Ham Radio
and
Power Converters

Angelo Ferraro, AC2BC

February 2, 2015

W4CAE

Ham Radio or the Radio's Ham ?

- Power Supplies: a viewpoint of frequency.
- A smattering of history.
- No heavy duty math,
  - Just +, - , x, /
- Insight on troubleshooting noise in your radio
  - Most hams already have the equipment needed
- Reduce the fear of switching power supplies
- Answers to the Mysteries of the Universe

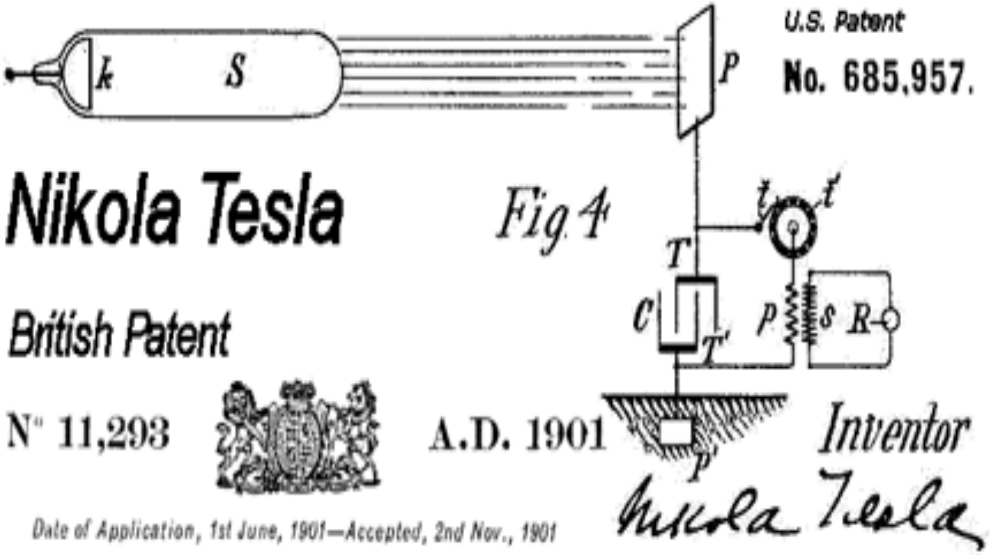
Power Converter

- Device for the conversion, control, and use of electromagnetic energy.
- Control of Voltage, Current, Power, Frequency, and Noise
- Primary goal is the transfer of energy.

Radio

- Device for the conversion, control, and use of electromagnetic energy wirelessly at a distance.
- Control of Voltage, Current, Power, Frequency, and Noise
- Primary goal is the transfer of information.

Nikola Tesla and His ‘Ham Shack’



Wardenclyffe Tower

Shoreham, NY 11786

Circa: 1901

Height: 187' (57 m)

RF CW Transmitter using L-C resonant circuit

Receiver either matching L-C resonant circuits or even gas tubes.

The first fluorescent lighting

US Amateur Radio Bands

US AMATEUR POWER LIMITS

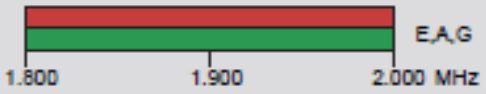
FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications. (b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.

Effective Date March 5, 2012

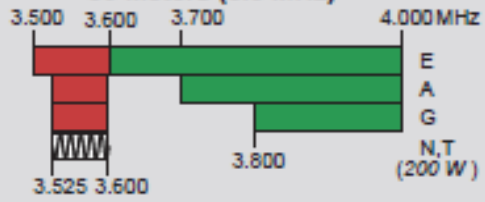
Published by:
ARRL The national association for AMATEUR RADIO®
www.arrl.org
225 Main Street, Newington, CT USA 06111-1494

160 Meters (1.8 MHz)

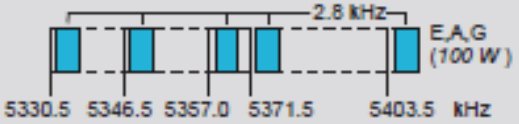
Avoid interference to radiolocation operations from 1.900 to 2.000 MHz



80 Meters (3.5 MHz)

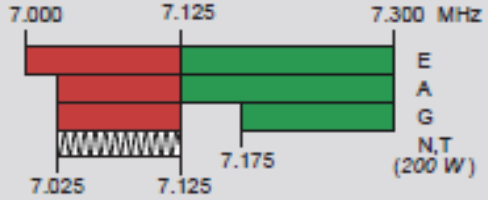


60 Meters (5.3 MHz)



General, Advanced, and Amateur Extra licensees may operate on these five channels on a secondary basis with a maximum effective radiated output of 100 W PEP. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III as defined by the FCC Report and Order of November 18, 2011. USB is limited to 2.8 kHz centered on 5332, 5348, 5358.5, 5373 and 5405 kHz. CW and digital emissions must be centered 1.5 kHz above the channel frequencies indicated above. Only one signal at a time is permitted on any channel.

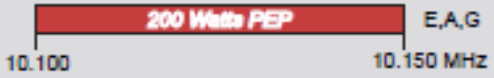
40 Meters (7 MHz)



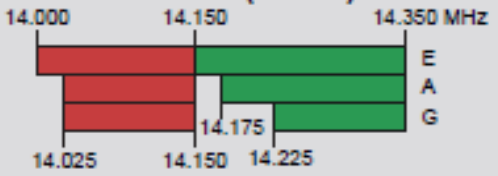
Phone and image modes are permitted between 7.075 and 7.100 MHz for FCC licensed stations in ITU Regions 1 and 3 and by FCC licensed stations in ITU Region 2 West of 130 degrees West longitude or South of 20 degrees North latitude. See Sections 97.305(c) and 97.307(f)(11).
Novice and Technician licensees outside ITU Region 2 may use CW only between 7.025 and 7.075 MHz and between 7.100 and 7.125 MHz. 7.200 to 7.300 MHz is not available outside ITU Region 2. See Section 97.301(e). These exemptions do not apply to stations in the continental US.

30 Meters (10.1 MHz)

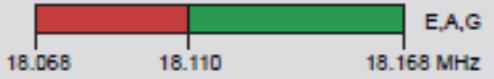
Avoid interference to fixed services outside the US.



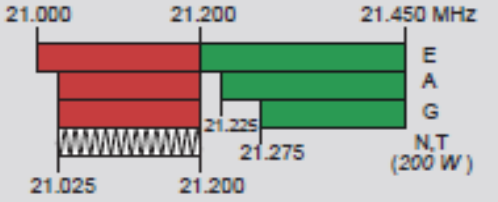
20 Meters (14 MHz)



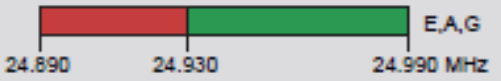
17 Meters (18 MHz)



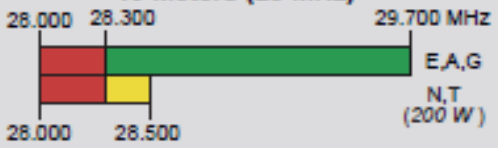
15 Meters (21 MHz)



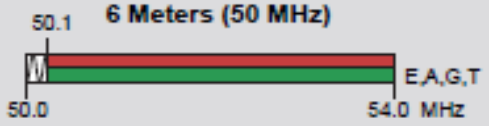
12 Meters (24 MHz)



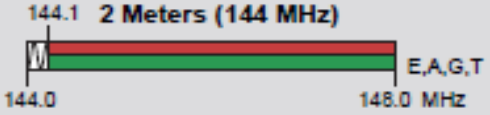
10 Meters (28 MHz)



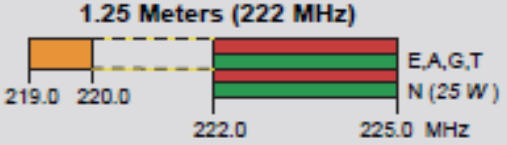
6 Meters (50 MHz)



2 Meters (144 MHz)

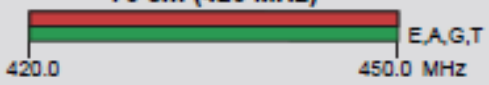


1.25 Meters (222 MHz)



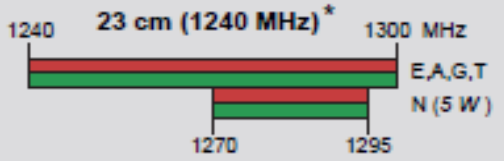
*Geographical and power restrictions may apply to all bands above 420 MHz. See *The ARRL Operating Manual* for information about your area.

70 cm (420 MHz)*



33 cm (902 MHz)*

23 cm (1240 MHz)*



All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	10.0-10.5 GHz *	122.25-123.0 GHz
2390-2450 MHz	24.0-24.25 GHz	134-141 GHz
3300-3500 MHz	47.0-47.2 GHz	241-250 GHz
5650-5925 MHz	76.0-81.0 GHz	All above 275 GHz

* No pulse emissions

KEY

Note:
CW operation is permitted throughout all amateur bands.

MCW is authorized above 50.1 MHz, except for 144.0-144.1 and 219-220 MHz.

Test transmissions are authorized above 51 MHz, except for 219-220 MHz

- = RTTY and data
- = phone and image
- = CW only
- = SSB phone
- = USB phone, CW, RTTY, and data
- = Fixed digital message forwarding systems only

E = Amateur Extra
A = Advanced
G = General
T = Technician
N = Novice

See *ARRLWeb* at *www.arrl.org* for detailed band plans.

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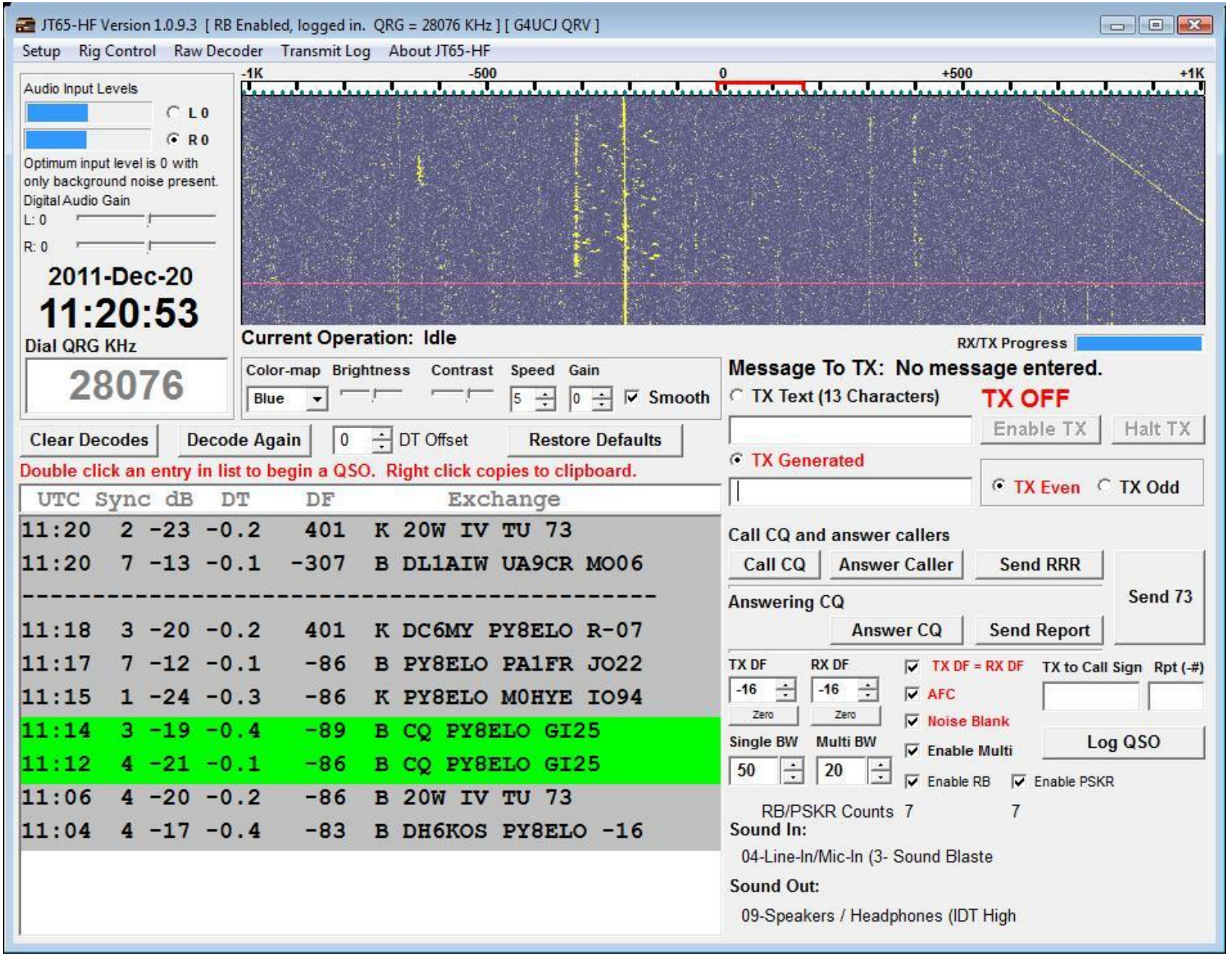
email: newham@arrl.org

