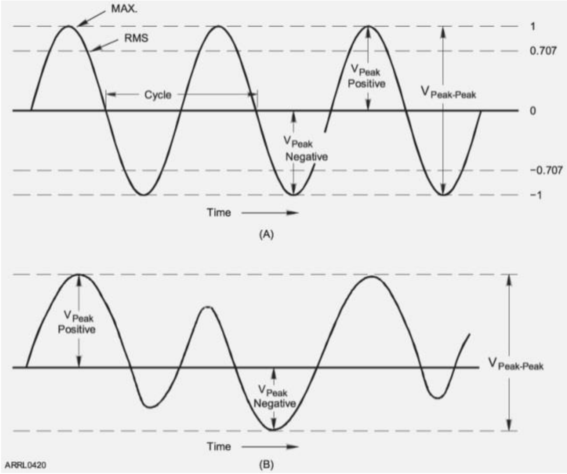
Chapter 7

Radio Signals
and Measurements

Jim Andera K0NK

We will Look at:

* AC Waveforms and Measurements
* Test Equipment
* Receiver Performance
* Interference and Noise



Thanks to:

* Information from:
  * The ARRL Library
  * ARRL Extra Class License Manual
  * Gordon West Extra Class License Class
  * Various websites

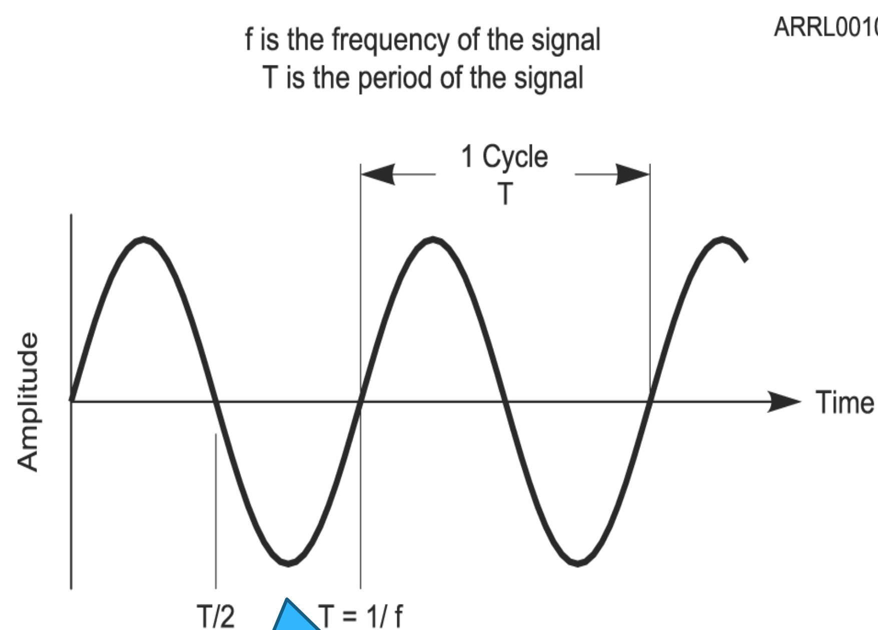
AC Waveforms and Measurements

Section 7-1

Remember the Sine Wave?

Technician Review

- **Basic <u>Alternating Current</u> Signal**
- **Varying <u>amplitude</u> and <u>polarity</u>**
- **Repeats in <u>cycles</u>**
- **How many cycles it completes in one second is its <u>frequency.</u>**
- **The <u>period</u> is the time it takes to complete on cycle.**



