# An Introduction to Satellite Communication Systems

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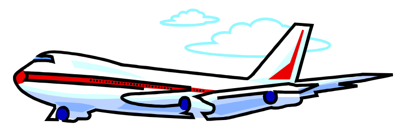
September 30, 2003

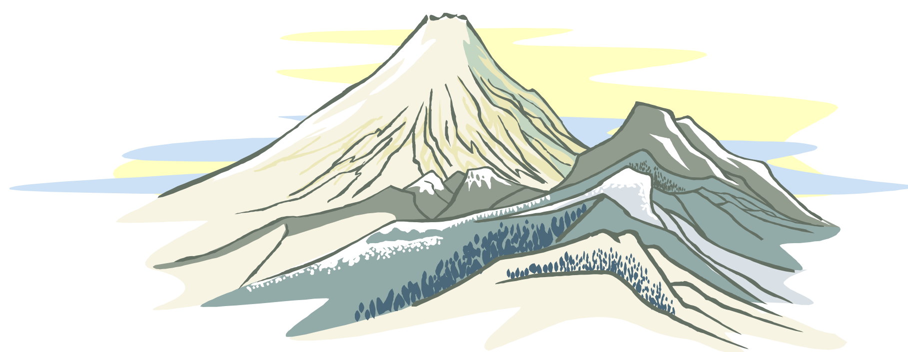
# Some data about satellite location

Satellite at Low Earth Orbit: 800 km

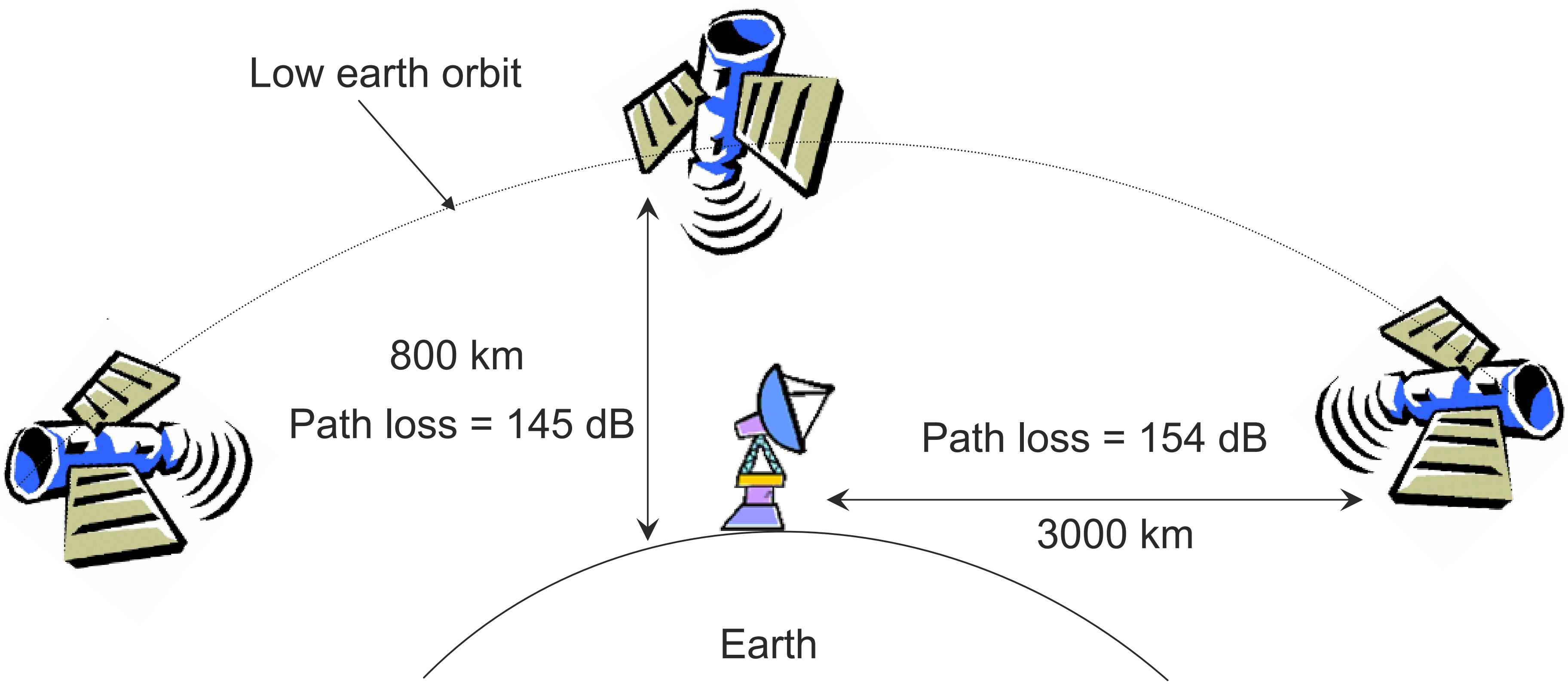
Aircraft: 20 km



Everest: 9 km

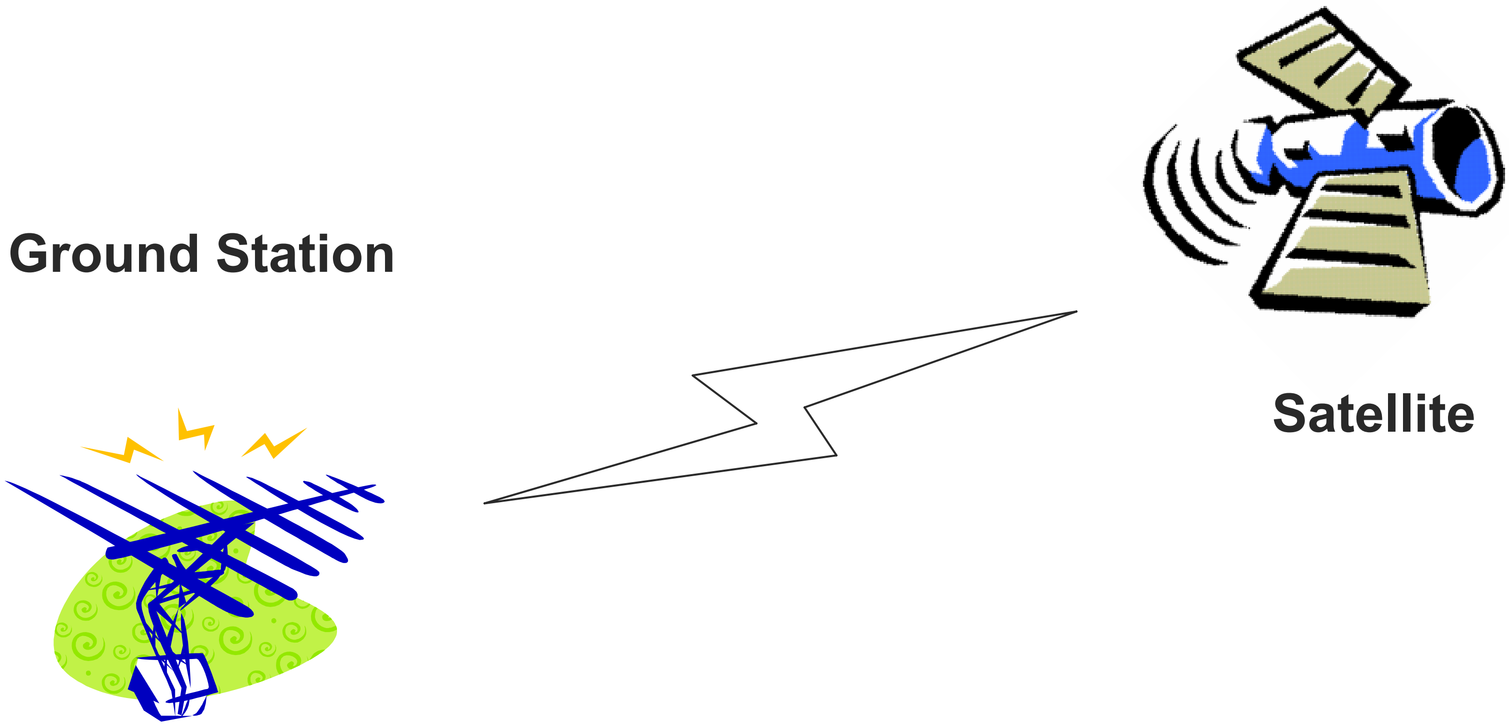


# More data about satellite location

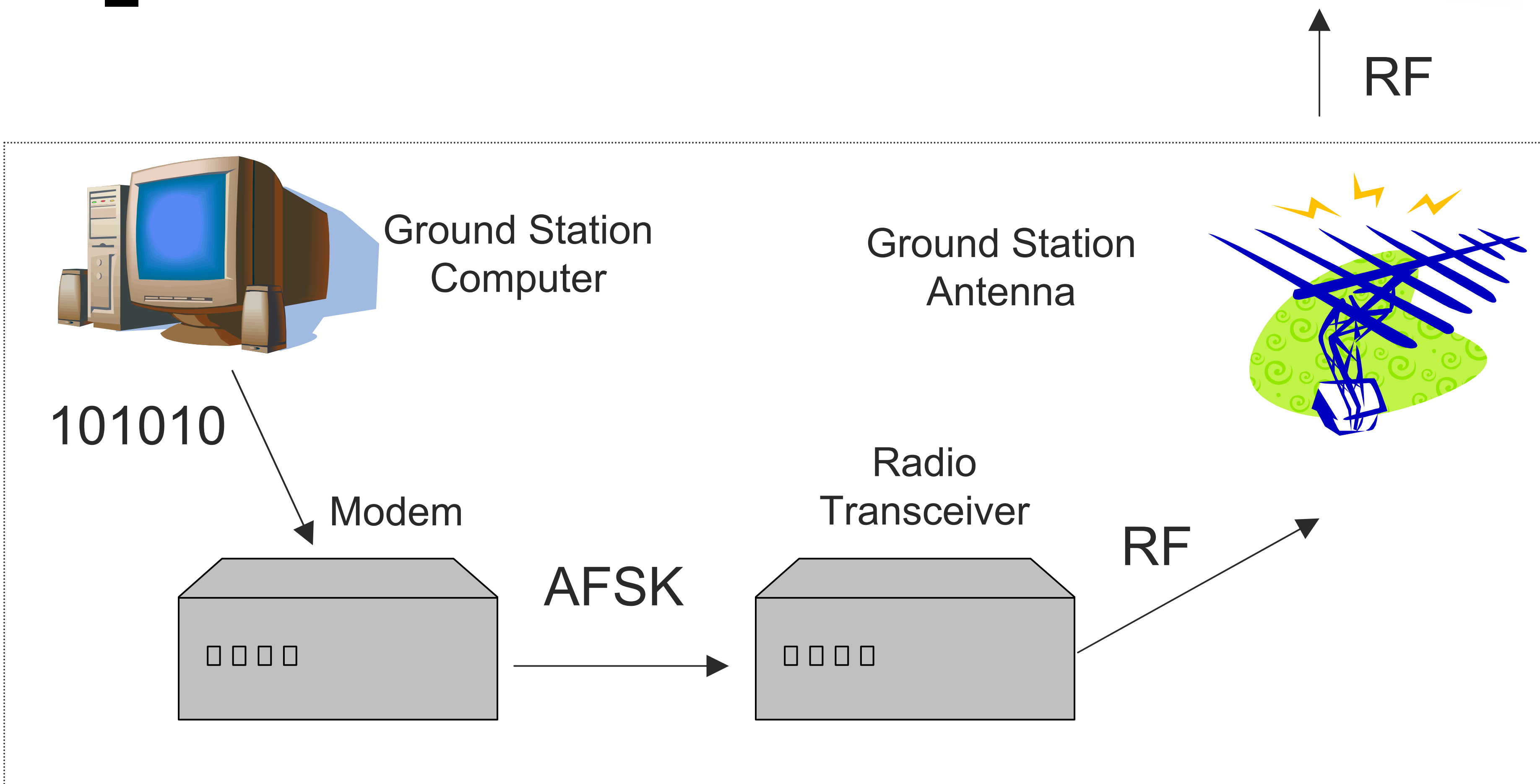


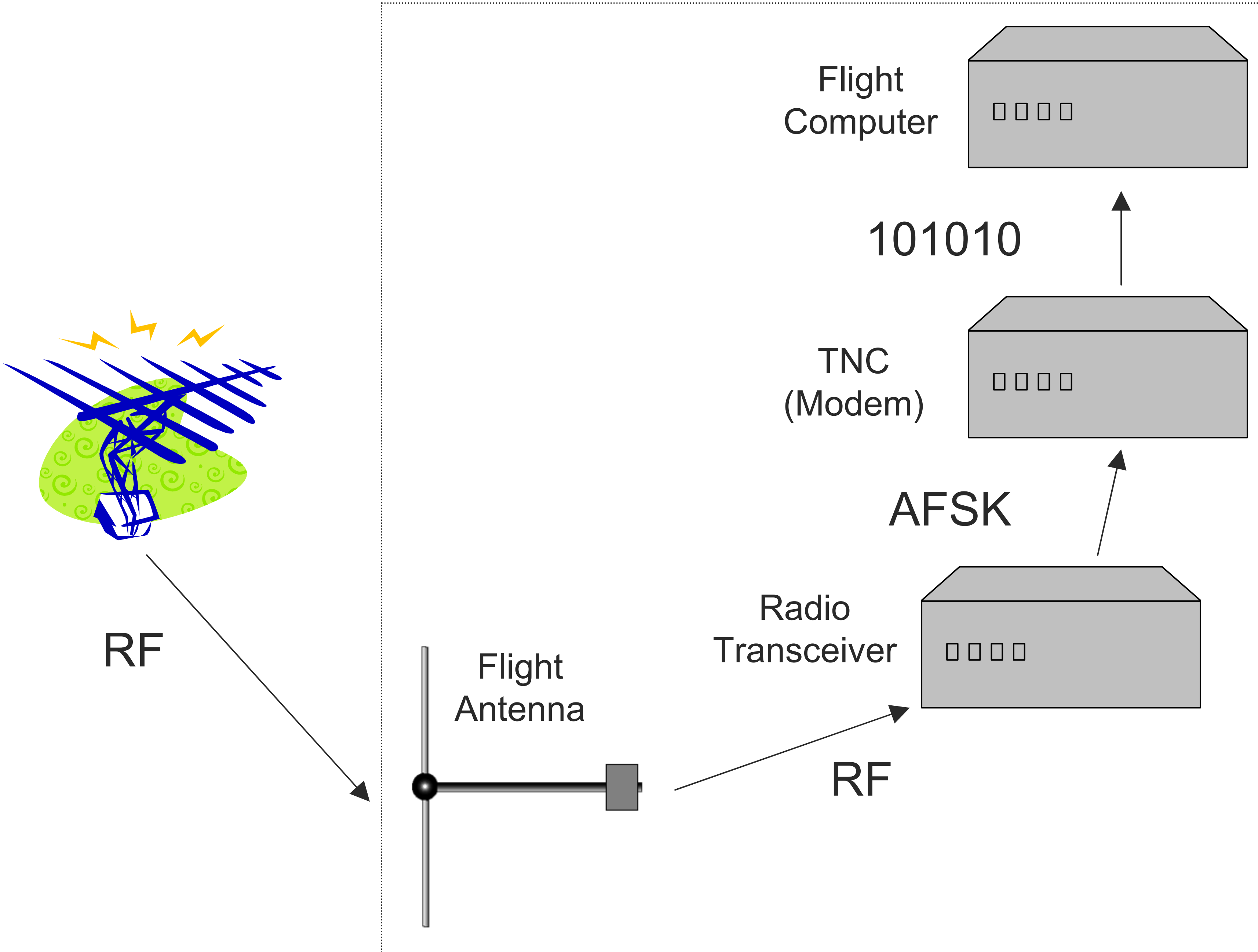