Exams: 860-594-0300 email: vec@arrl.org

 rev. 4/12/2012

Ham's aren't Frightened by Technology



James C. Maxwell and friends

James C. Maxwell
(1831 – 1879)

Michael Faraday
(1791-1867)

Carl Friedrich Gauss
(1777-1853)

André-Marie Ampère
(1775-1836)

Maxwell's Equations

Differential form

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

Maxwell's Equations

Integral form

$$\oint \vec{E} \cdot d\vec{a} = \frac{Q_{enc}}{\varepsilon_0}$$

$$\oint \vec{E} \cdot d\vec{l} = -\int \frac{\partial \vec{B}}{\partial t} \cdot d\vec{a}$$

$$\oint \vec{B} \cdot d\vec{a} = 0$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc} + \mu_0 \varepsilon_0 \int \frac{\partial \vec{E}}{\partial t}$$

The Basic Equations of Electromagnetism (Maxwell's Equations) *

Name	Equation	Describes	Crucial Experiment
Gauss's law for electricity	$\epsilon_0 \oint \mathbf{E} \cdot d\mathbf{S} = q$	Charge and the electric field	1. Like charges repel and unlike charges attract, as the inverse square of their separation. 1′. A charge on an insulated conductor moves to its outer surface.
Gauss's law for magnetism	$\oint \mathbf{B} \cdot d\mathbf{S} = 0$	The magnetic field	2. It is impossible to create an isolated magnetic pole.
Ampère's law (as extended by Maxwell)	$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i$	The magnetic effect of a changing electric field or of a current	3. The speed of light can be calculated from purely electromagnetic measurements. 3′. A current in a wire sets up a magnetic field near the wire.
Faraday's law of induction	$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$	The electrical effect of a changing magnetic field	4. A bar magnet, thrust through a closed loop of wire, will set up a current in the loop.

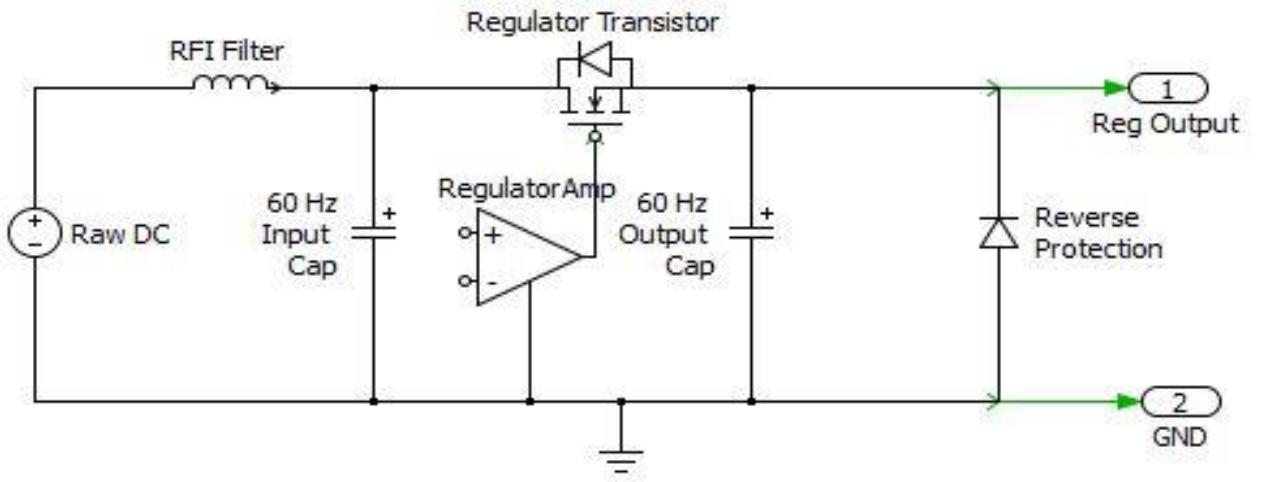
The Result Of Maxwell's Equations

- Capacitors defined
- Inductors defined
- Voltage described
- Current defined
- Ohm's Law can be derived
- Electromagnetic spectrum and behavior defined
- Radio predicted

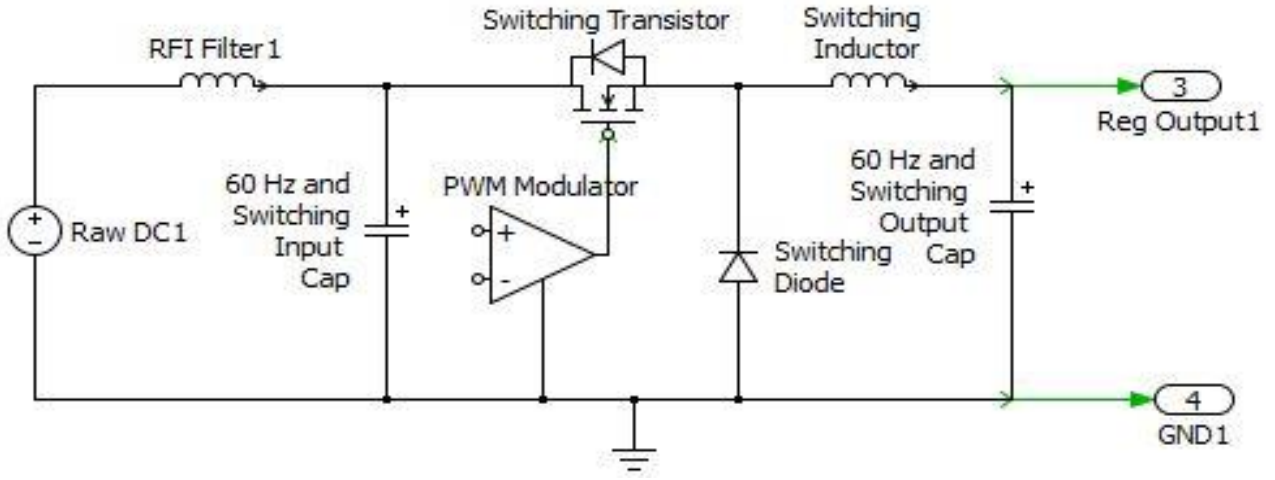
Pretty good day's work !!!