Looking at Amplitude vs. Time, called the **time domain**

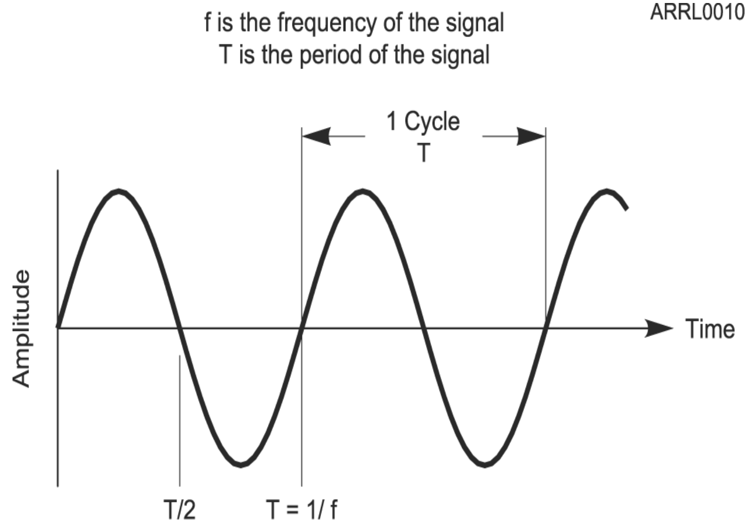
Frequency & Period

The ***period of a wave*** is the ***time required to complete one cycle of that wave.***

If the frequency is 1 MHz, then T = 1 ÷ 1MHz = 1µs. If a wave goes through one million cycles in one second, then each cycle takes 1 one-millionth of a second.

$$T = \frac{1}{f}$$

$$f = \frac{1}{T}$$

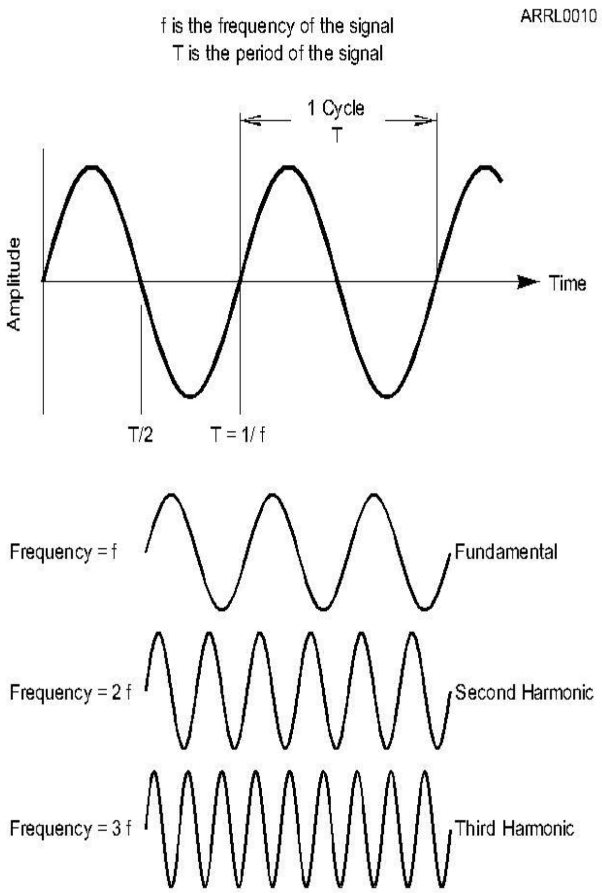


Harmonics

Technician Review

Unless it is a perfect sine shape, it will also contain <u>harmonics</u>. x2, x3, x4, … of the fundamental.

With a typical sine wave, the harmonics are generally small in amplitude, however they can still be troublesome is some cases.



