RF Basics

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RF Basics

- RF stands for Radio Frequency, but it often used in the sense of “ anything related with EM signals”.
- The sine wave is the basic example of a signal that can be generated, transmitted and received with RF equipment.
- It may be characterized by:
  - Frequency
  - Amplitude

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- Frequency: the number of times a signal goes through a complete “up and down” cycle in one second of time. It is measured in **Hertz**.
- Amplitude: the difference between the maximum and the minimum value during one cycle. It is measured in **Volts**, and it is related with the strength, or power, of the signal.

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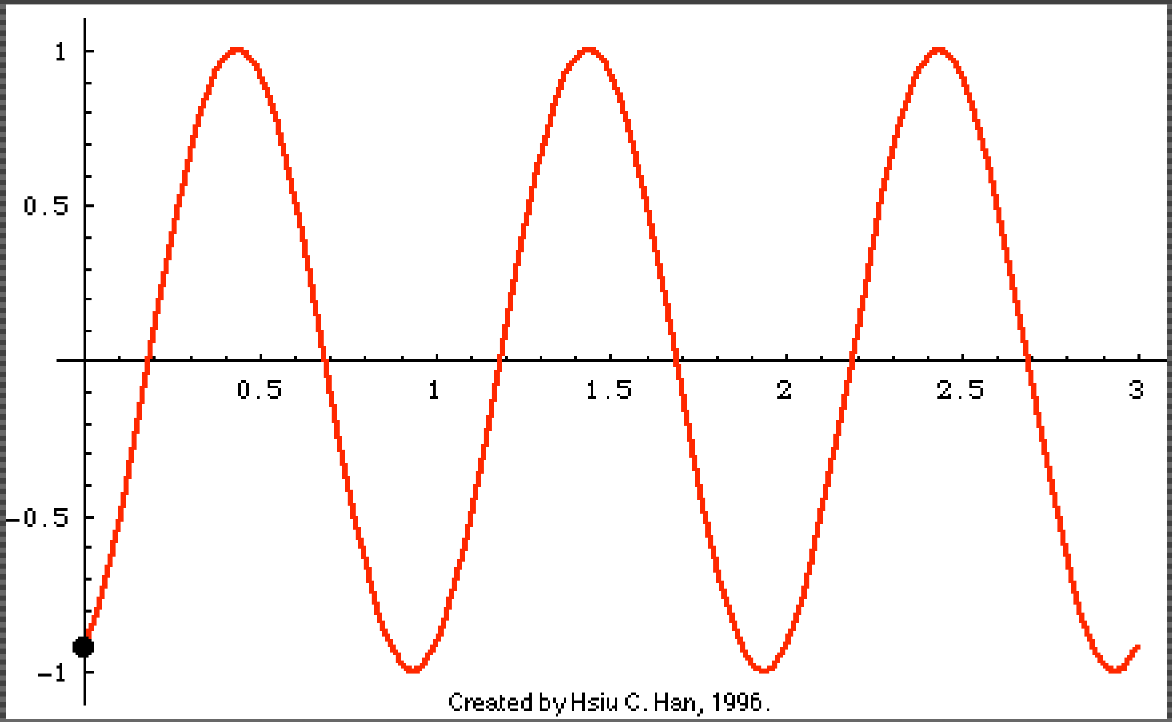

- Frequency: the number of times a signal goes through a complete "up and down" cycle in one second of time. **1 Hz**
- Amplitude: the difference between the maximum and the minimum value during one cycle. **2 V**

RF Basics

- We use the Scientific Notation that uses the power of ten to multiply the values.

milli (m)	10^{-3}	1 mV
micro(μ)	10^{-6}	1 μV
kilo(k)	10^{3}	1 kHz
mega(M)	10^{6}	1 MHz
giga(G)	10^{9}	1 GHz

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- Frequency Band: the standard name of a specific range of frequencies.
  - HF: High Frequency, 3 MHz to 30 MHz
  - VHF: Very High Frequency, 30 MHz to 300 MHz
  - UHF: Ultra High Frequency, 300 MHz to 3 GHz
  - SHF: Super High Frequency, 3 GHz to 30 GHz
  - EHF: Extra High Frequency, 30 GHz to 300 GHz

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- Bandwidth: width of the range of frequencies that a signal occupies on a given transmission medium. It is the difference between the highest-frequency signal component and the lowest-frequency signal component.
  - Voice transmission: 3 kHz
  - FM radio broadcast: 200 kHz
  - Analog TV broadcast: 6 MHz

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- Wavelength: the distance a radio wave will travel during one cycle.
  - $$\lambda = c/f$$
  -
  - λ is the wavelength, in meters
  - c is the speed of light, 299793 m/s
  - f is the frequency, in Hz

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Frequency	Wavelength
900 MHz	0.33 m
2.4 GHz	*0.125 m*
5.0 GHZ	0.06 m

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- Power: in the RF world, the power is commonly used to quantify a signal, instead of the amplitude.
- Power is expressed in *Watts*.
- For low-frequency signals, the power is given by
- $$P = EI$$
- For high-frequency signals with no reactance, by the root-mean-square values.
- For high-frequency signals with reactance, RF power is a vector, 2-D, quantity.

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- Decibel: the decibel (abbreviated as *dB*) is a logarithmic expression of the ratio between the power, voltage, or current of two signals.

- Signal one, with a power of P_1 Watts

- Signal two, with a power of P_2 Watts

$$P_{dB}=10\log_{10}(P_2/P_1)$$

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- If the load impedance is constant, decibels can be calculated in terms of effective voltage.
  - Signal one, with an RMS voltage of V_1 across a load
  - Signal two, with an RMS voltage of V_2 across a load

$$V_{dB}=20\log_{10}(V_2/V_1)$$

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- When the decibel figure is *positive*, the second signal is stronger than the first one, and the power ratio is called *gain*.
- When the decibel figure is *negative*, the second signal is weaker than the first one, and the power ratio is called *loss*.
- In amplifiers the gain, also called the amplification factor, in often expressed in decibels.

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+ 3 dB	two times bigger
+10 dB	ten times bigger
-3 dB	one half
-10 dB	one tenth

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- To express power using decibels we need a specific power to be assumed as a reference.
- In the RF world the common standard is to refer powers to 1 mW (0.001 Watts).
- Such power ratio, expressed in decibels, is called ***dBm***.

$$P_{dBm}=10\log_{10}(P_{watts}/1mW)$$

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- The advantage of using decibels instead of Watts to express the power of a signal along an RF chain is that instead of dividing or multiplying powers to take care of amplifications and attenuations, we just *add or subtract the gains and the losses expressed in decibels*.

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- Using amplification and attenuation factors and expressing the powers in Watts, we obtain the value of the power at the receiver's input in this way:

$$P_{rec}=P_{transm} \times (1/Att_{cable1}) \times Amp \times (1/Att_{cable2})$$

- If we use dB to express the gains and the losses and dBm to express the powers, the calculation becomes a simple addition:

$$P_{rec}=P_{transm} + Loss_{cable1} + Gain_{amp} + Loss_{cable2}$$

- This procedure is called ***Power Budget Calculation***

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- Signals are characterized by frequency.
- We are interested in signals at 2.4 GHz.
- At 2.4 GHz, the wavelength is 12.5 cm.
- We will use dB, so we can use Power Budget Calculation.