Let's Build DC Power Converters

Linear Power Converter

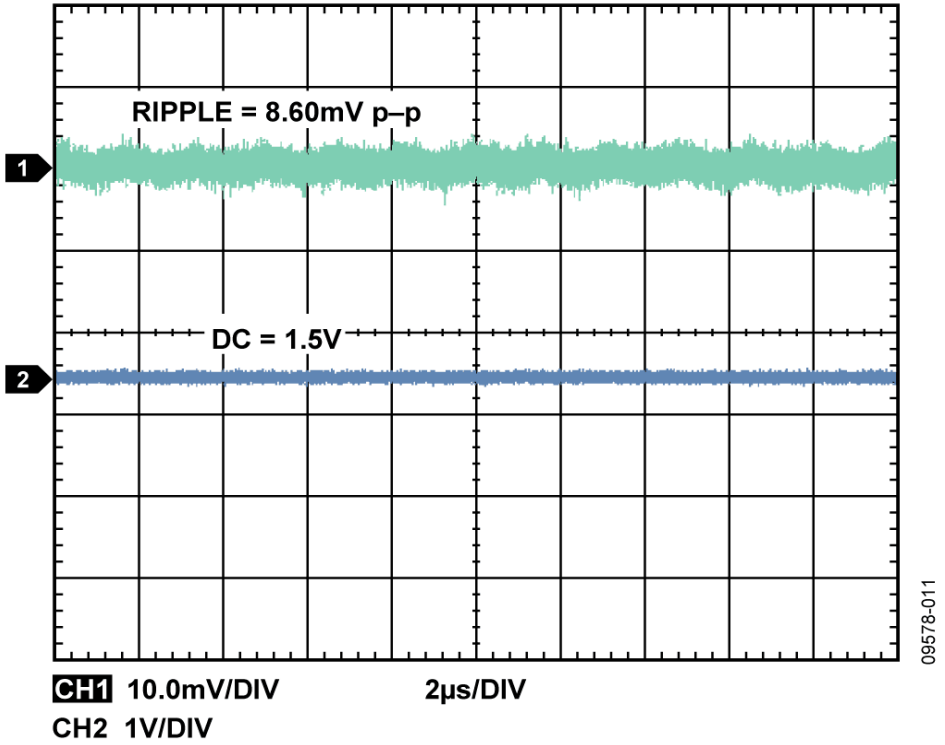


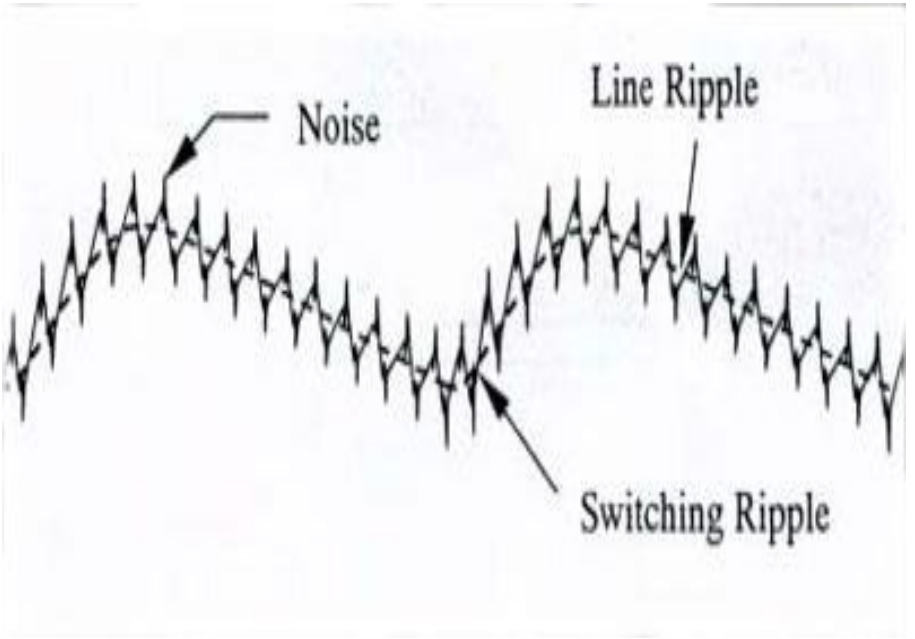
Switching Converter



Raw DC Input **Regulator** **'Clean' DC Output**

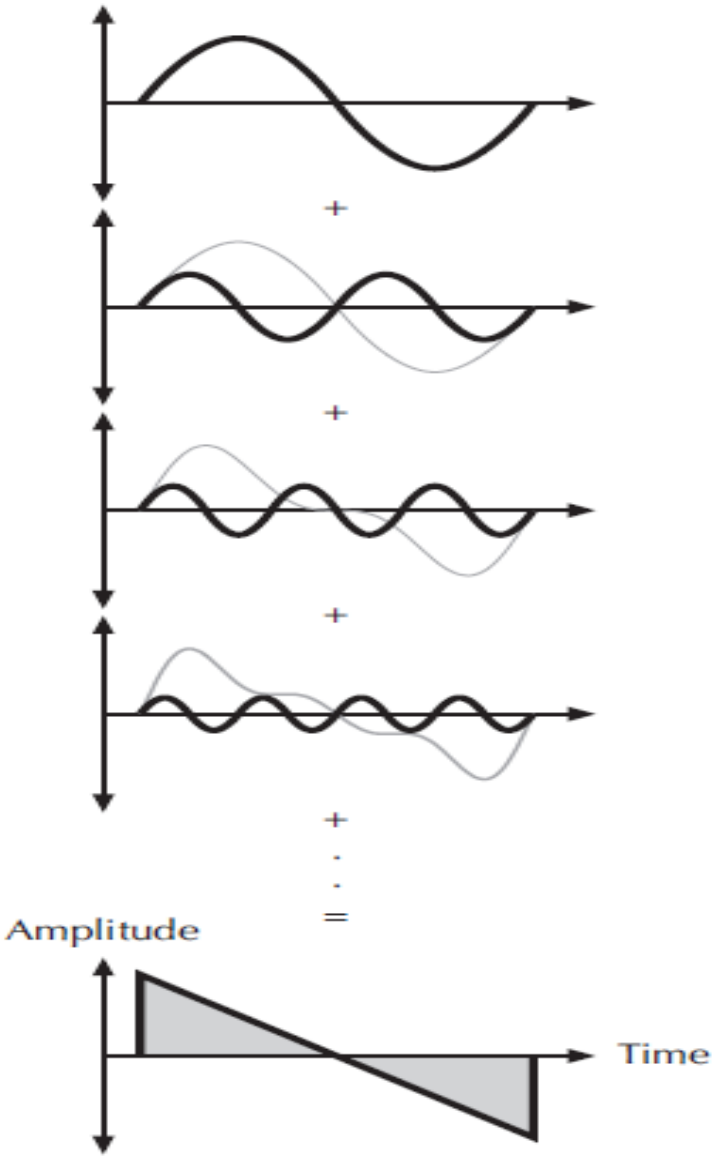
Power Converter Output Signal



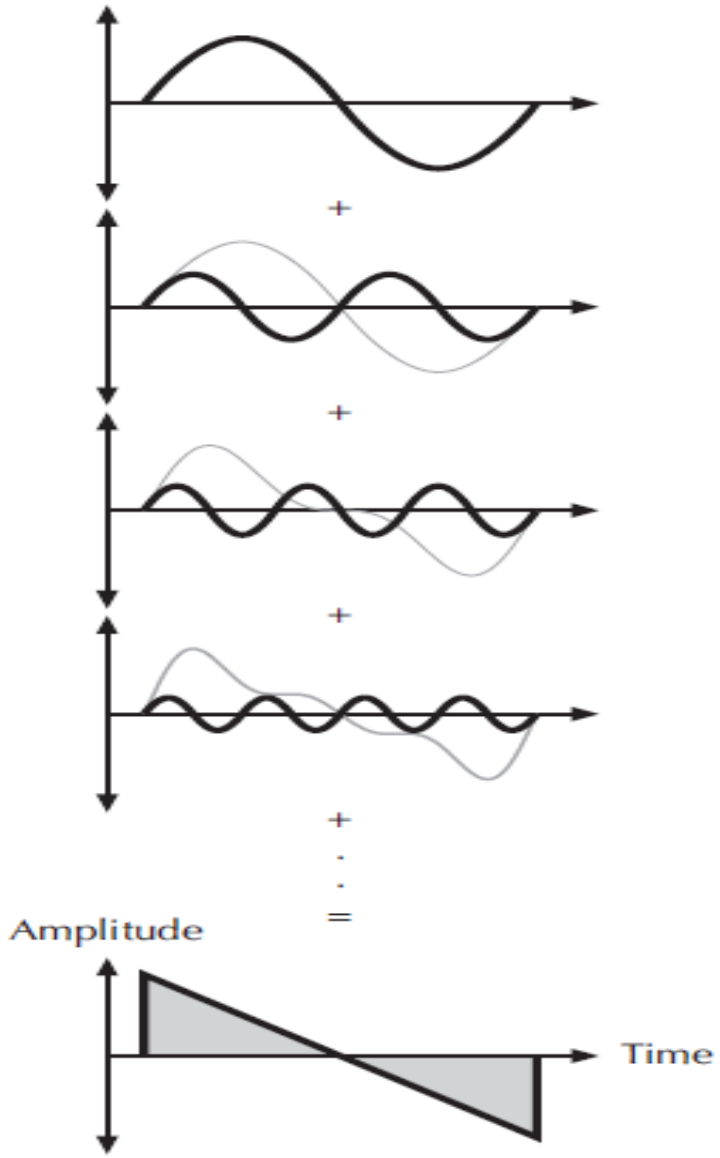


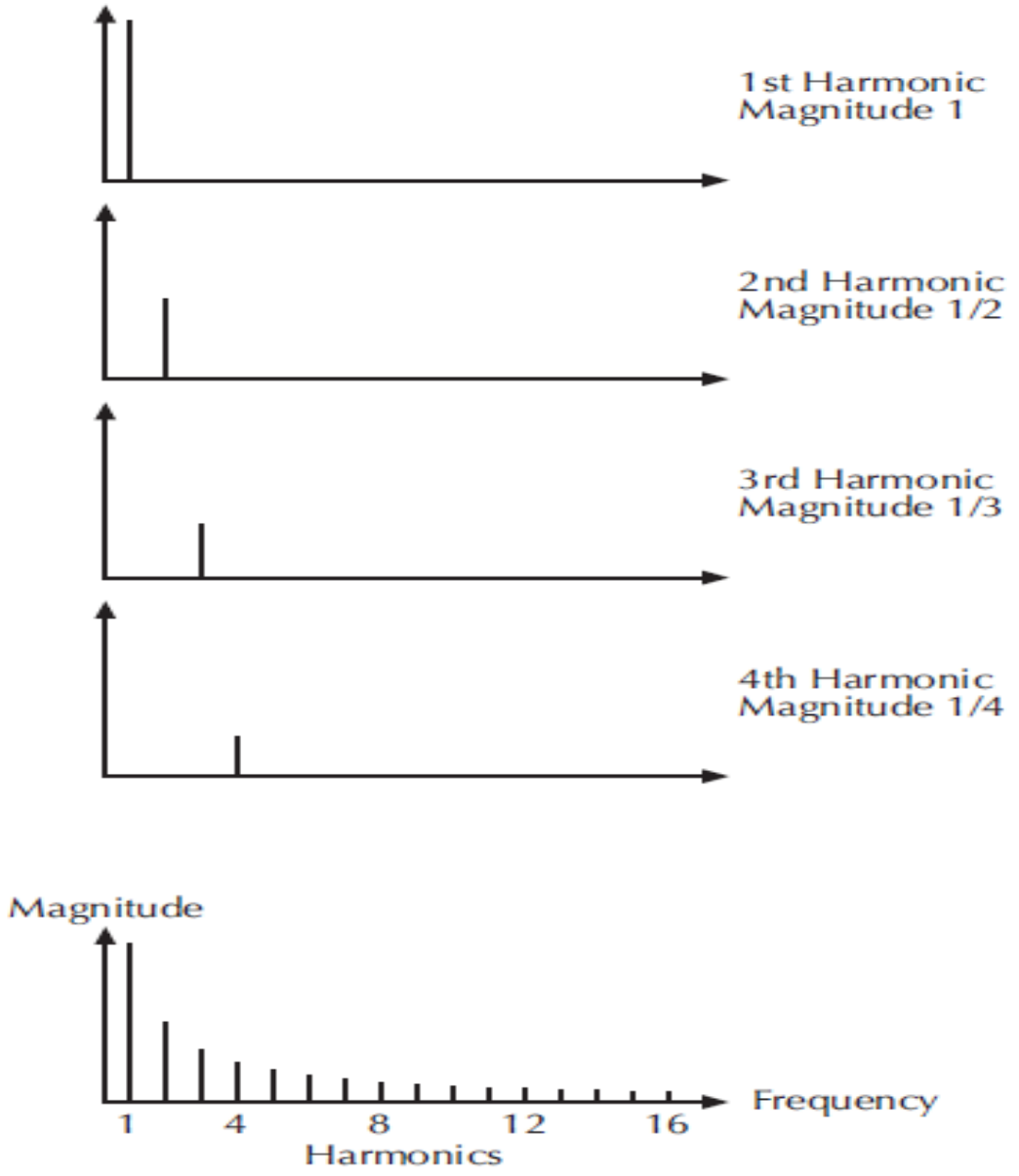
- Output ripple and Noise (top, light blue)
- Output voltage (bottom, blue)