Path loss based on transmission frequency: 435 MHz

# How does it work?



# From Ground Station to Satellite




Flight
Computer
101010
TNC
(Modem)
AFSK
Radio
Transceiver
RF
Flight
Antenna
RF

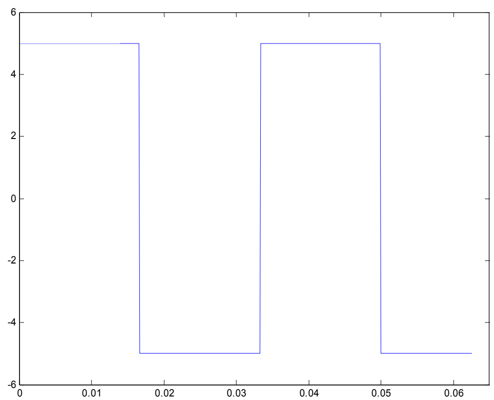
# Behind the Communication: Digital Modulation

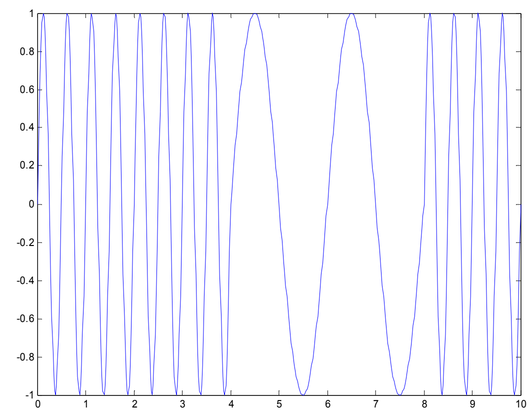
..1010..
(Binary Signal, PC)

1 = ♪, 0 = ♫

..♪..♫..♪..♫..
(AFSK Signal, TNC)

**A**udio **F**requency **S**hift **K**eying




(Time-Domain)

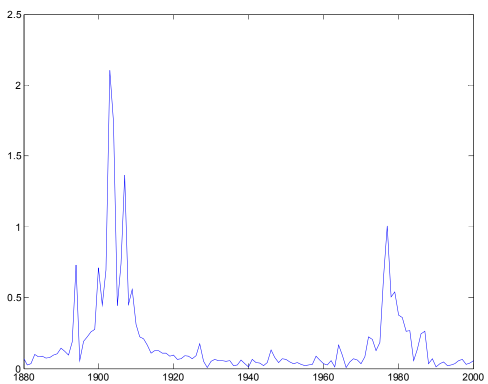
# Behind the Communication: Analog Modulation

