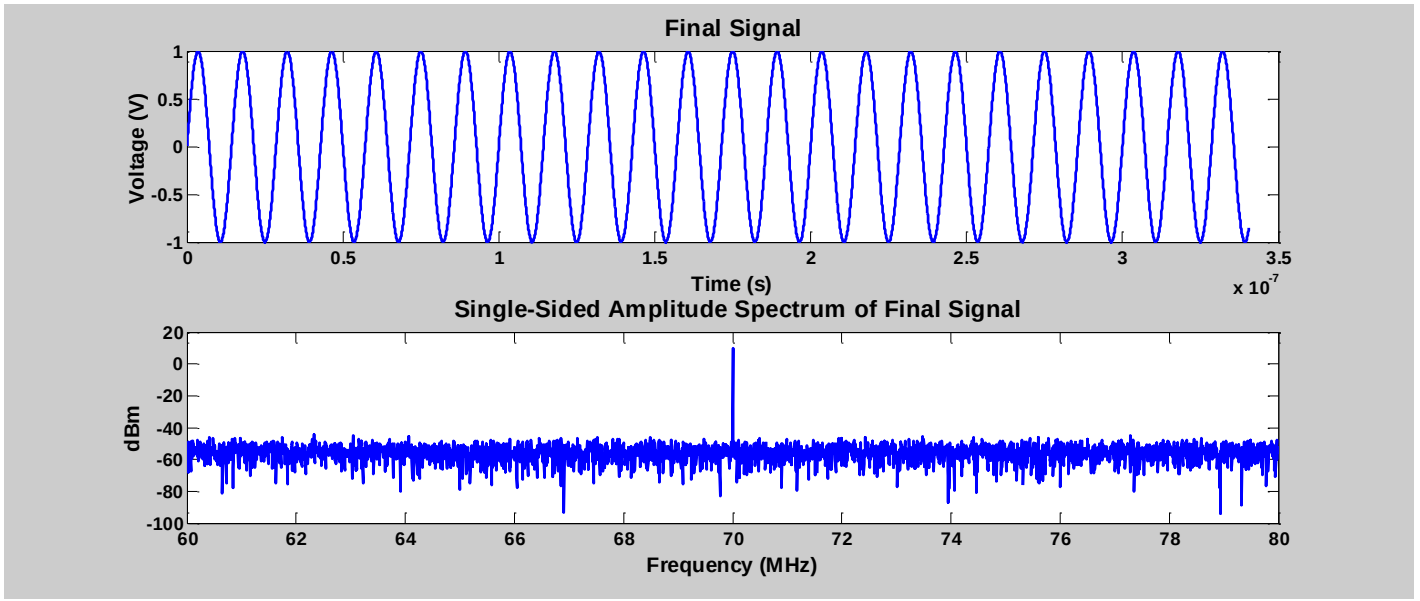

```
Attenuation After Link
    Gain (dB): -4
    Noise Figure (dB): 4
  System Bandwidth (GHz): 1
Plot signal and amplitude spectrum of current signal?(y/n): y
```



# Modeling




```
RCVR Parameters
  Gain of RCVR (dB): 10
  Output P1dB of RCVR (dBm): 10
  Noise Figure of RCVR (dB): 7
  Output Frequency of RCVR (MHz): 70
  System Bandwidth (MHz): 20
Plot signal and amplitude spectrum of final signal?(y/n): y
```



# Direct Modulation Analog Optical Link

**Parameters:**

- Relative intensity noise (RIN) of transmitter *(-150 dB/Hz)*
- Laser slope efficiency *(0.15 W/A)*
- Laser bias current *(0.07 A)*
- Laser threshold current *(0.012 A)*
- Fiber attenuation *(0 dB/km)*
- Length of fiber *(0 km)*
- Other excess losses – including coupling losses *(0 dB)*
- Photodiode responsivity *(0.85 A/W)*

| Component | Parameter | Expected Value | Simulated Value |
|---|---|---|---|
| **LBL-10M4P5G Analog Optical Link with no external circuitry and negligible fiber loss** | Gain (dB) | -22 to -23 | −17.9 |
| | Noise Figure (dB) | 45 to 50 | 43.2 |

# External Modulation Analog Optical Link

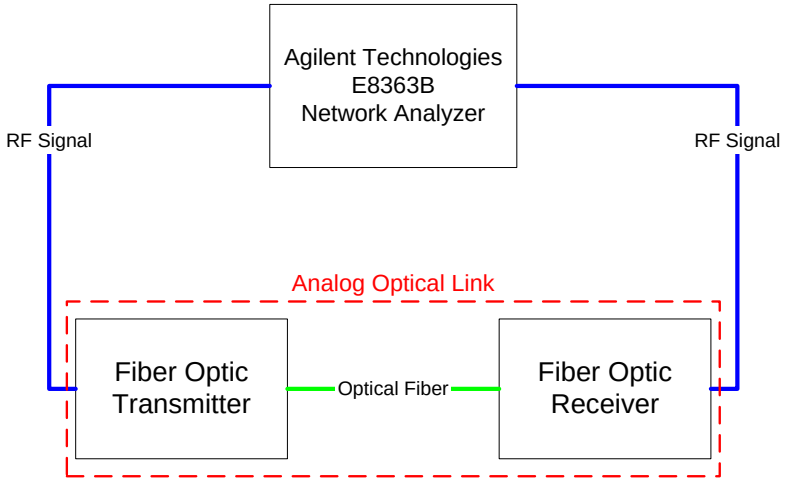
**Parameters:**

- **Total excess modulator loss *(4 dB)***
- **$V_\pi$ *(5.5 V)***
- **DC bias voltage of modulator *(2.75 V)***
- **Optical output power from CW laser *(0.01 W)***
- **Fiber attenuation *(0 dB/km)***
- **Length of fiber *(0 km)***
- **Photodiode responsivity *(0.5 A/W)***