- Ripple: 60 Hz, switching, and noise



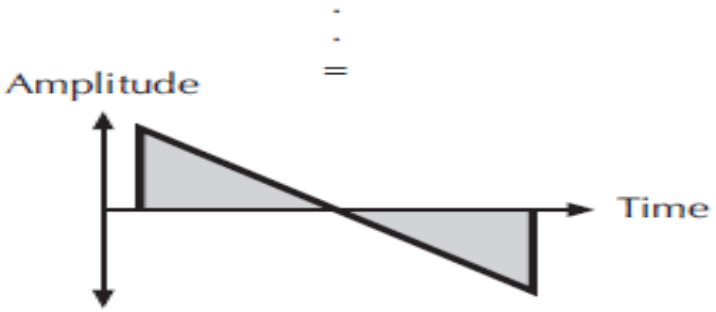
Time Domain

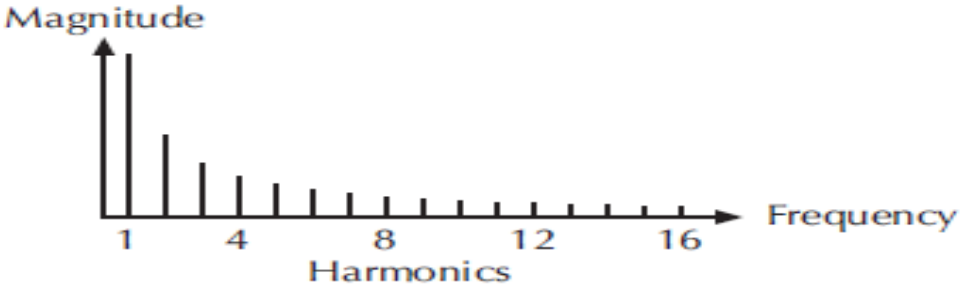




Time Domain

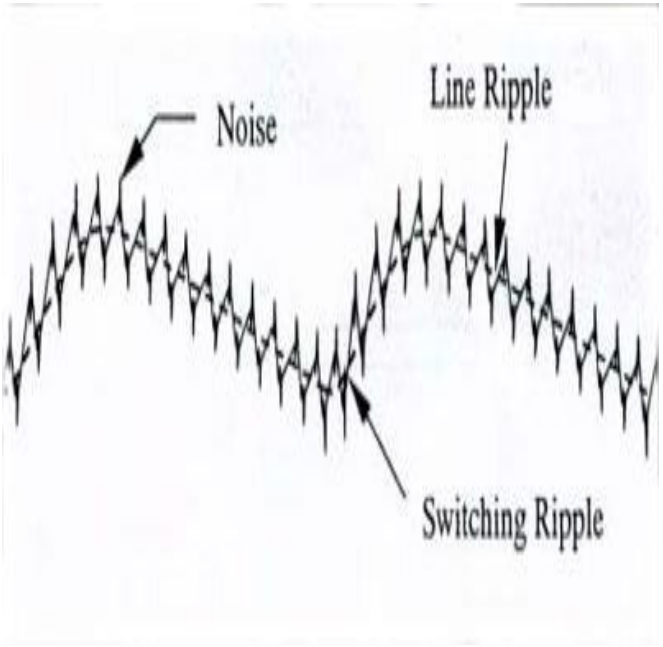
Frequency Domain

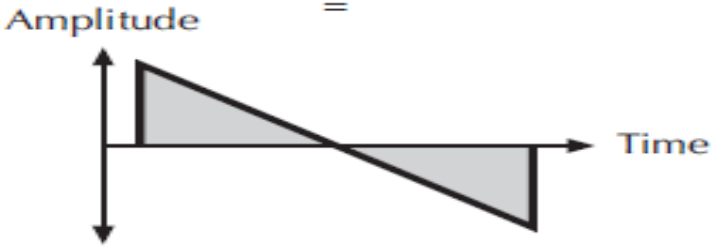


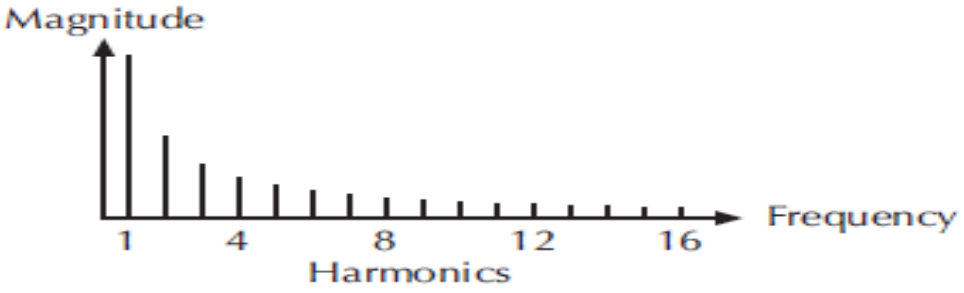


Time Domain

Frequency Domain

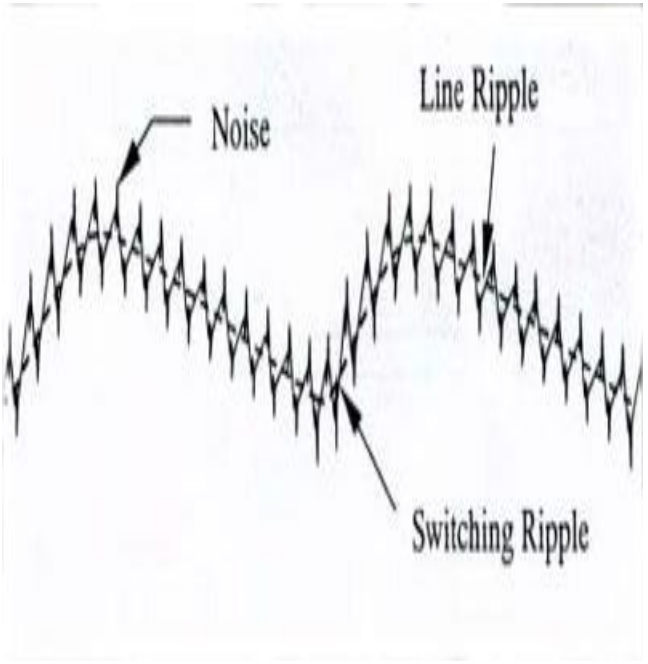






Time Domain

Frequency Domain



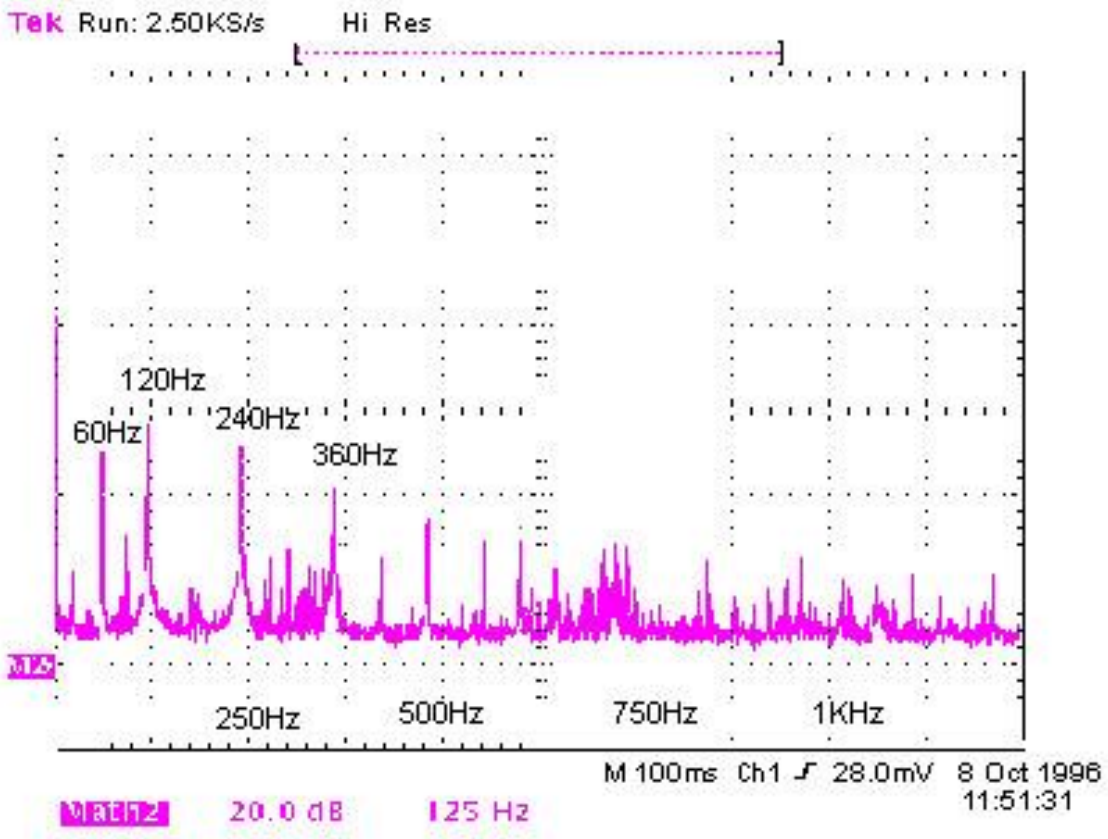
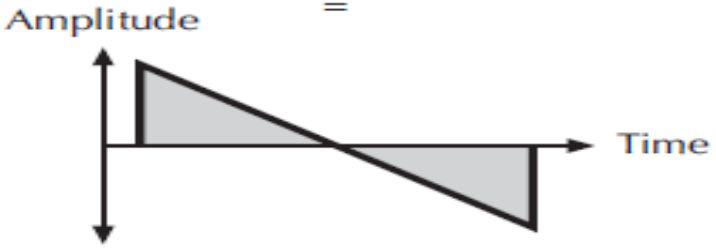
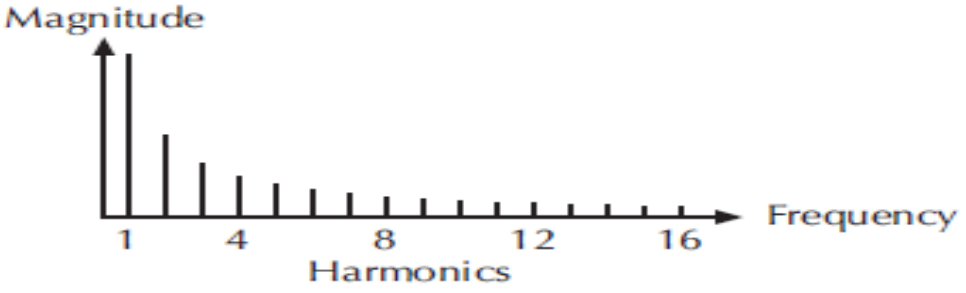


Figure 9(A)





Time Domain

Frequency Domain

Power Converter Output Frequency

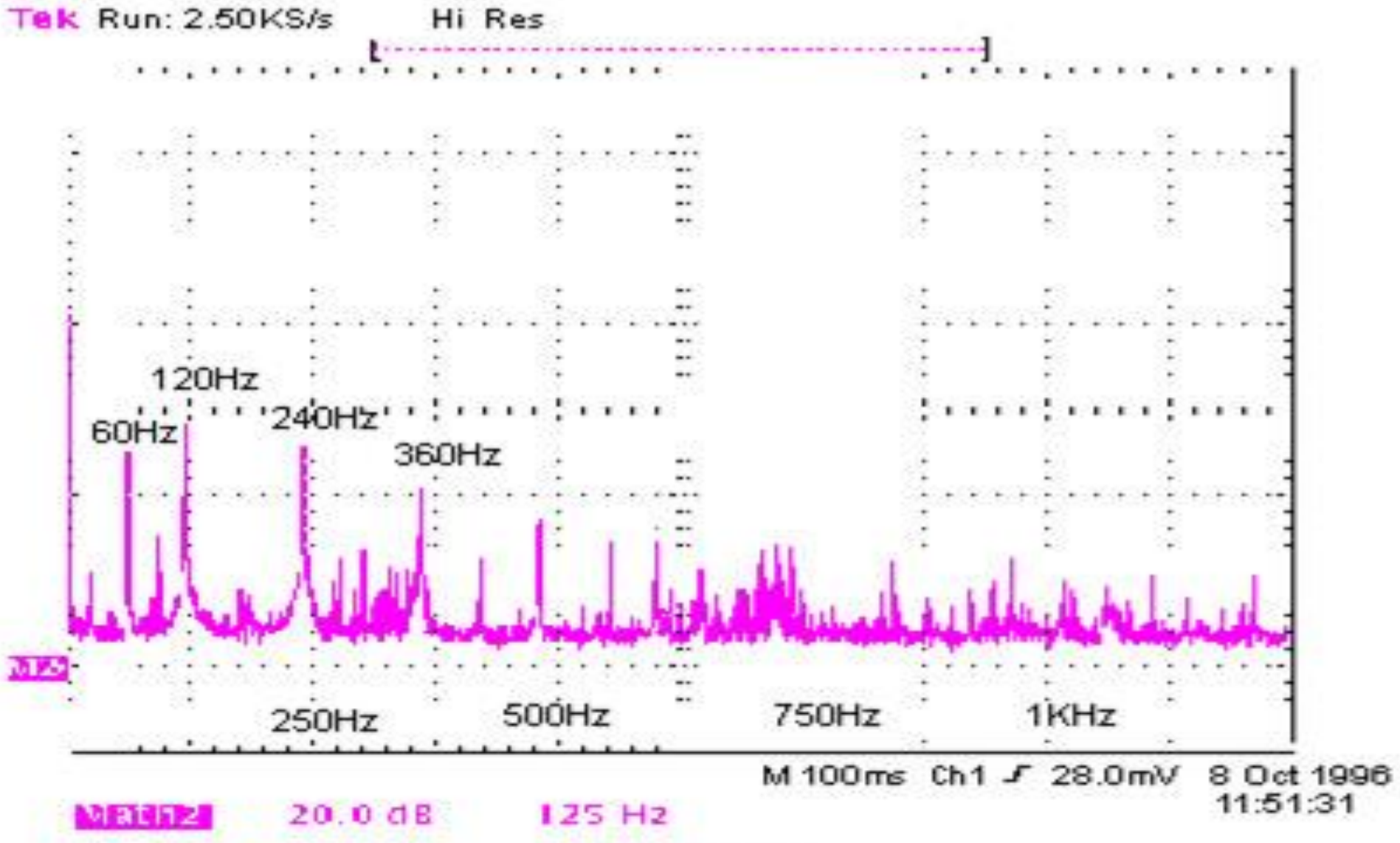
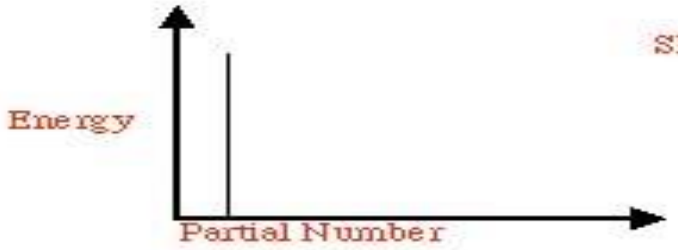
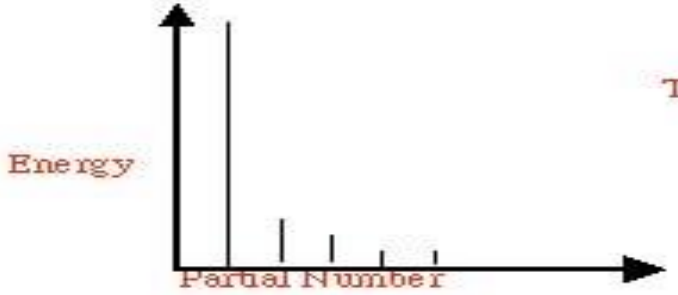


Figure 9 (A)