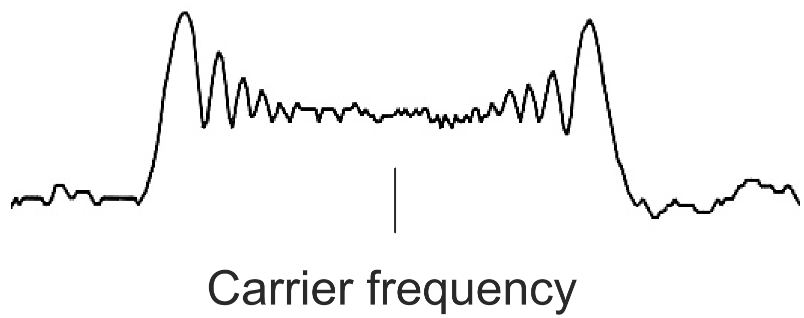
**F**requency **M**odulation
At **R**adio **F**requency

$f$ = kHz ($10^3$)
(AFSK Signal, TNC)

→

$f$ = MHz($10^6$)
(FM Signal, Radio)



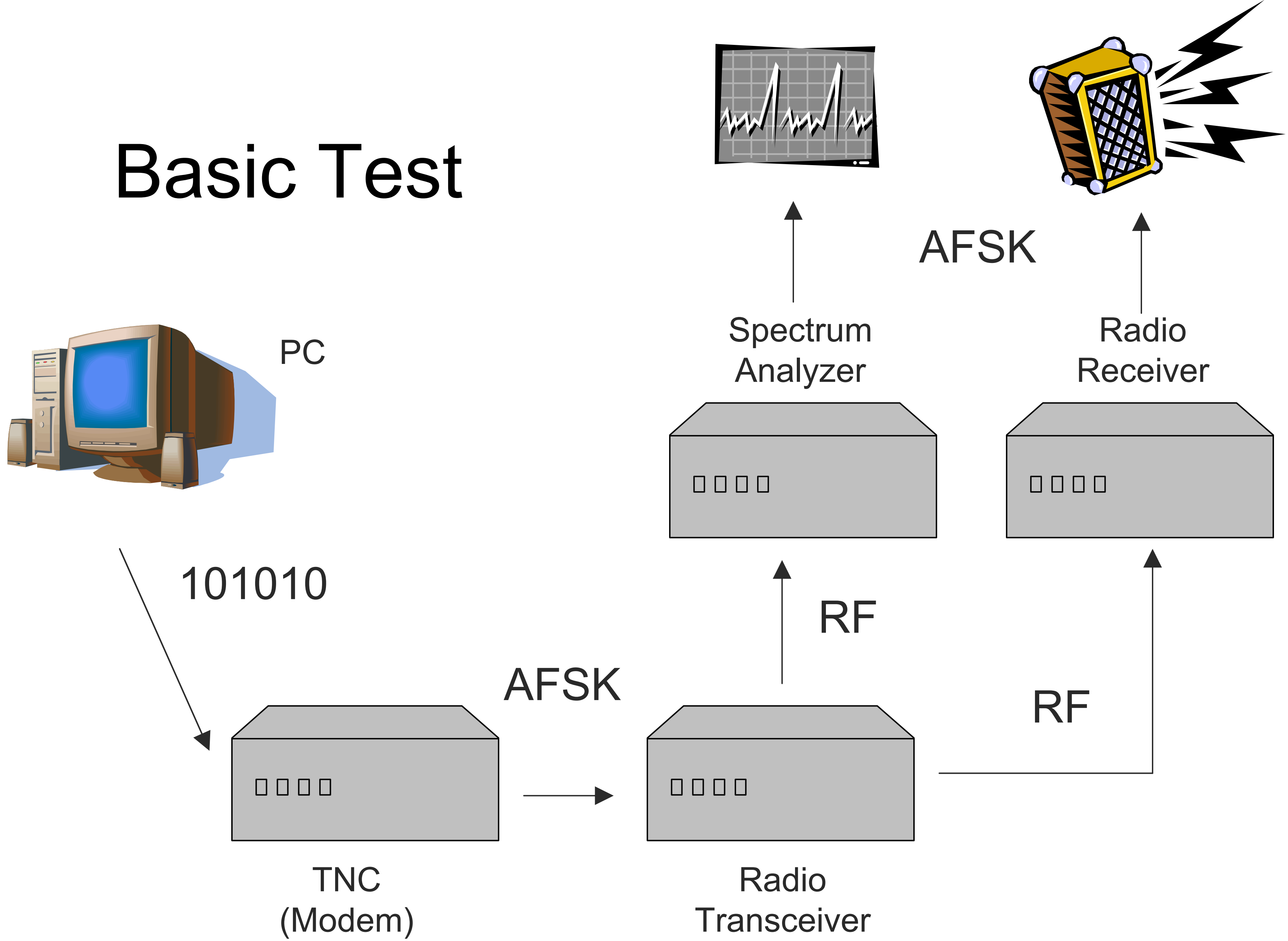




(Frequency-Domain)