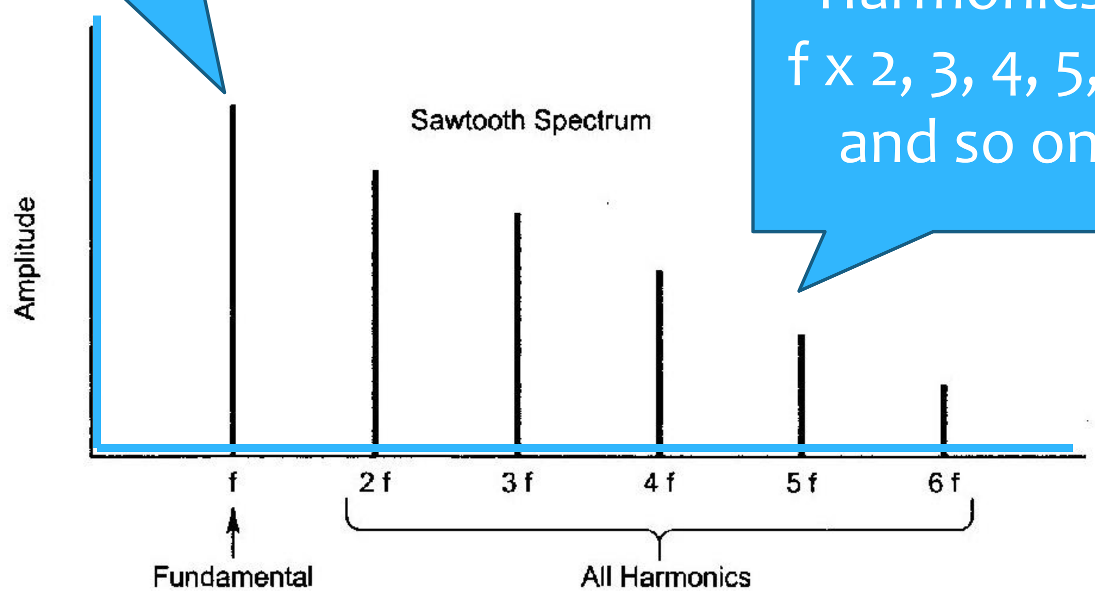
Harmonics

Let's Take a Spectral Look
(Fourier Analysis)

Here is a signal that is rich in harmonics

* A plot of the **Amplitude** and the **Frequency**

Fundamental f



Harmonics:
f x 2, 3, 4, 5, 6
and so on

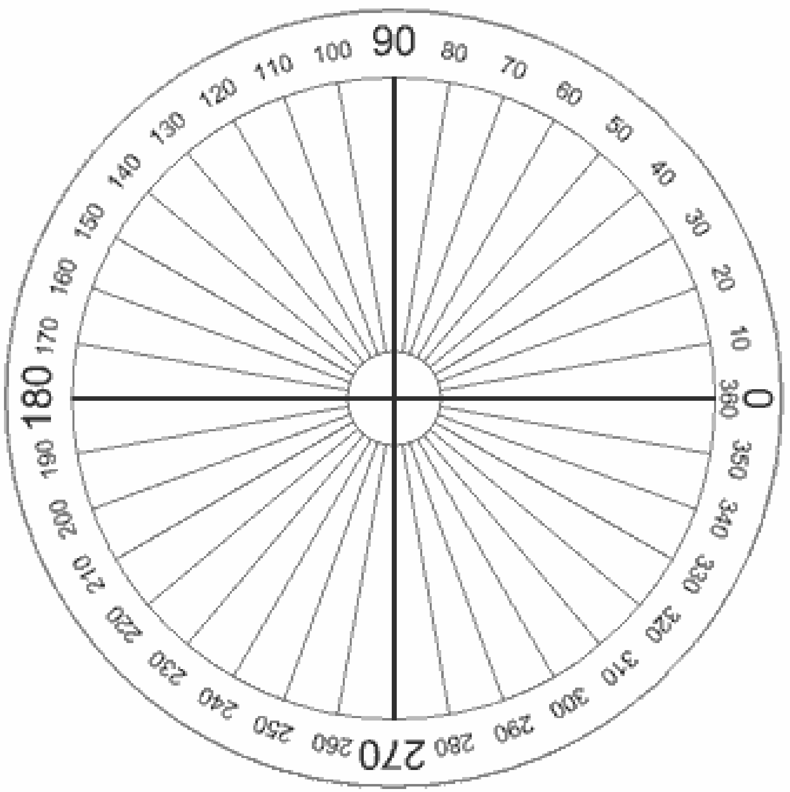
dB (Decibels)

Technician – General Review

* The decibel is a measure of change
  * Often the change of power

Decibel	Change in Power	Observed Effect
1 dB	Only 20%	Hardly perceivable
3 dB	Factor of 2	Just noticeable
6 dB	Factor of 4	Readily noticeable
10 dB	Factor of 10	Quite significant
15 dB	Factor of 32	A bit more significant
20 dB	Factor of 100	Very significant
30 dB	Factor of 1,000	Very-very significant
60 dB	Factor or 1,000,000	Extremely significant

Let's Look at a Circle



We can define the position on the circle in terms of **degrees**.