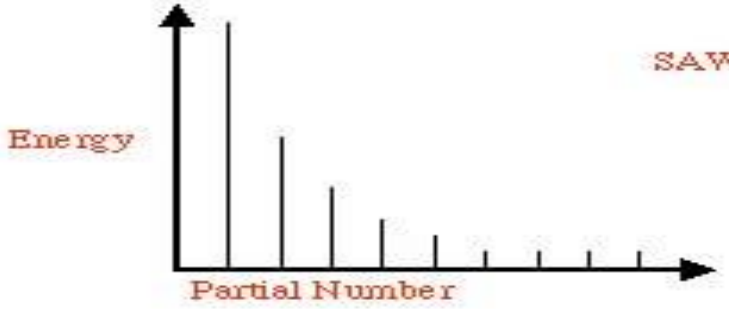
SINE WAVE



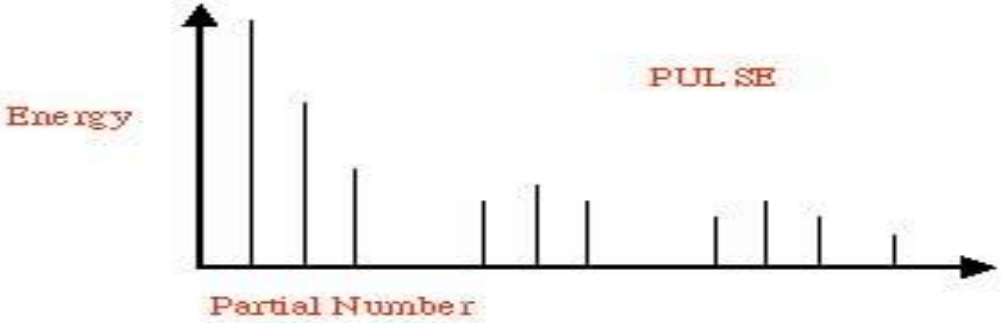
TRIANGLE WAVE



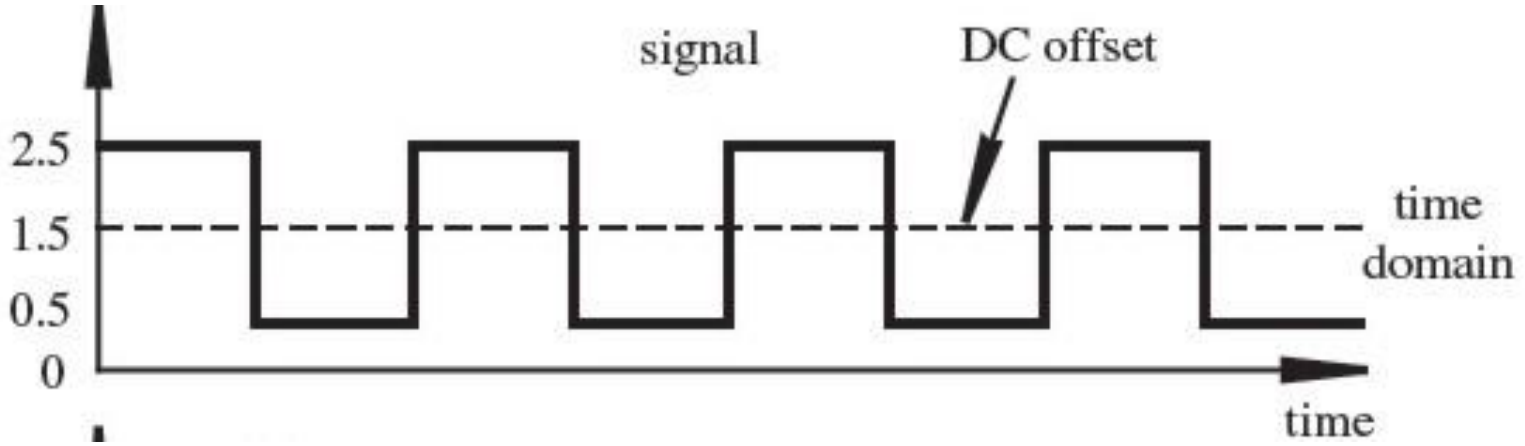
SAWTOOTH WAVE



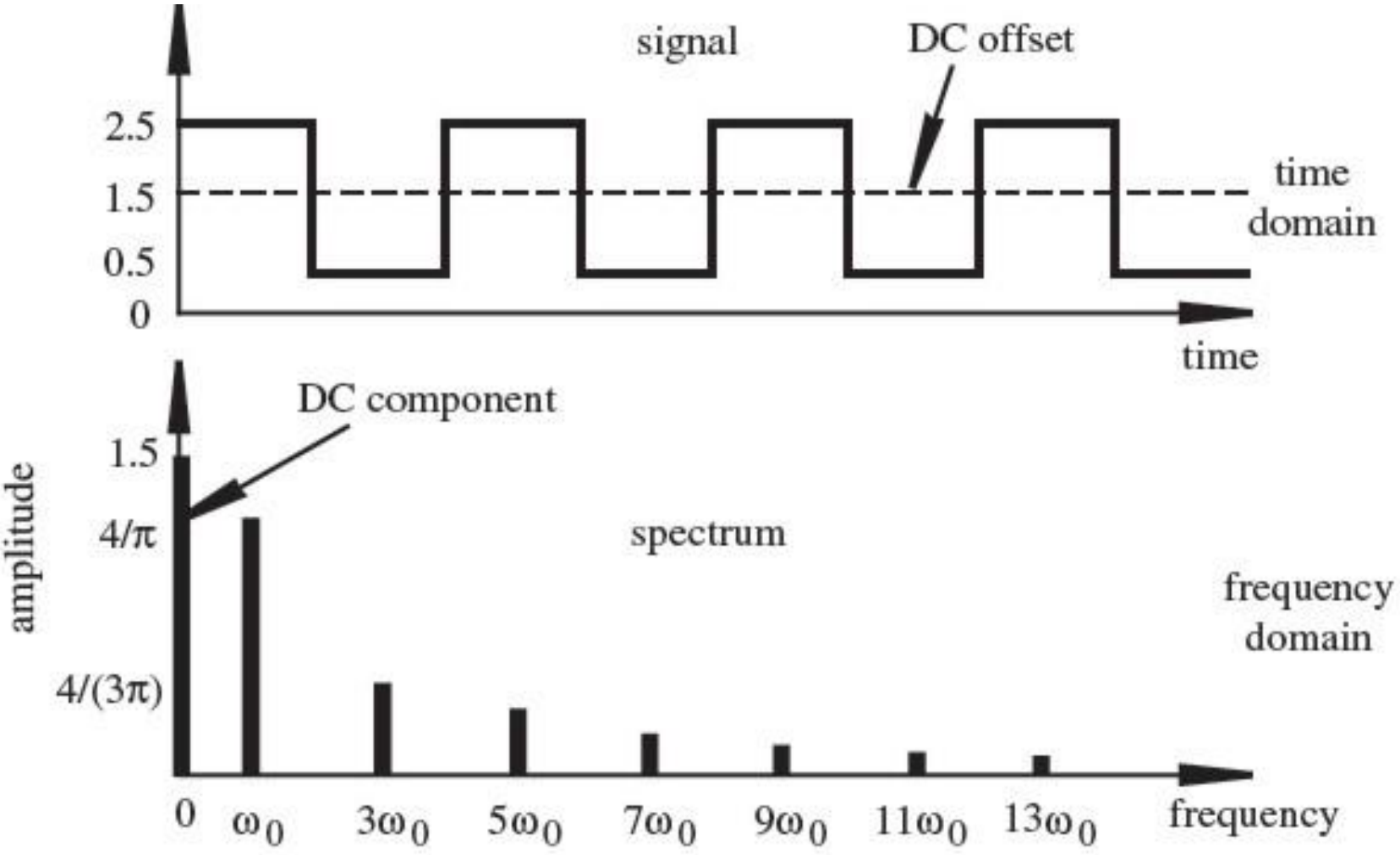
PULSE



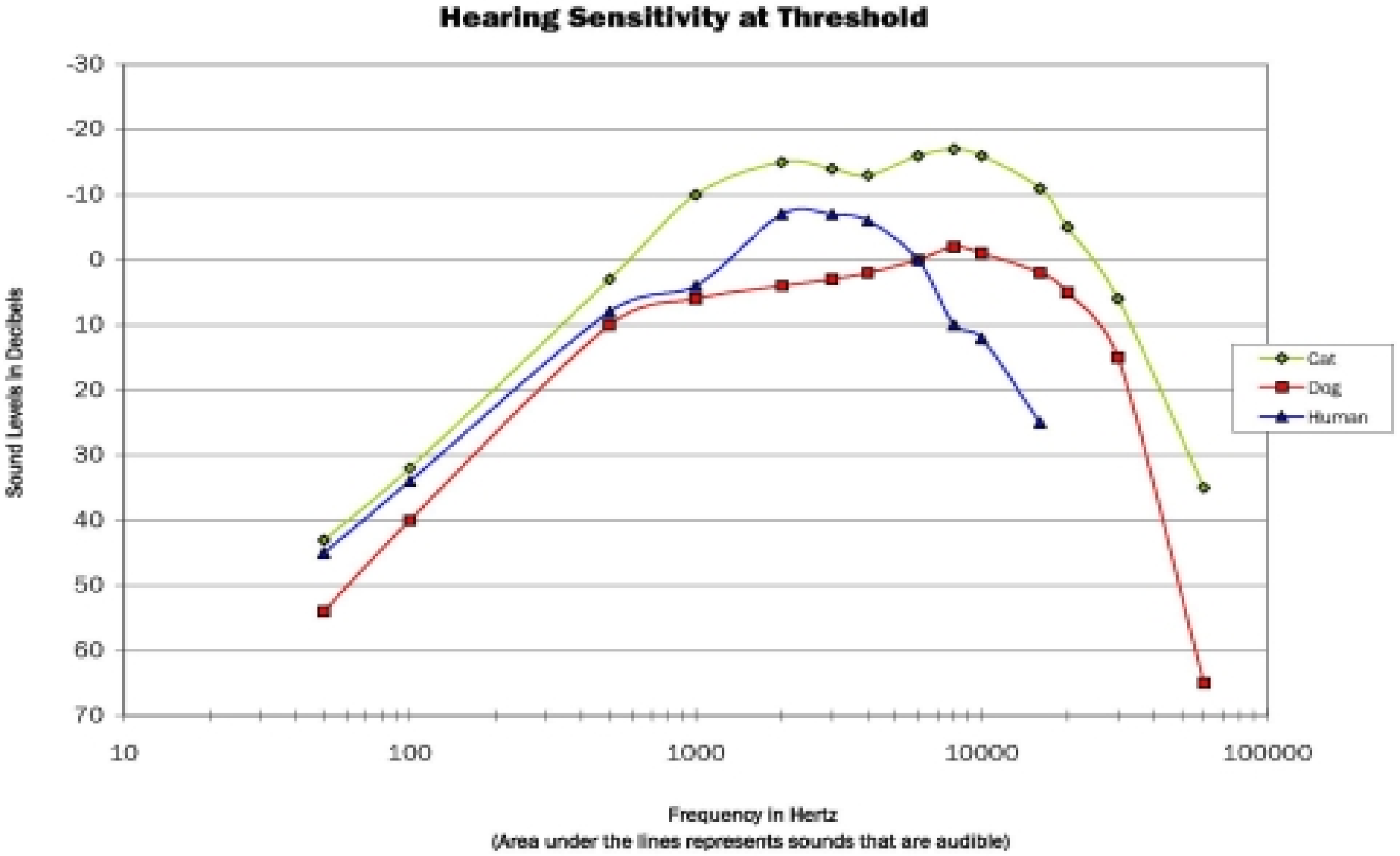
POP Quiz !!!



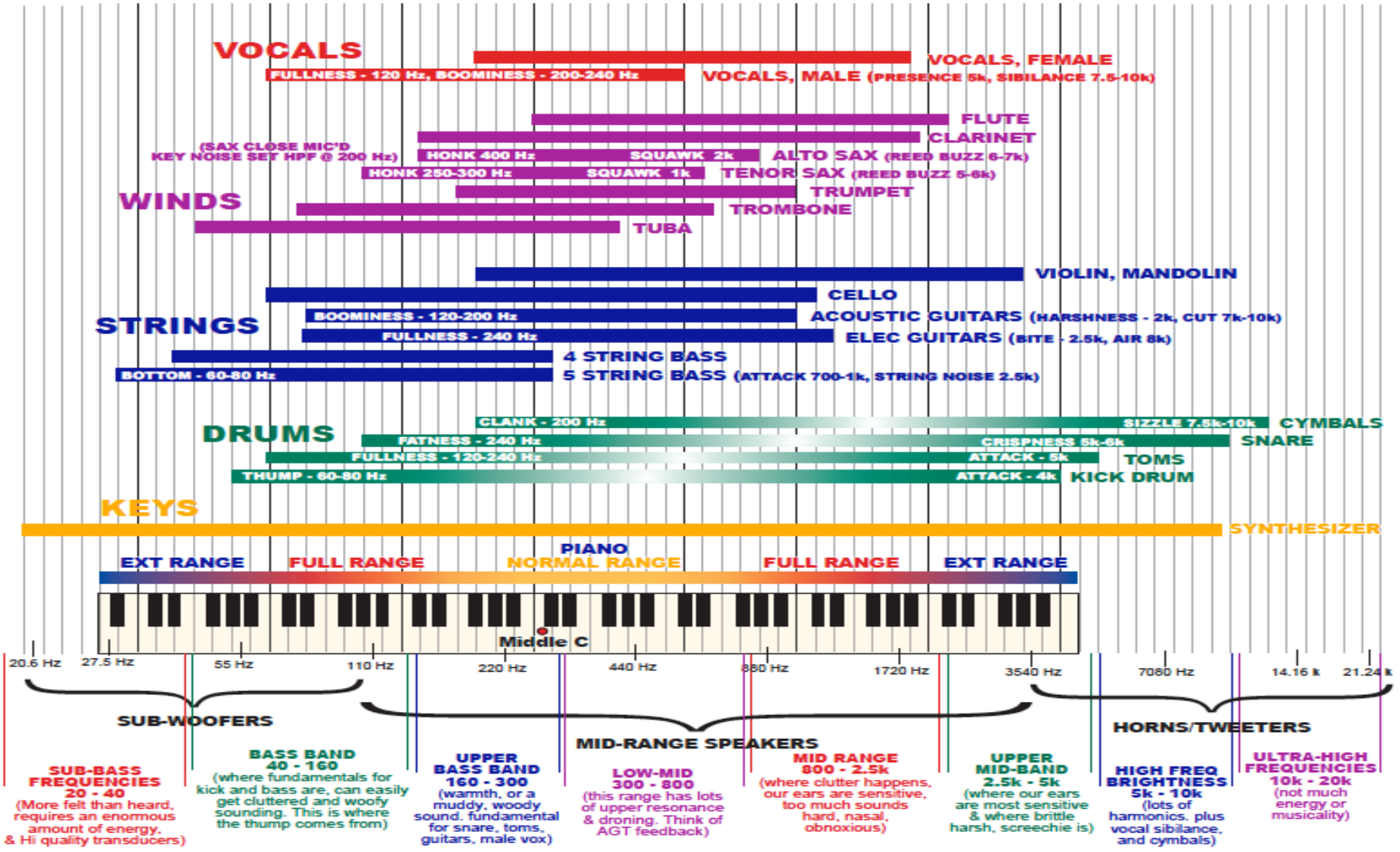
POP Quiz !!!