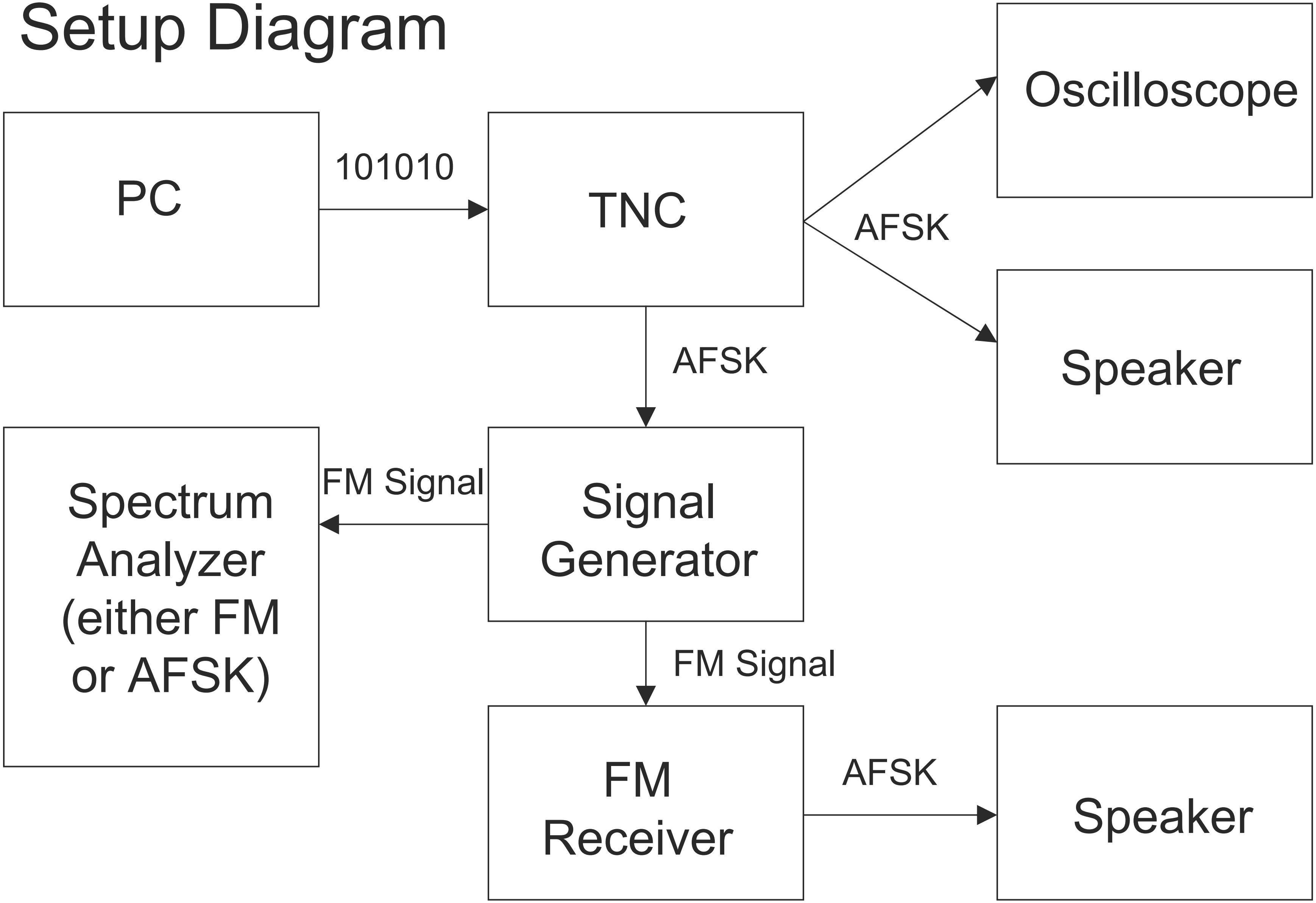
# Goal

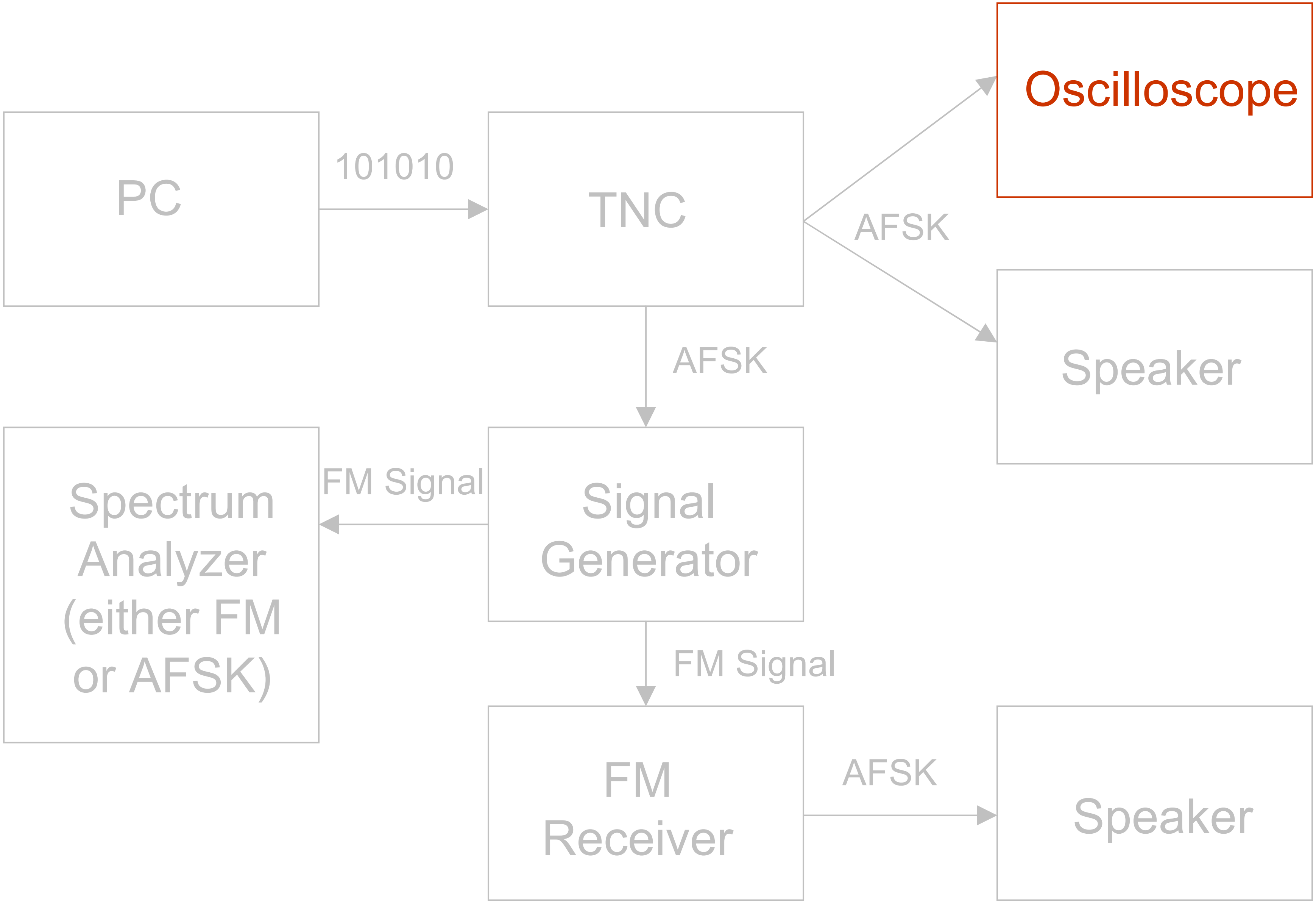
- Make sure the communication system works.
- Measure the performance of communication system using:
  - Quality of the signal: Signal to Noise Ratio
  - Noise Level: Power of Noise Floor and path loss
  - Error Rate: Bit Error Rate
  - Transmission Rate

# Basic Test

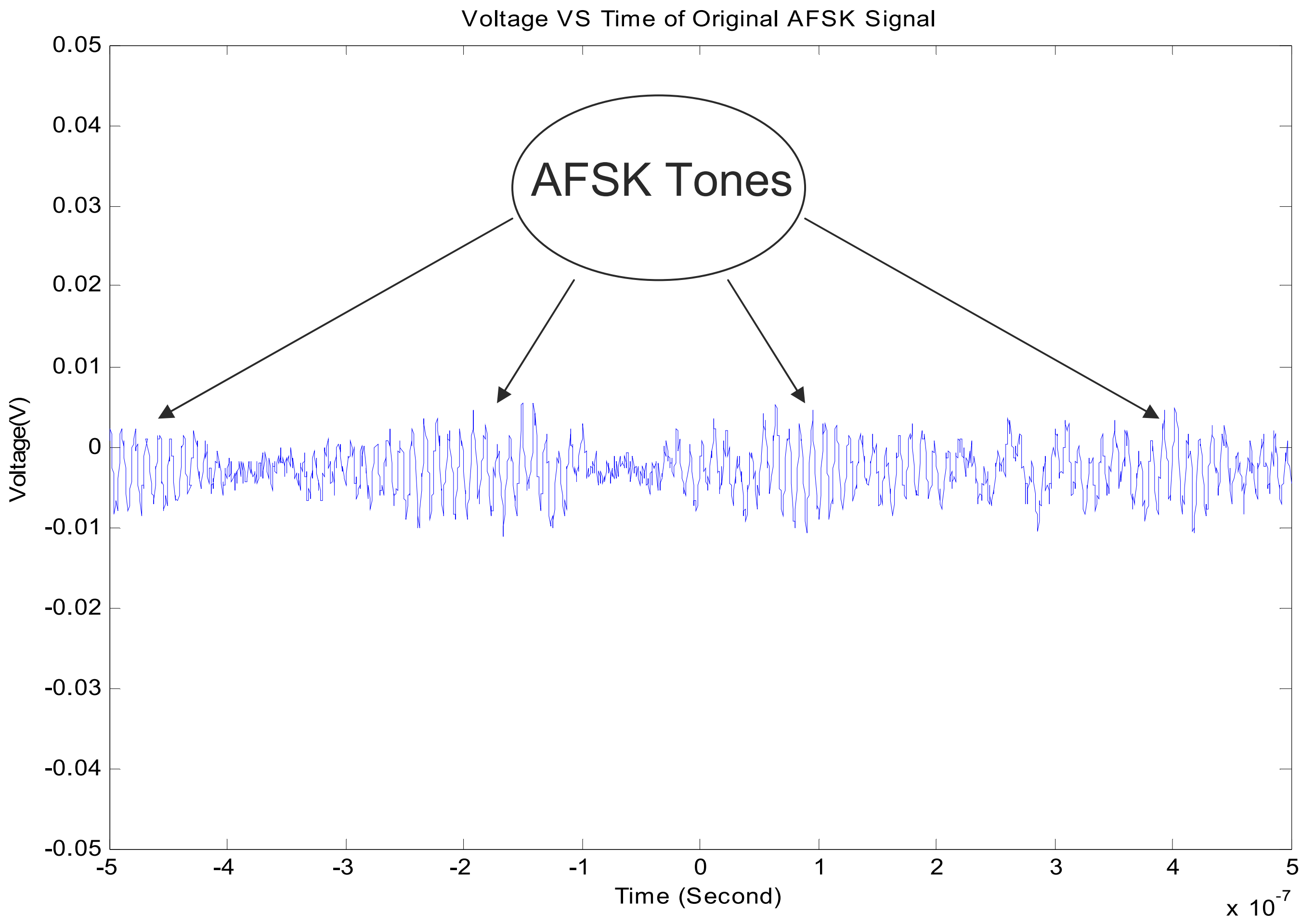

PC
101010
TNC
(Modem)
AFSK
Radio
Transceiver
RF
Spectrum
Analyzer
RF
Radio
Receiver
AFSK