From www.mathisfun.com

Think of a circle as being an old-fashioned wagon wheel.

If it had 360 spokes, each spoke would be 1 degree apart.

A Closer Look at the Sine Wave

Pg. 7-2

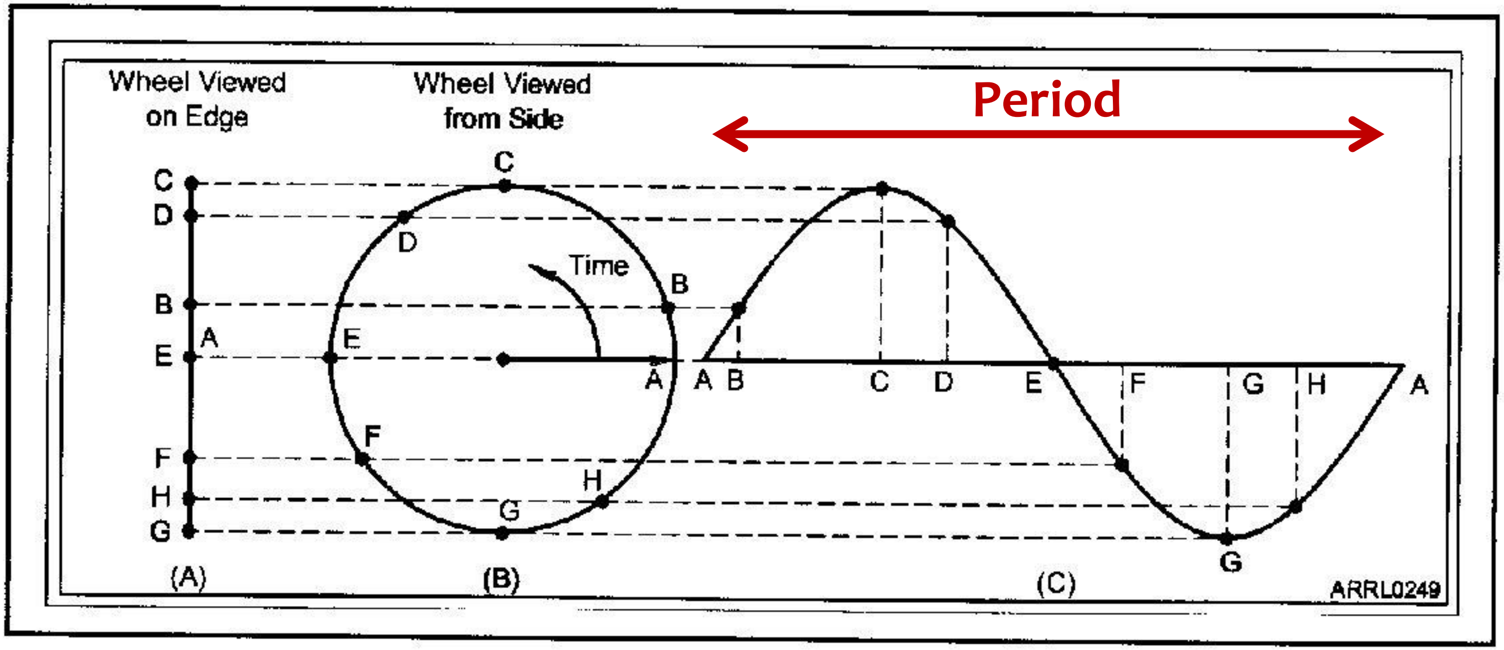


Figure 7-1 — This diagram illustrates the relationship between a sine wave and circular rotation. You can see how various points on the circle correspond to values on the sine wave.