signal
DC offset
2.5
1.5
0.5
0
time
time domain
DC component
amplitude
1.5
4/π
4/(3π)
spectrum
frequency domain
0
ω0
3ω0
5ω0
7ω0
9ω0
11ω0
13ω0
frequency

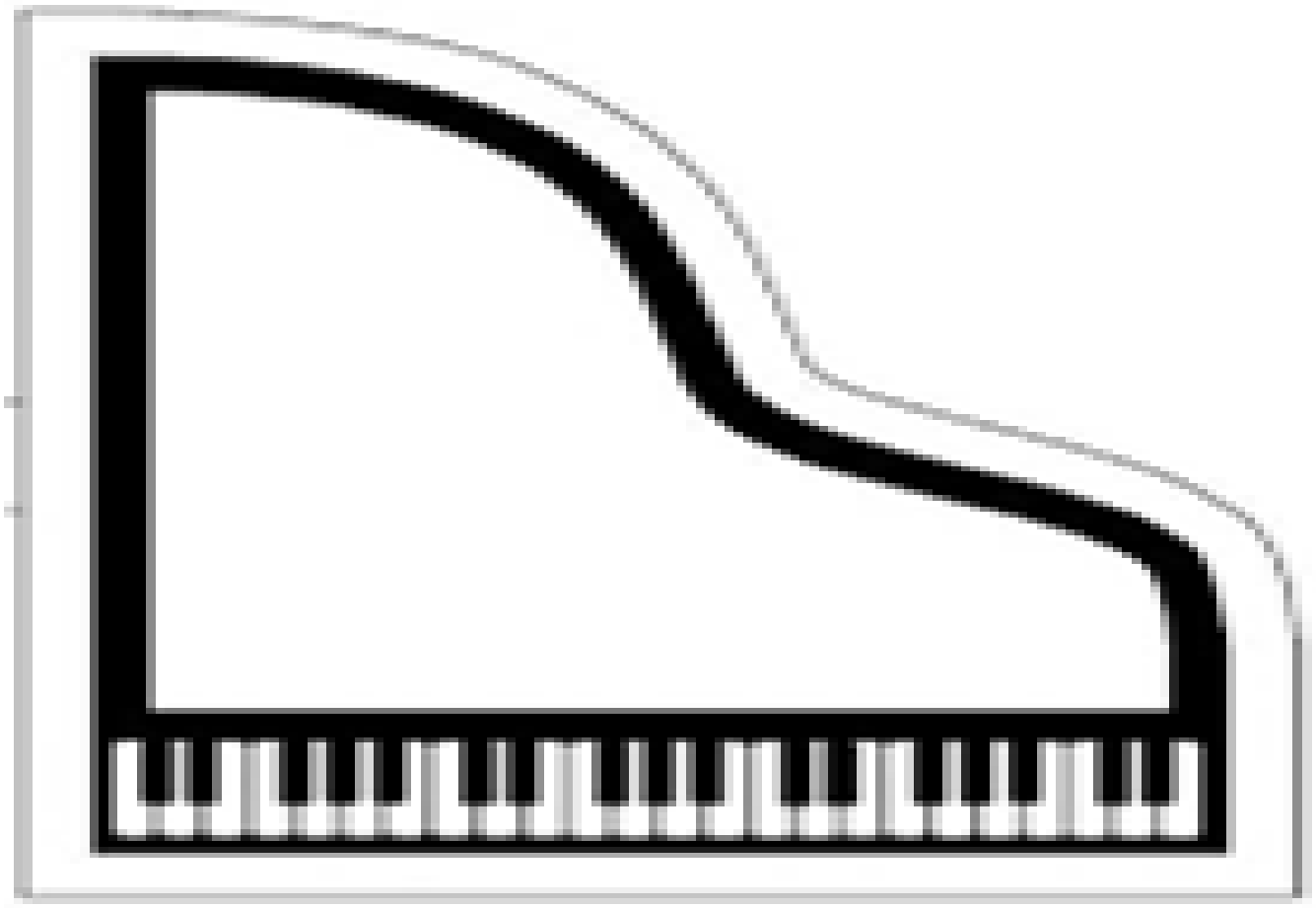
Concern about ripple and noise ?



THE FREQUENCY SPECTRUM, INSTRUMENT RANGES, AND EQ TIPS



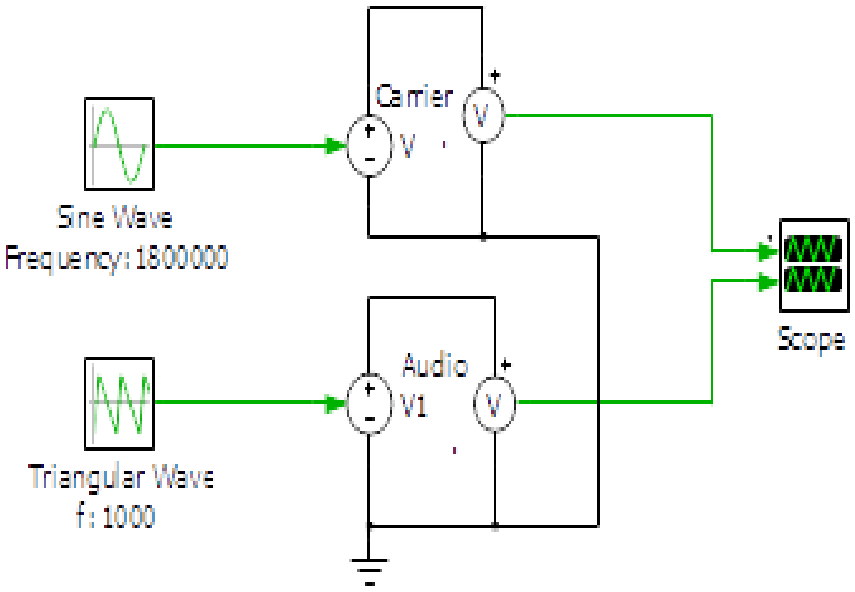
Audio Band of Concern for Hams

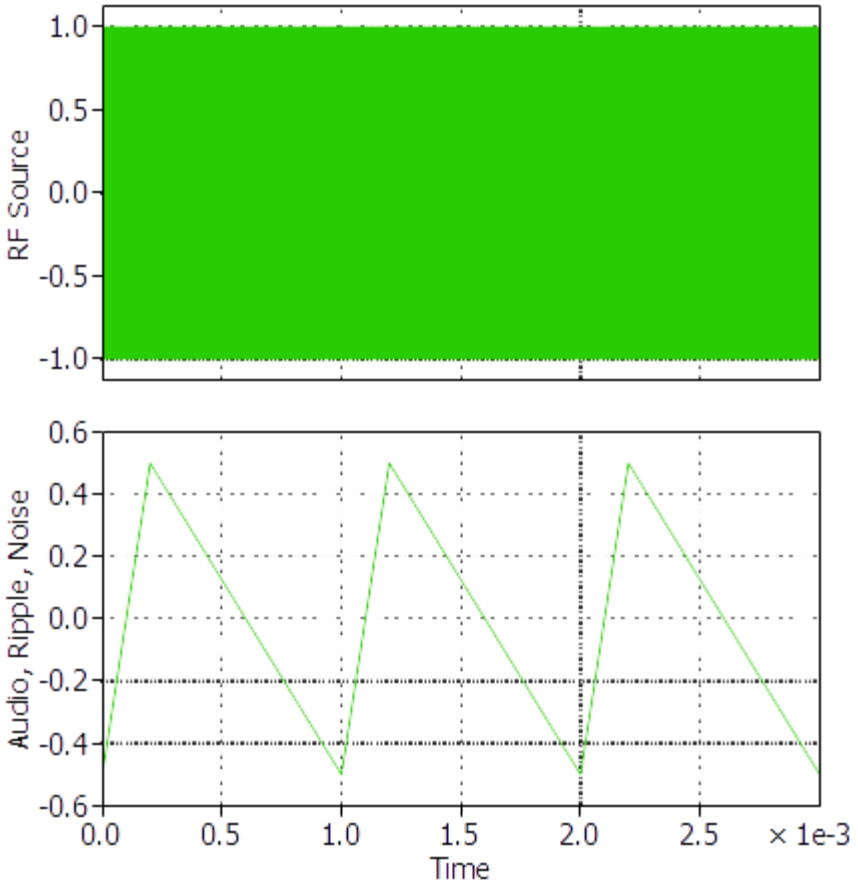


Bass.....Mid-Range.....Highs

Amplifiers (time)