# Setup Diagram

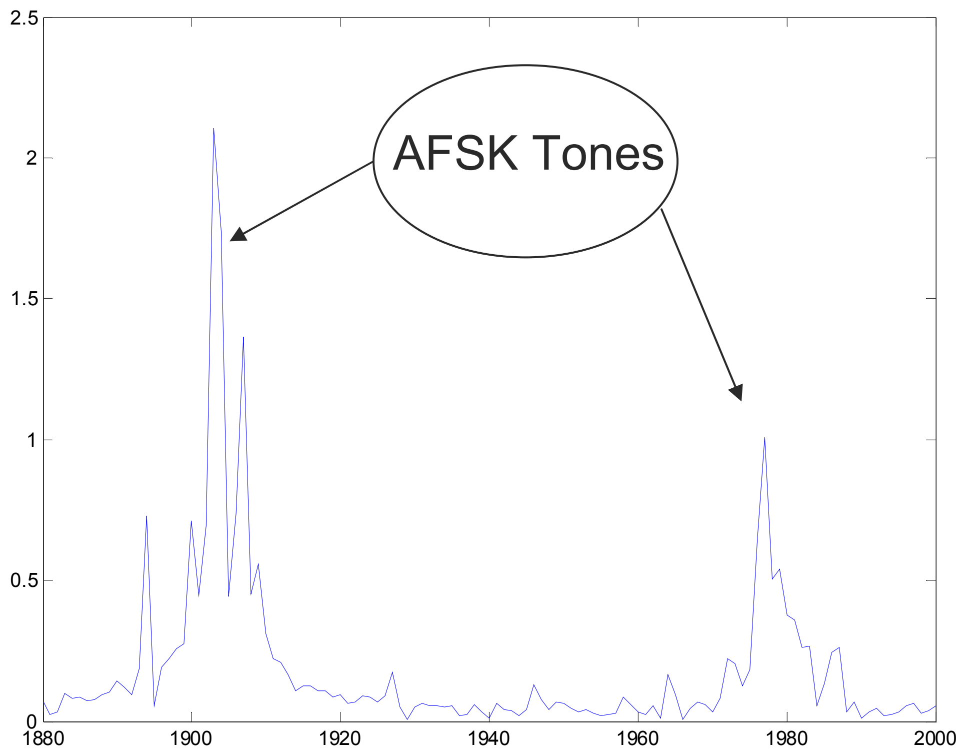


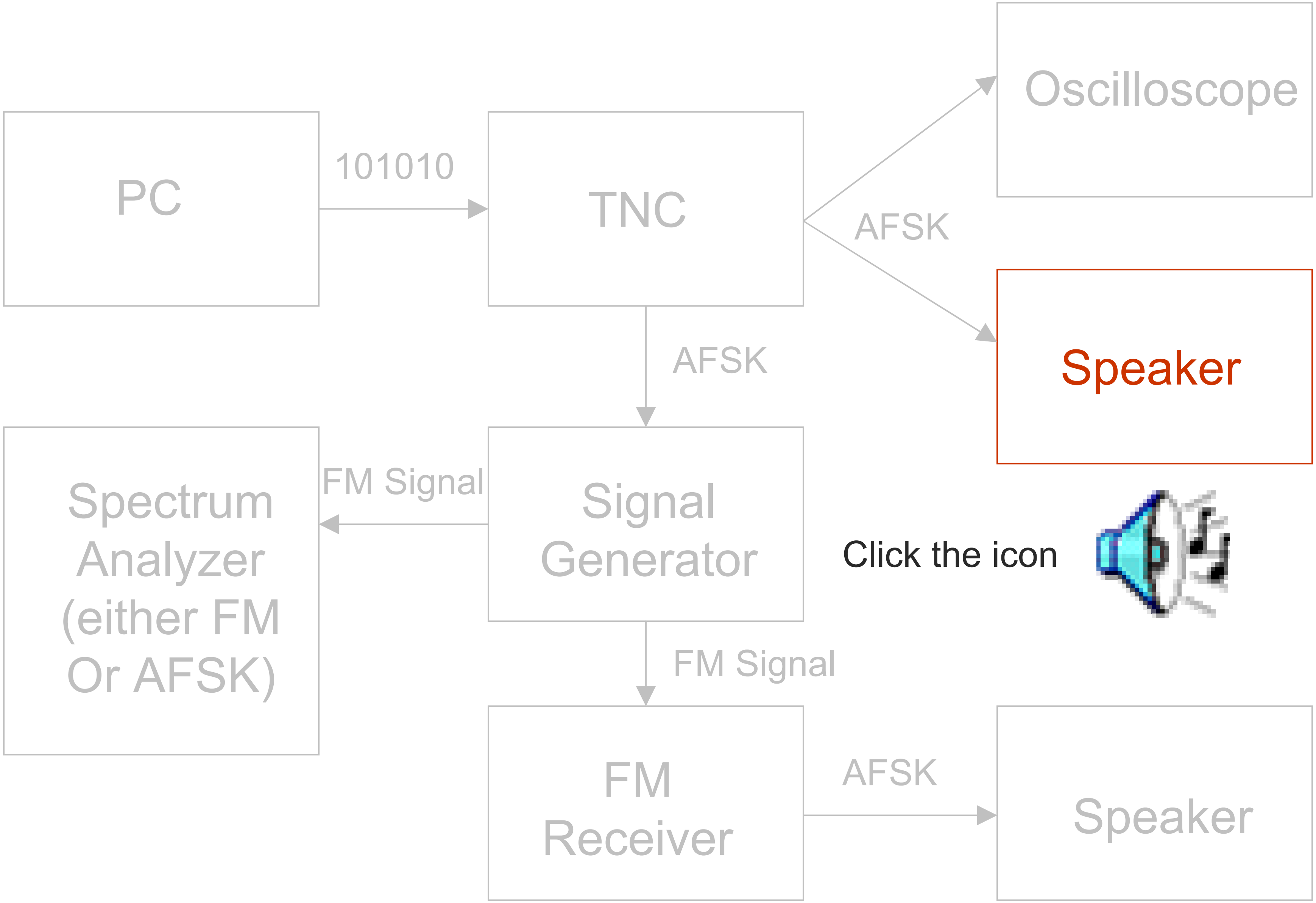

PC
101010
TNC
Oscilloscope
AFSK
Speaker
AFSK
Spectrum Analyzer (either FM or AFSK)
FM Signal
Signal Generator
FM Signal
FM Receiver
AFSK
Speaker

# Wave form of Original AFSK Signal



# Frequency Spectrum of Original AFSK Signal




PC
101010
TNC
AFSK
Oscilloscope
Speaker
AFSK
Spectrum Analyzer (either FM Or AFSK)
FM Signal
Signal Generator
Click the icon
FM Signal
FM Receiver
AFSK
Speaker

# Amplitude of Carrier Signal

- Let m(t) be the AFSK Signal.
- After FM Modulation, the modulated signal s(t) becomes:

$$s(t) = A_C \cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(t')dt')$$

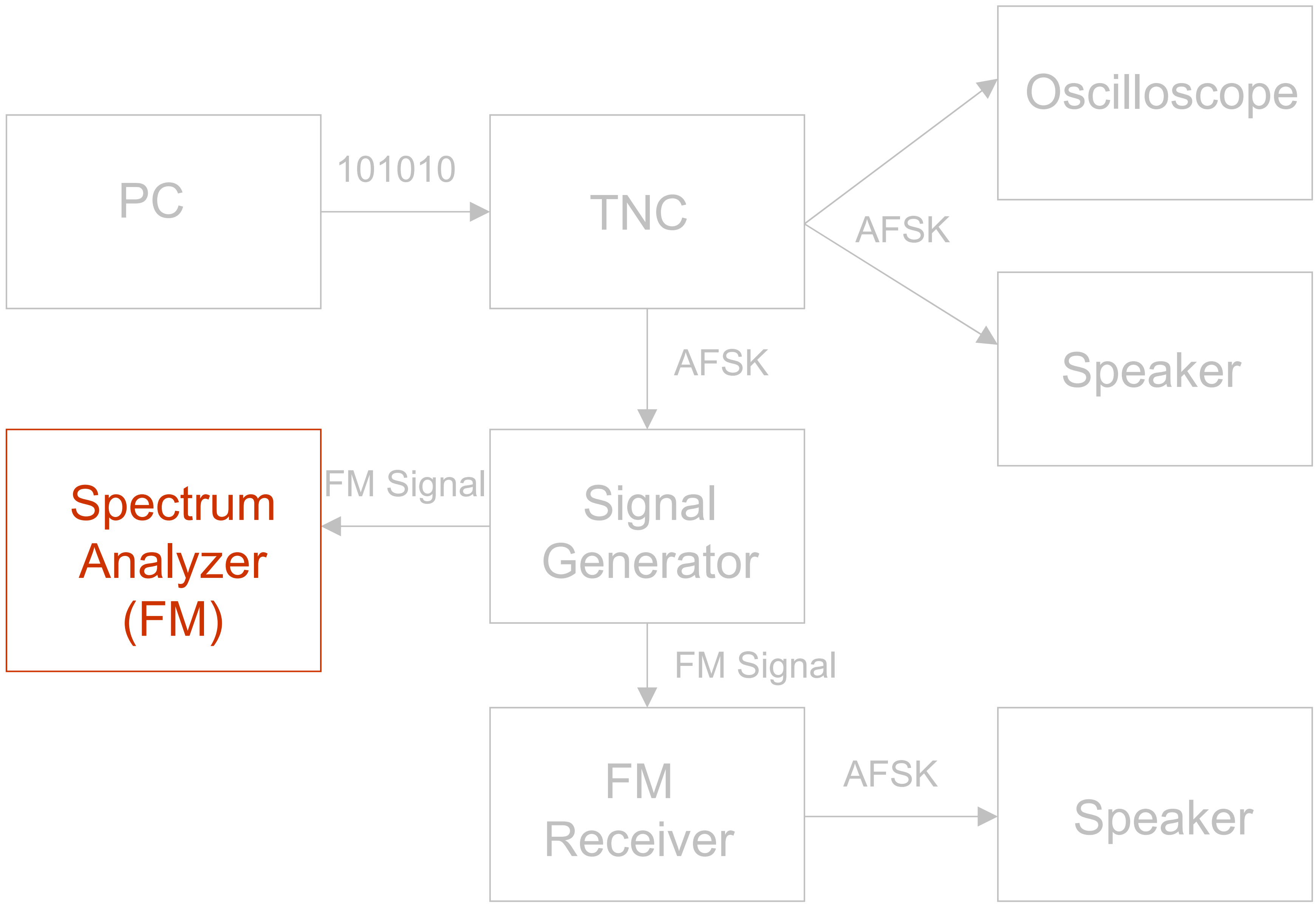
- $A_C$ : amplitude of the carrier signal
- $f_C$ : frequency of the carrier signal