A Closer Look at the Sine Wave

Pg. 7-2

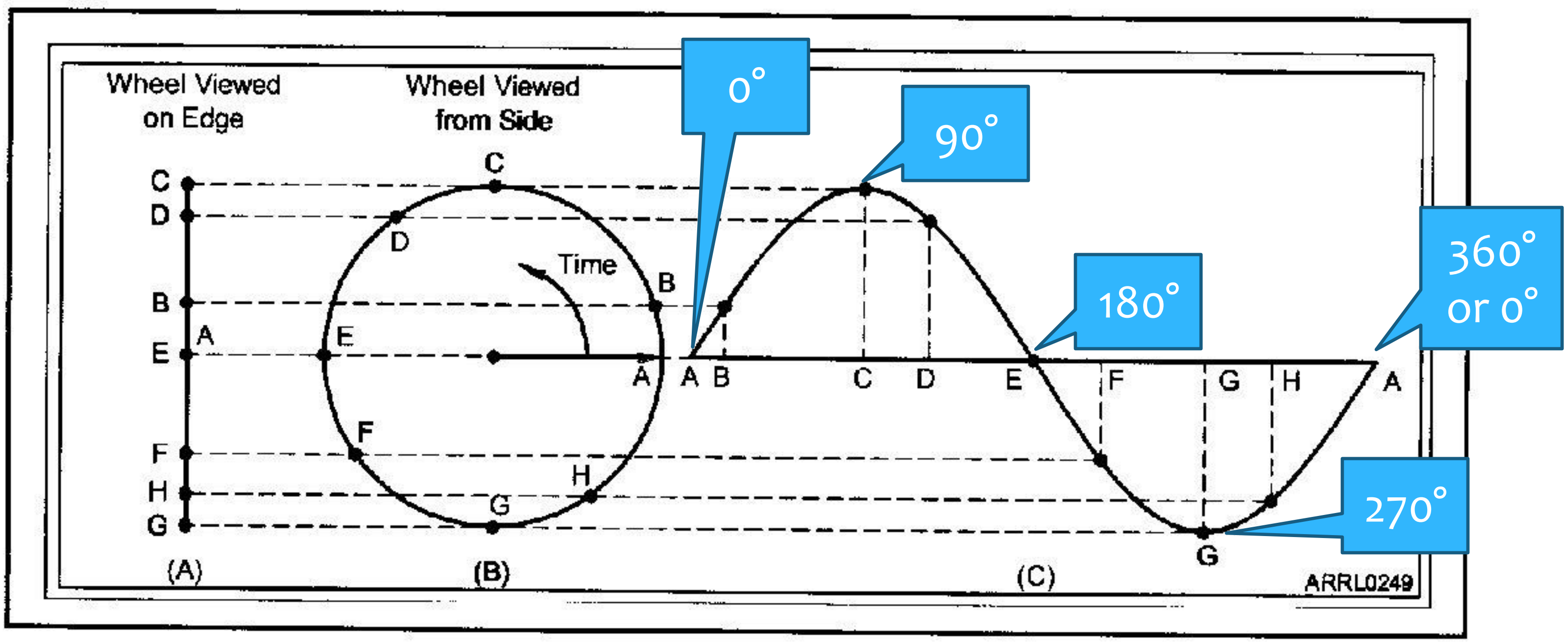


Figure 7-1 — This diagram illustrates the relationship between a sine wave and circular rotation. You can see how various points on the circle correspond to values on the sine wave.

Trigonometric Functions

* Sine
* Cosine
* Tangent

The sine of 0° is: **0** (sin 0 = 0)