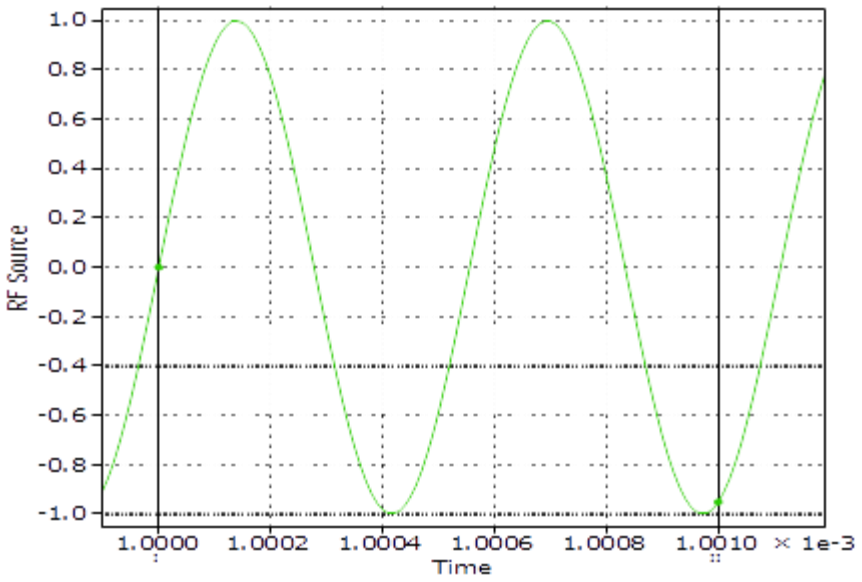
RF Amplifier

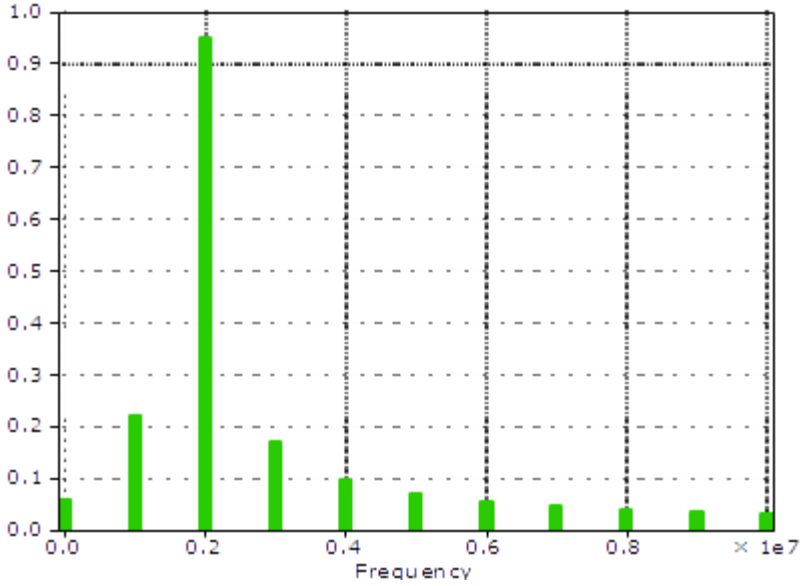


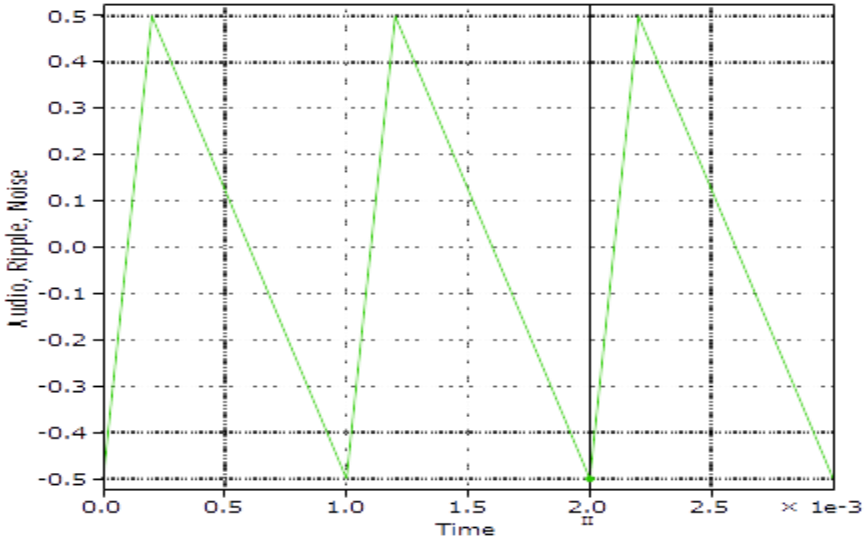


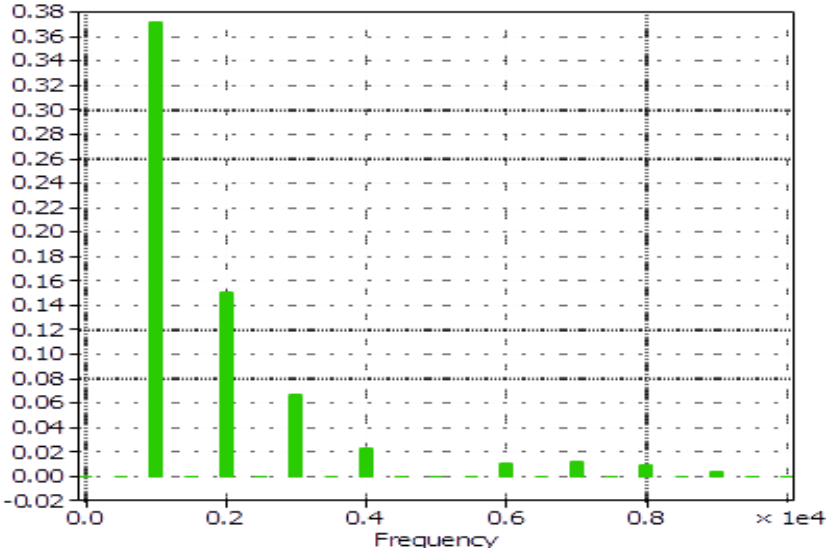
Audio Amplifier

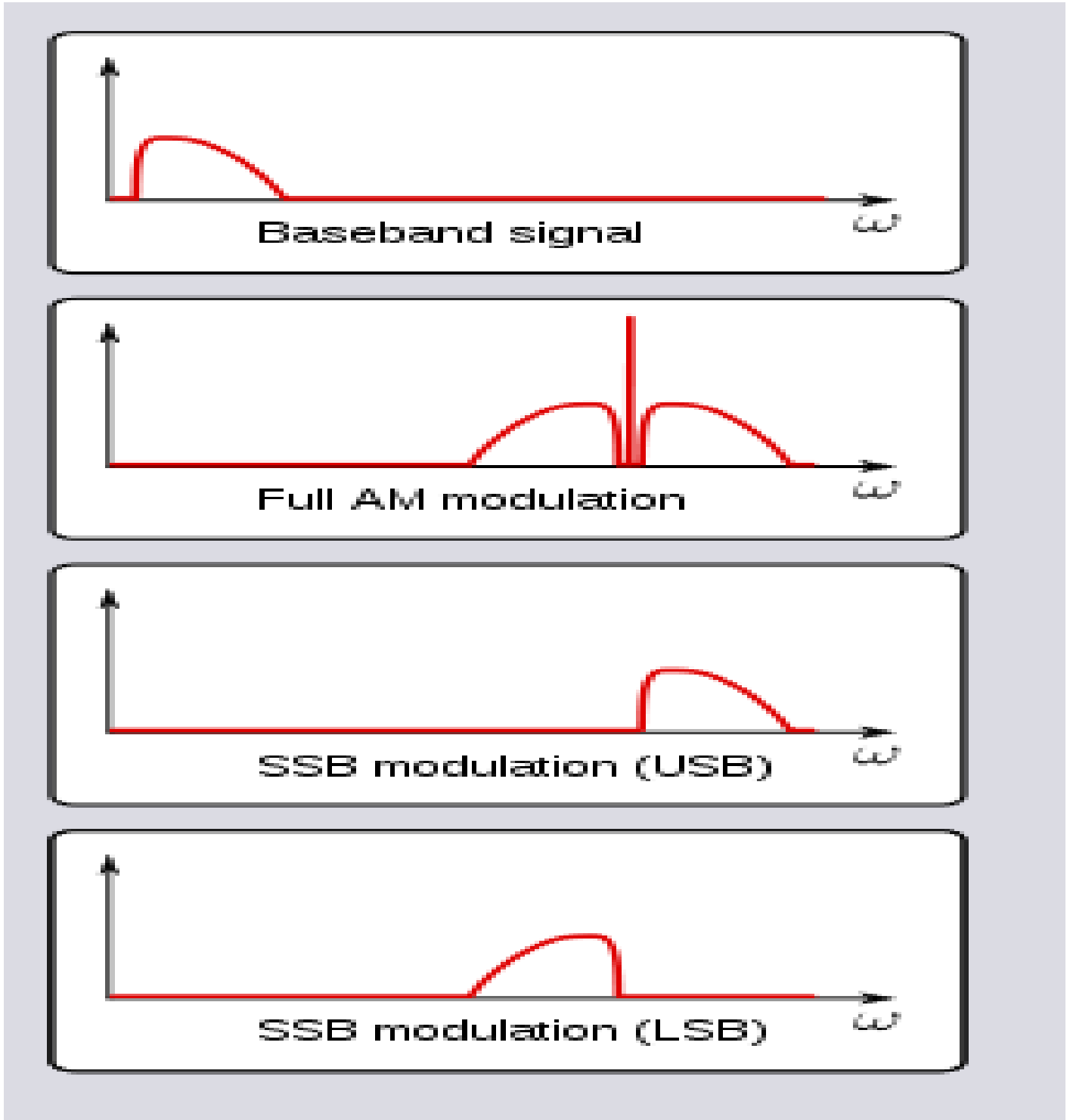
Amplifiers (time and frequency)