# Signal to Noise Radio (SNR)

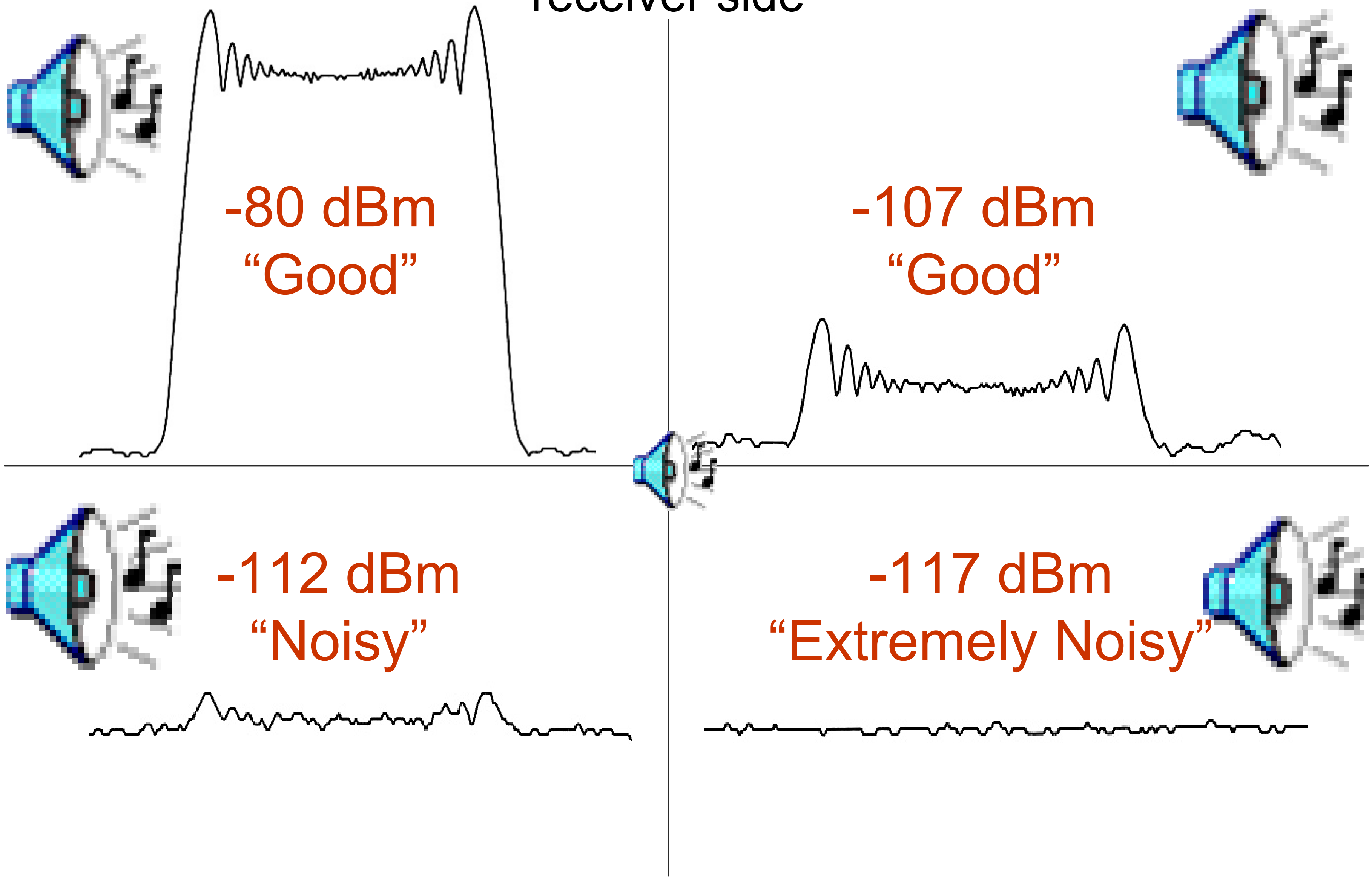
- SNR depends on $A_C$

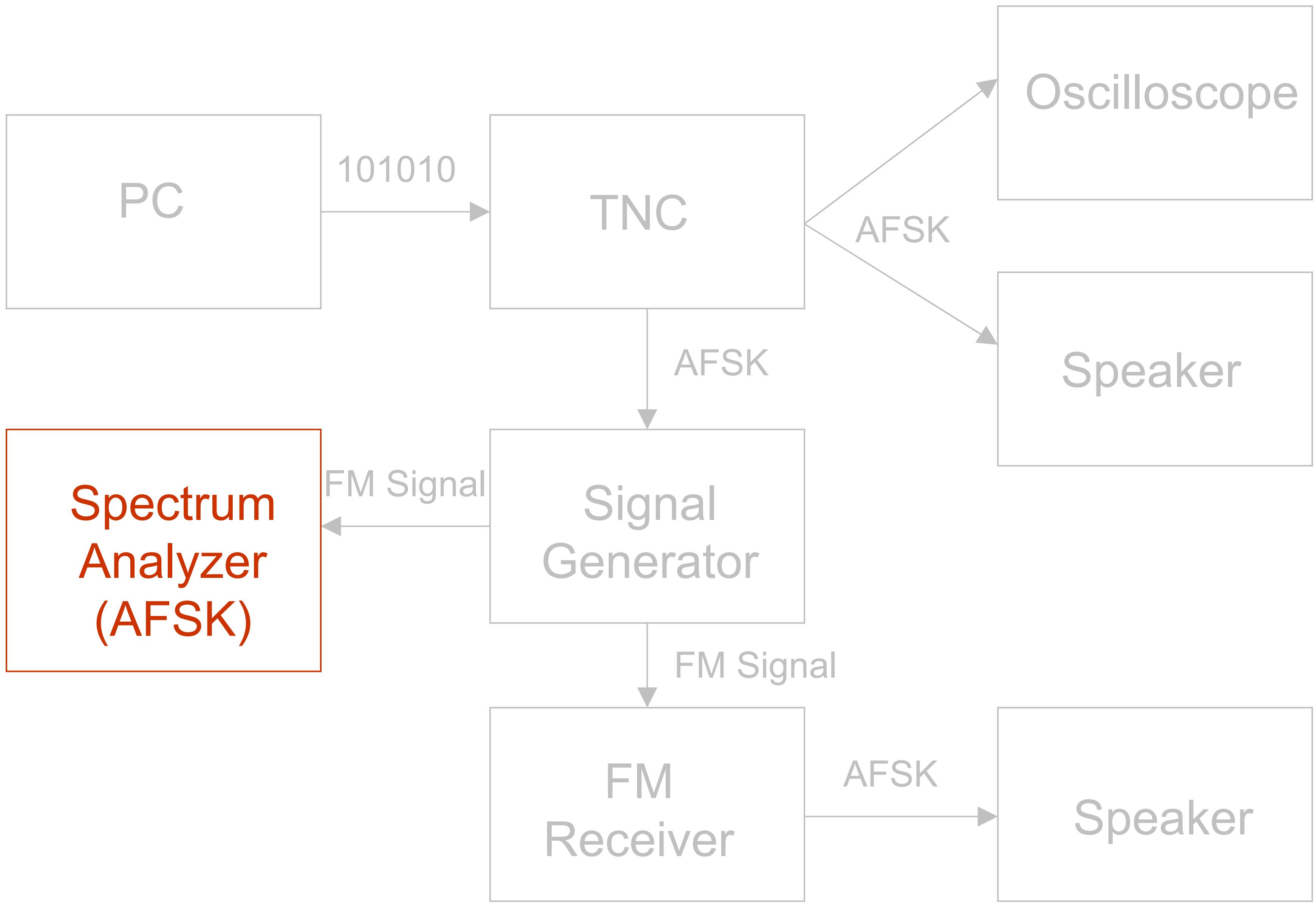
$$SNR = \frac{\text{Power of Signal}}{\text{Power of Noise}} = \frac{\int_{-\infty}^{\infty} s^2(t)dt}{\int_{-\infty}^{\infty} n^2(t)dt}$$

$$= \frac{A_c^2 \int_{-\infty}^{\infty} \left( \cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(t')dt') \right)^2 dt}{\int_{-\infty}^{\infty} n^2(t)dt}$$


PC
101010
TNC
AFSK
Oscilloscope
Speaker
AFSK
Spectrum Analyzer (FM)
FM Signal
Signal Generator
FM Signal
FM Receiver
AFSK
Speaker

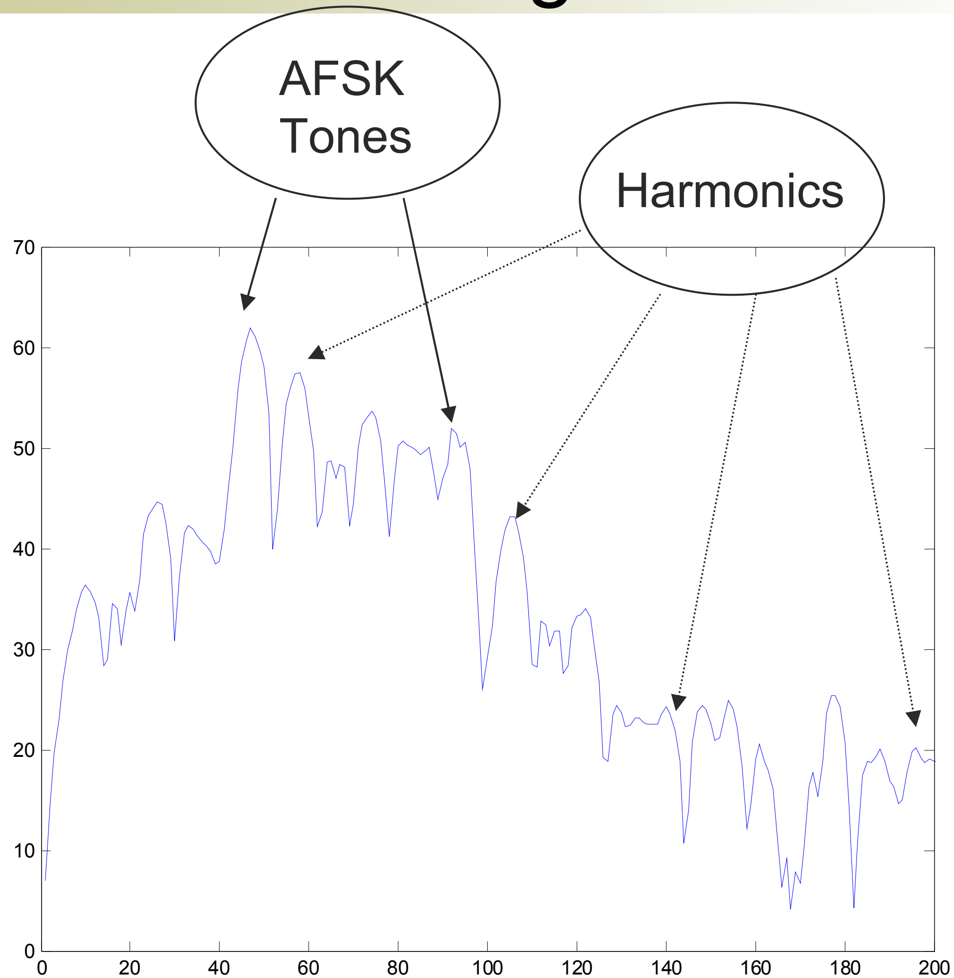
# Frequency Spectrum of Modulated Signal at receiver side