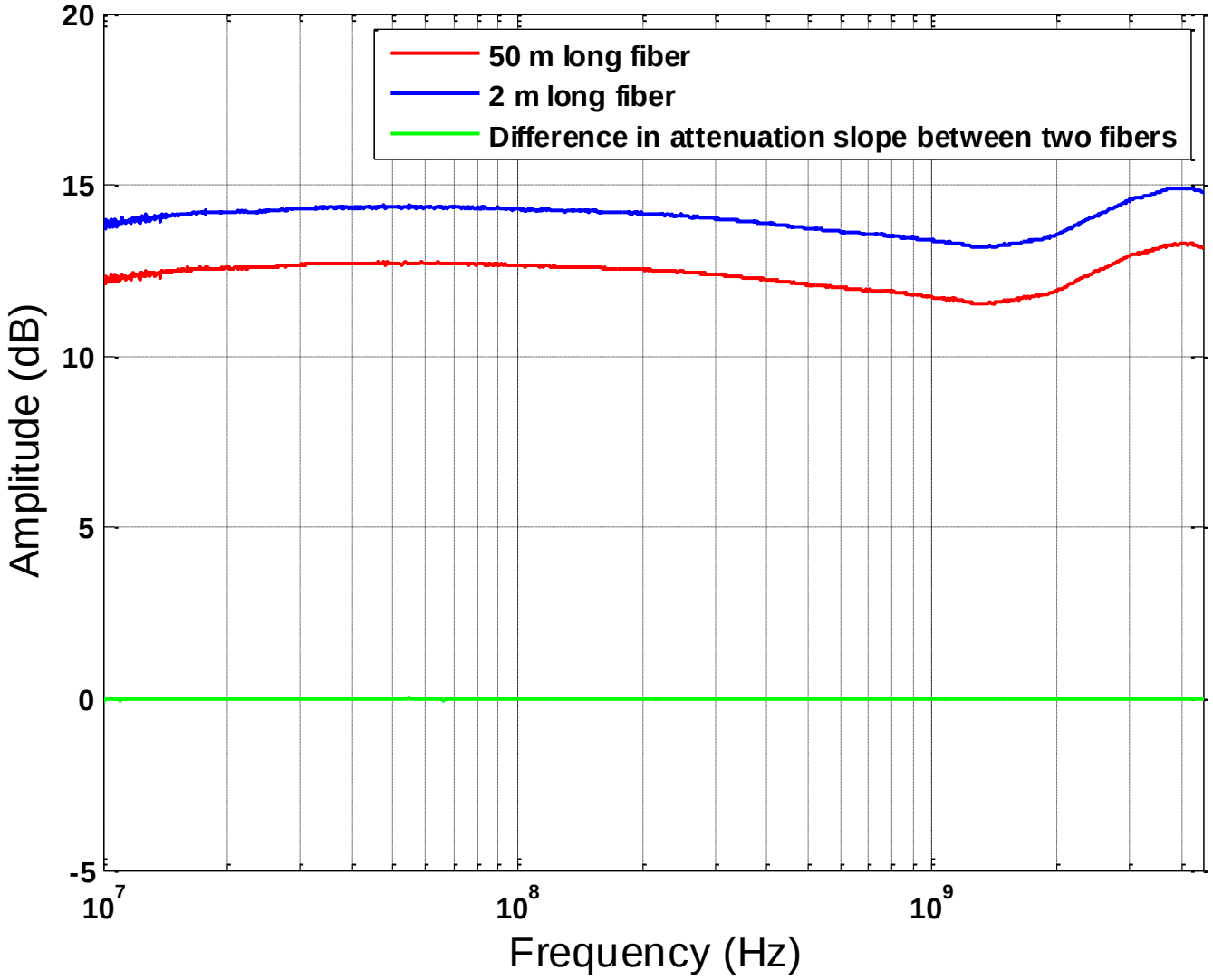
| Component | Parameter | Expected Value | Simulated Value |
|---|---|---|---|
| **Mach-Zehnder Modulated Analog Optical Link with no external circuitry and negligible fiber loss** | Gain (dB) | −34 | −31 |
| | Noise Figure (dB) | 49 | 40 |
| | Output P1dB (dBm) | −17 | −16.1 |

# Testing

- **MITEQ LBL-10M4P5G Analog Optical Link**

# Testing


50 m long fiber
2 m long fiber
Difference in attenuation slope between two fibers
Amplitude (dB)
20
15
10
5
0
-5
10^7
10^8
10^9
Frequency (Hz)

# Conclusions

- Using MITEQ SCML-100M11G analog optical link dynamic range specification is met, sensitivity specification is not
- To meet sensitivity, link must have lower gain or lower noise figure
- By adjusting component parameters a link can be built to meet both dynamic range and sensitivity specifications
- Improvement in performance for analog optical link over coaxial cable only occurs once a certain distance is reached
- Analog Optical Link is only cost-effective for long distances (greater than ≈ 300 ft)

# Acknowledgements


- Professor Alexander Emanuel
- Jeffrey Hargreaves
- Paul Juodawlkis
- MITEQ® Inc.

# Questions