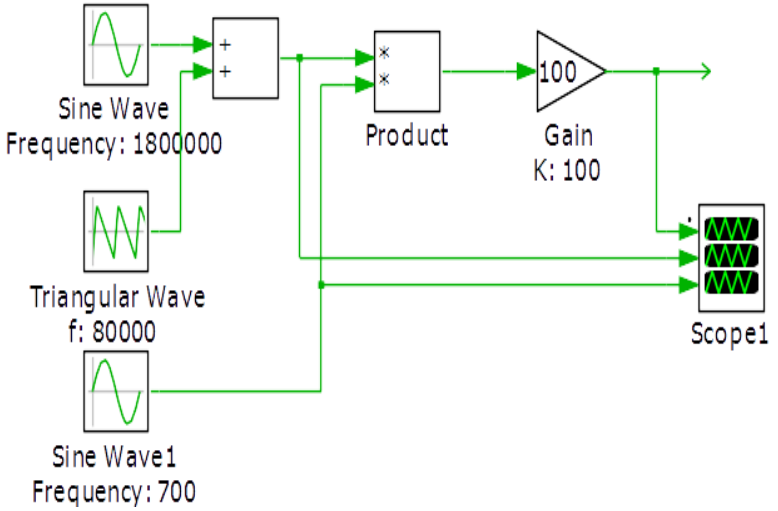


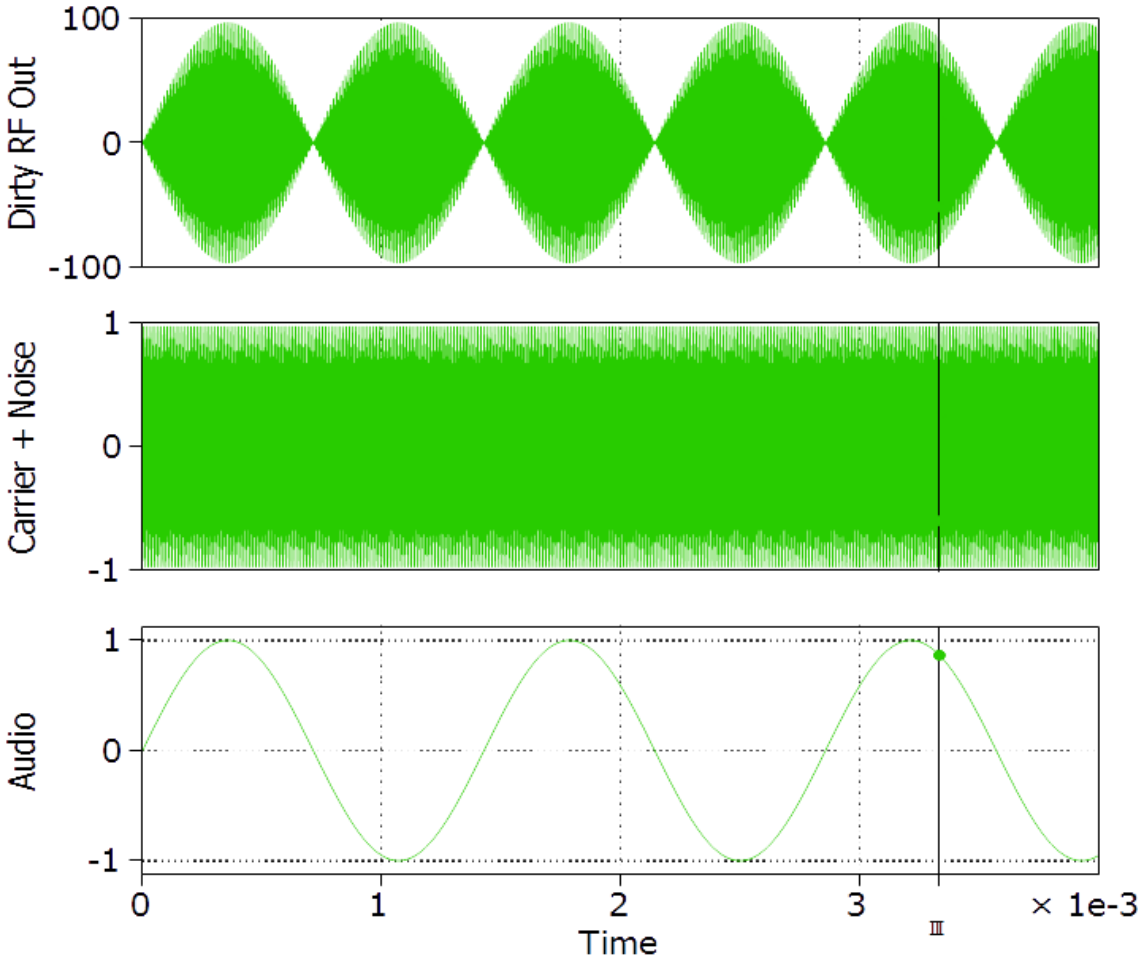




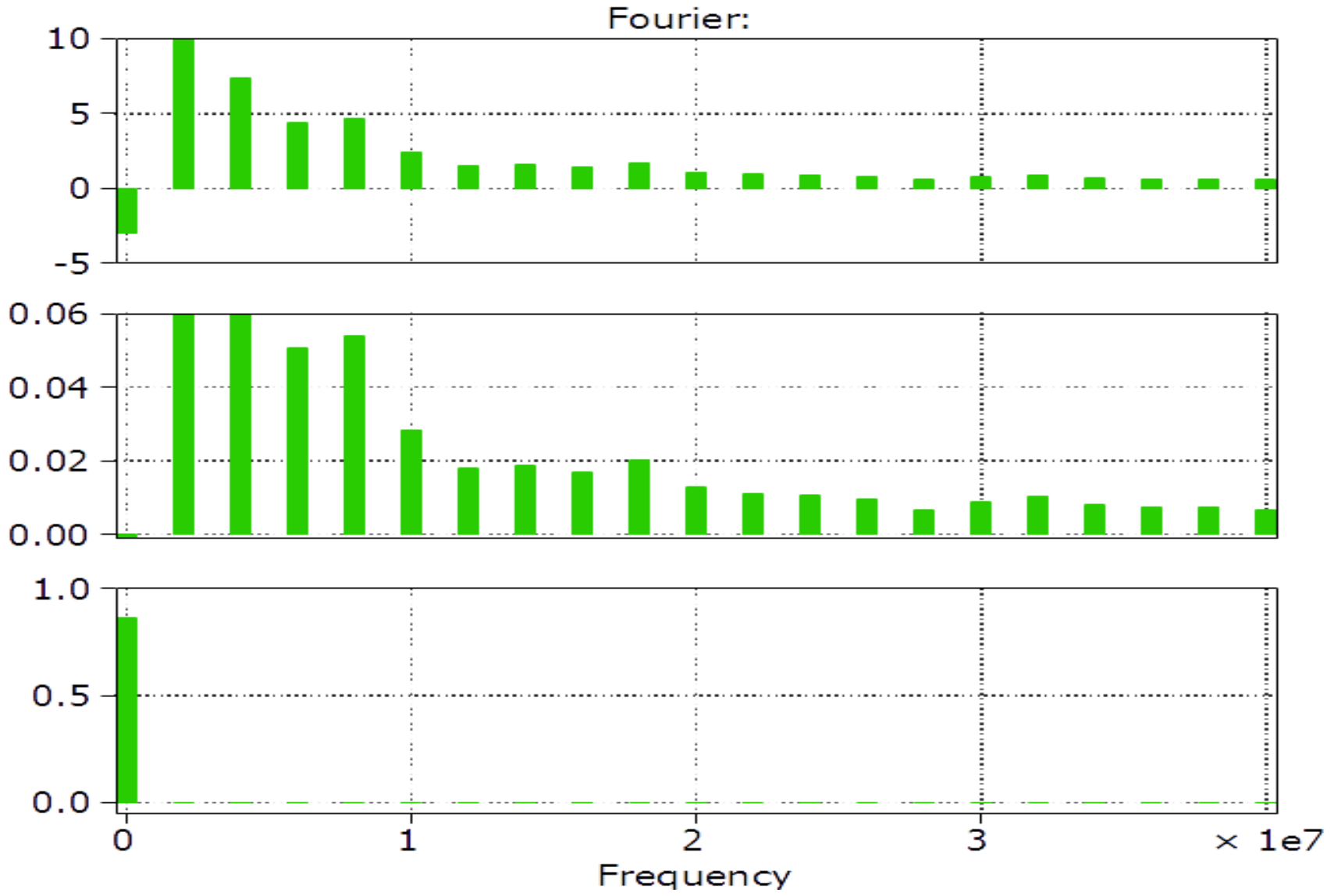

Baseband signal
ω
Full AM modulation
ω
SSB modulation (USB)
ω
SSB modulation (LSB)
ω

160 Meter Modulation (time)

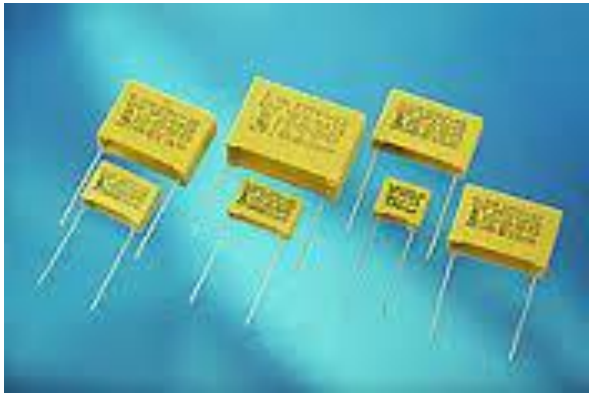


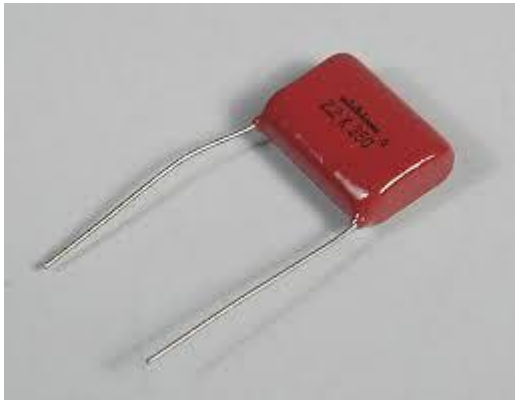


160 Meter Modulation (frequency)

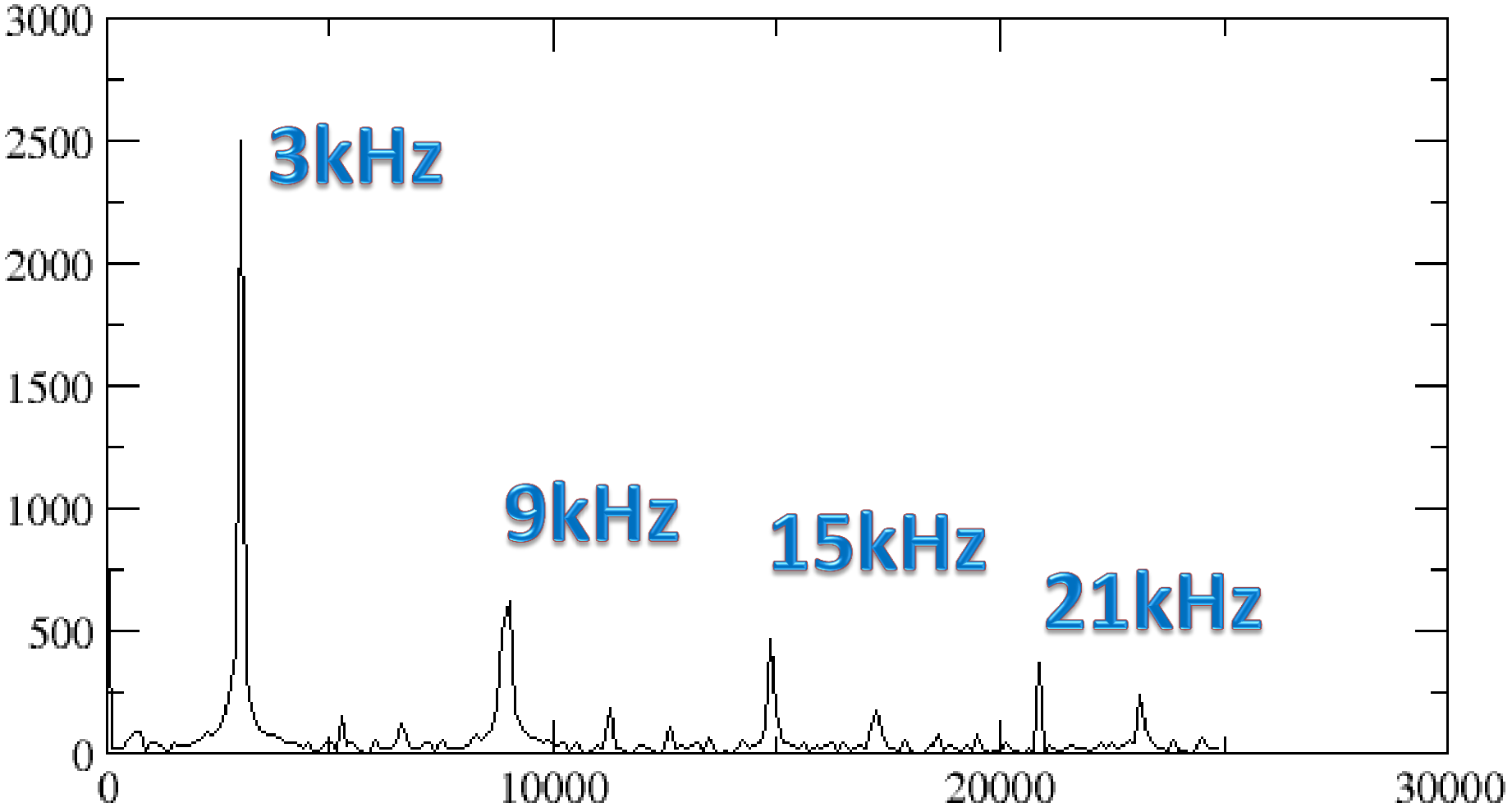


Filter the Noise – at the right spot!





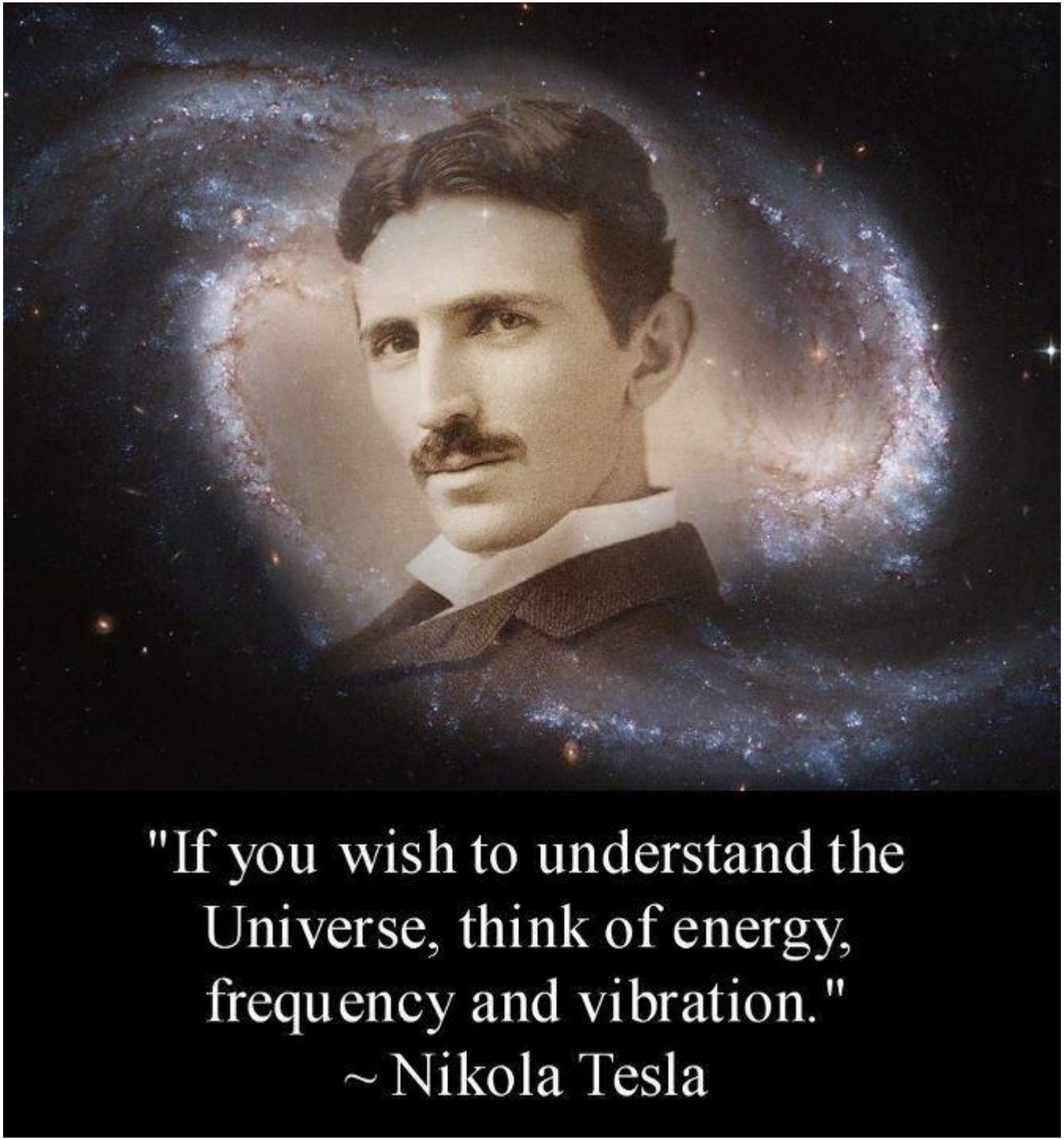
Final Exam


3000
2500
2000
1500
1000
500
0
0
10000
20000
30000
3kHz
9kHz
15kHz
21kHz

Review

- Met some pioneers of the science of our hobby
- We have studied
  - Energy conversion,
  - Electromagnetic frequency spectrum,
  - Vibration and the audio signal spectrum,
- As Hams we each have a Spectrum Analyzer

…..and as to Ham Radio being a shortcut to the mysteries of the Universe….


"If you wish to understand the
Universe, think of energy,
frequency and vibration."
~ Nikola Tesla