PC
101010
TNC
Oscilloscope
AFSK
Speaker
AFSK
Spectrum Analyzer (AFSK)
FM Signal
Signal Generator
FM Signal
FM Receiver
AFSK
Speaker

# Frequency Spectrum of Demodulated AFSK Signal

-80 dBm
“Good”



# Summary of Important values

- $A_C$ > -107 dBm: Good
- $A_C$ = -112 dBm: Noisy
- $A_C$ < -117 dBm: Extremely Noisy
- $f_C$ : 435 MHz
- $k_f$ : 15 kHz

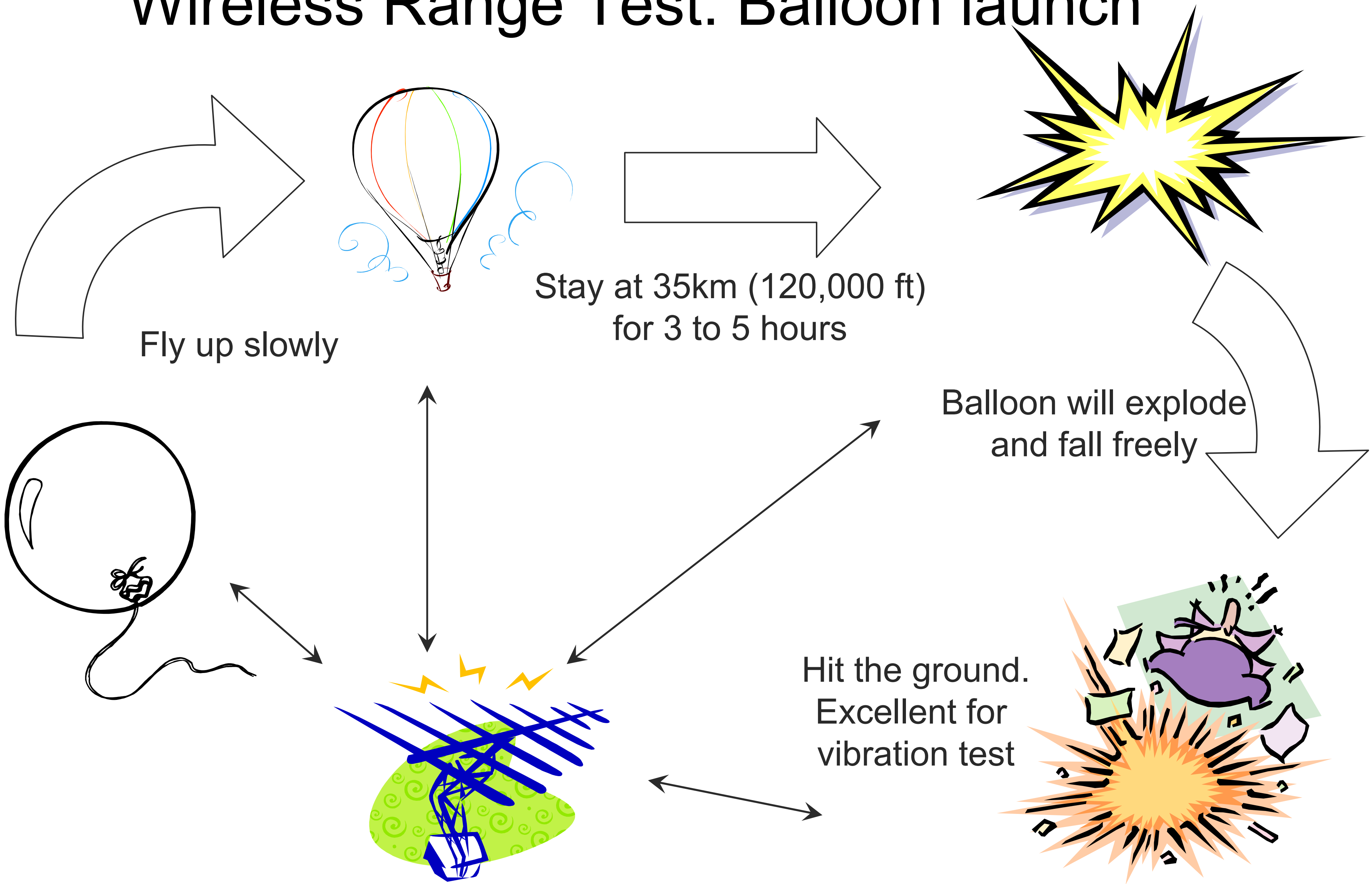
# Measurement Method

- Signal to Noise Ratio: Spectrum Analyzer
- Noise Floor: Spectrum Analyzer
- Path Loss: Spectrum Analyzer

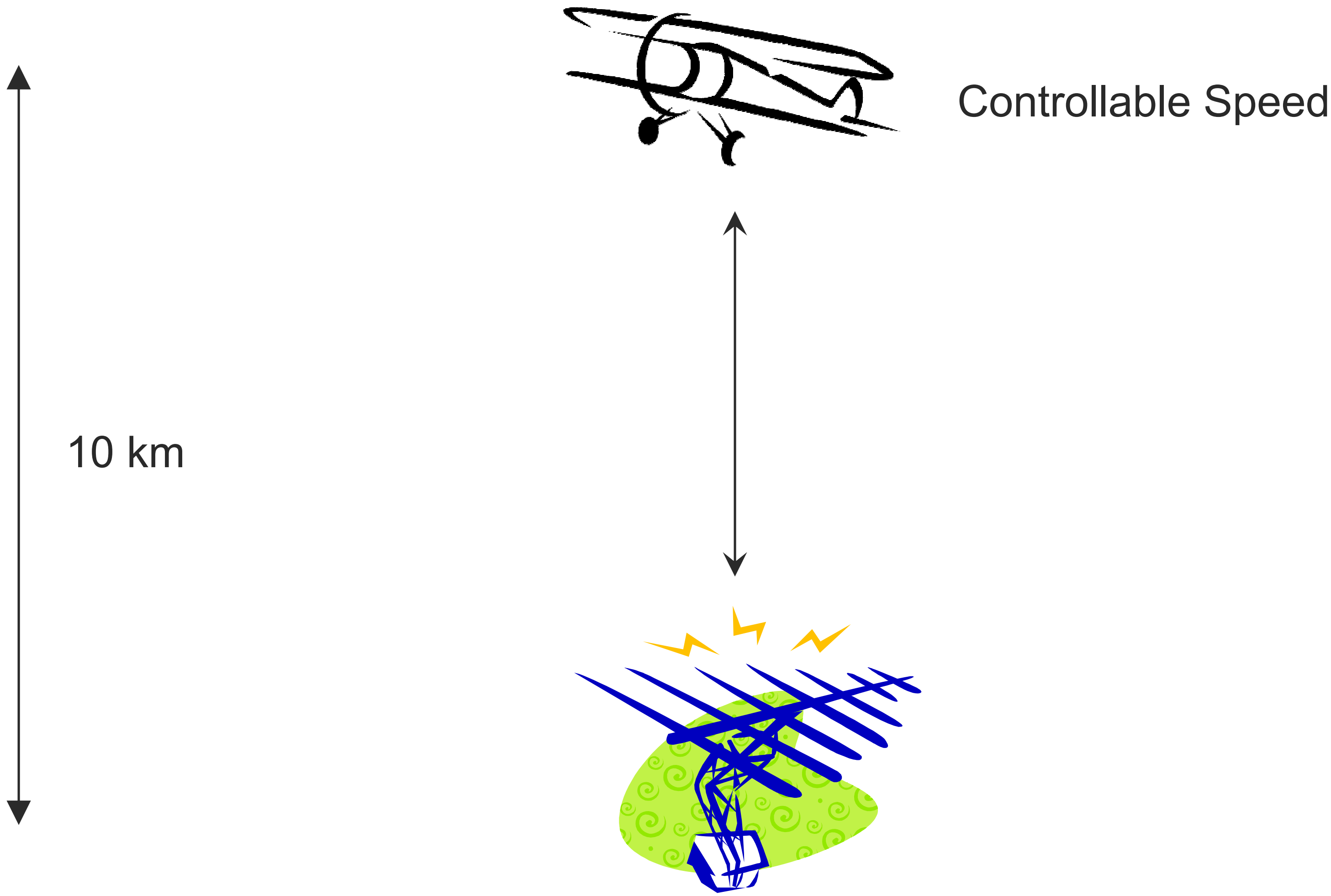
# Wireless Range Test

- Short Range
  - Within Everitt Lab and Quad
- Long Range
  - Field Site: 16 km (Horizontal distance)
  - Balloon Launch: 35 km (Vertical distance)
  - Small Aircraft: 10 km (Vertical distance)

# Wireless Range Test: Balloon launch



# Wireless Range Test: Small Aircraft



# Measurement details #1

- GPS will be installed on the flight unit for tracking the position.
- Temperature, pressure and height attitude will be collected.

# Measurement details #2

- Signal to Noise Ratio and Path loss will be measured using Spectrum Analyzer.
- Spectrum Analyzer will installed at the receiver side. It is possible to remotely control using Agilent VEE Pro.

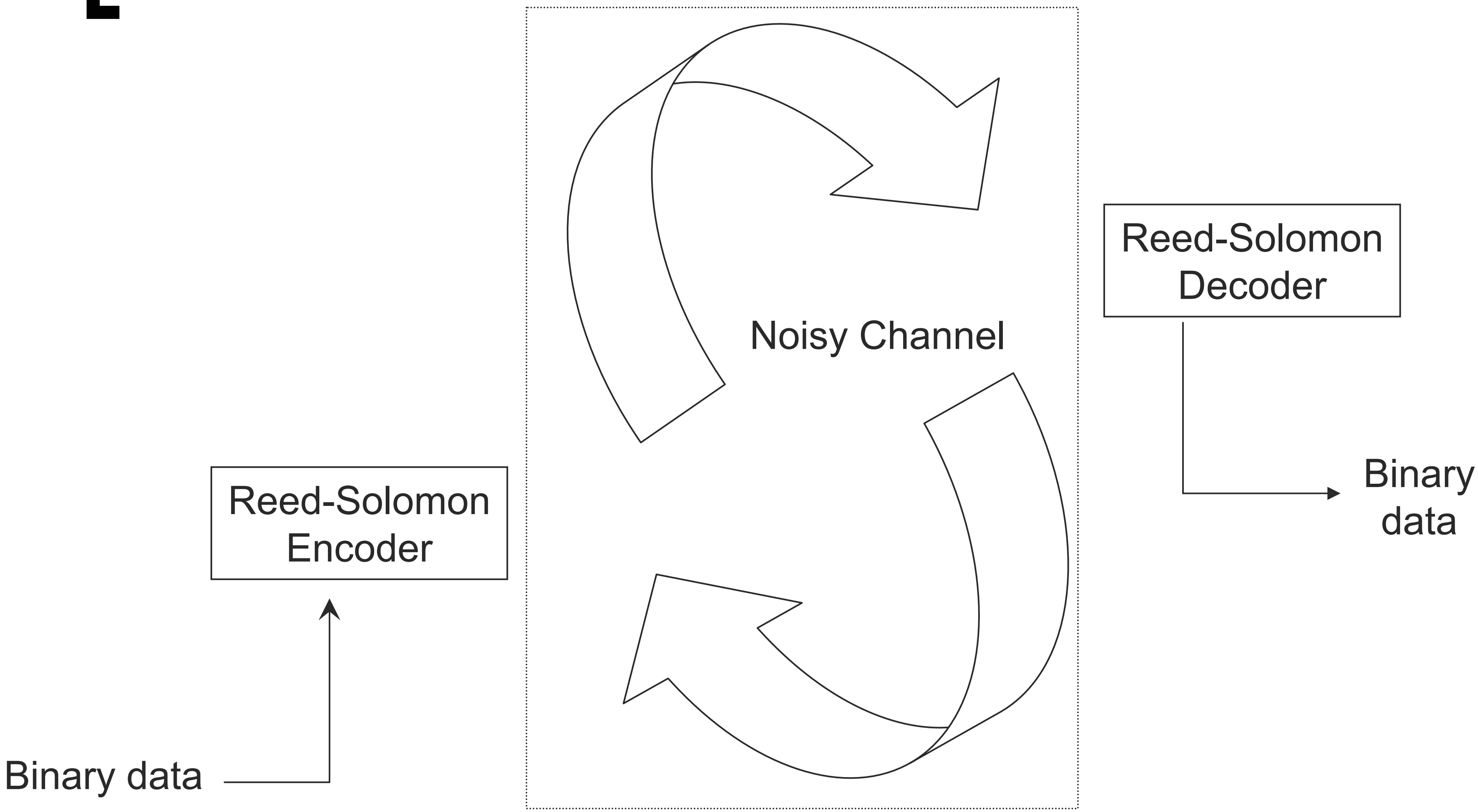
# Measurement details #3

- A file will be used for analyzing the performance

$$\text{Transfer Rate} = \frac{\text{No. of bit transferred}}{\text{Total time}}$$

$$\text{Bit Error Ratio} = \frac{\text{No. of bit of error}}{\text{Total no. of bit transferred}}$$

# Error Handling: Reed-Solomon Coding

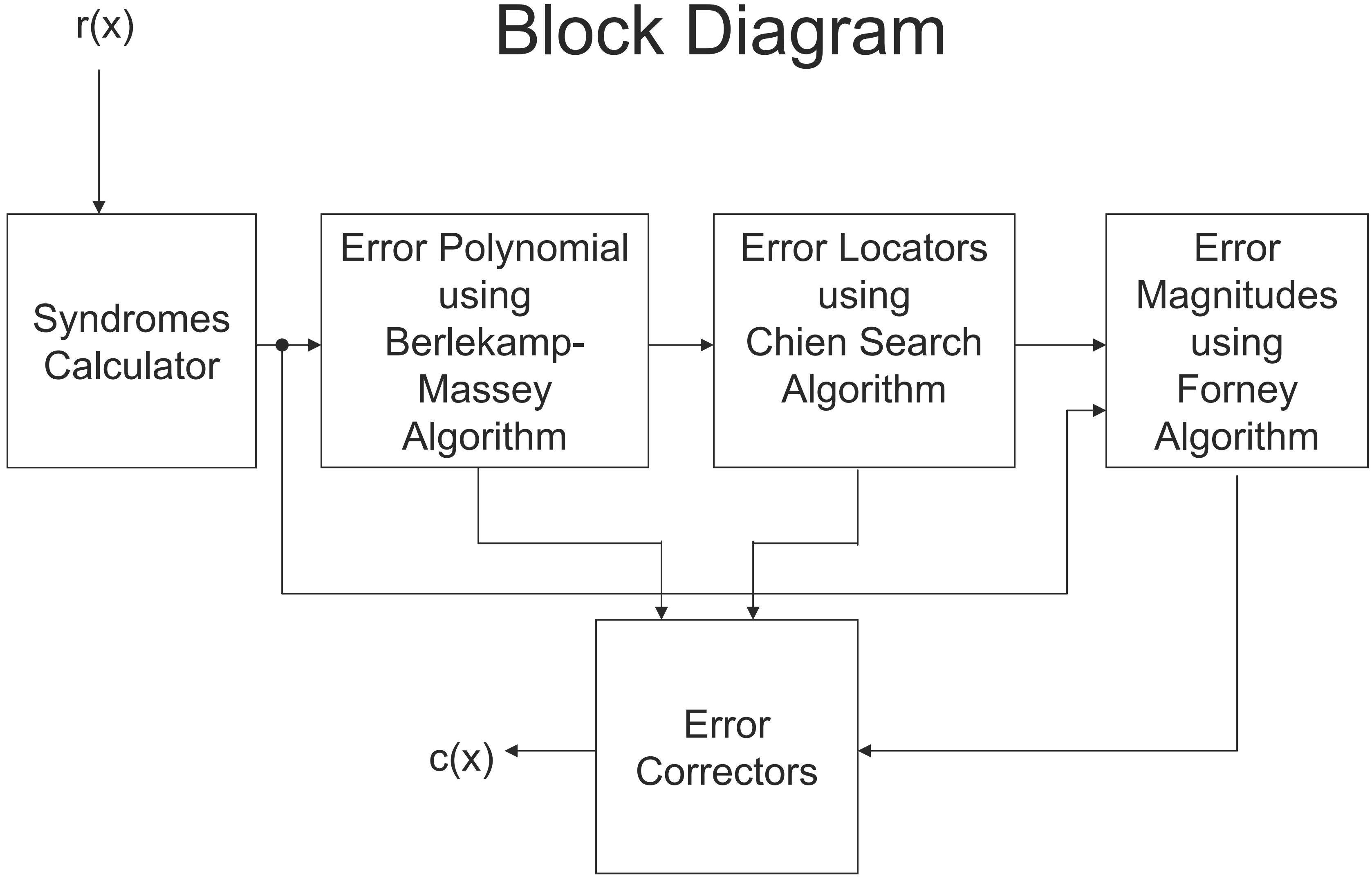


# Error Handling: Reed-Solomon Coding

Let the received code word $r(x)$ is the orginal codeword $c(x)$ plus errors $e(x)$, i.e.,

$$r(x) = c(x) + e(x)$$

# Block Diagram



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