The sine of 45° is: **0.707**

The sine of 90° is: **1**

A Closer Look at the Sine Wave

Pg. 7-2

Theta

A = sin (θ) Equation 7-1

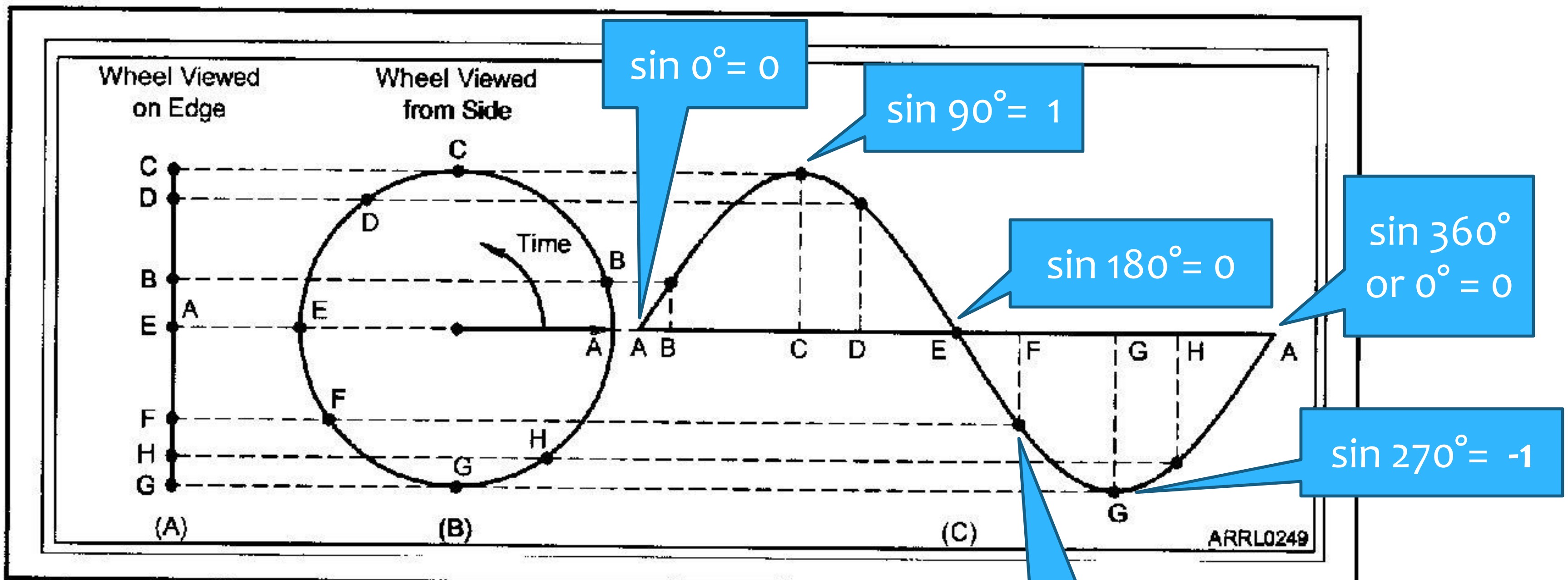


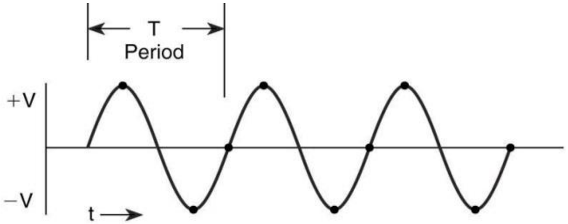
Figure 7-1 — This diagram illustrates the relationship betwe a sine wave and circular rotation. You can see how various points on the le correspond to values on the sine wave.

Waveforms

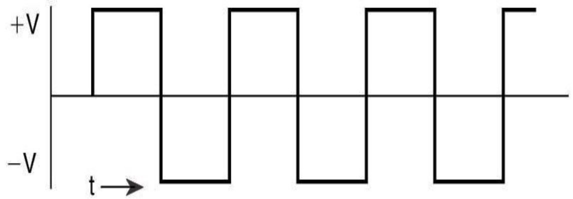
Pg. 7-4

- **There are many different types of wave shapes**
- **Each is made up of different frequency components (harmonics)**

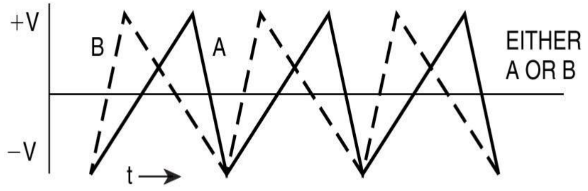
Sine Wave



Square Wave



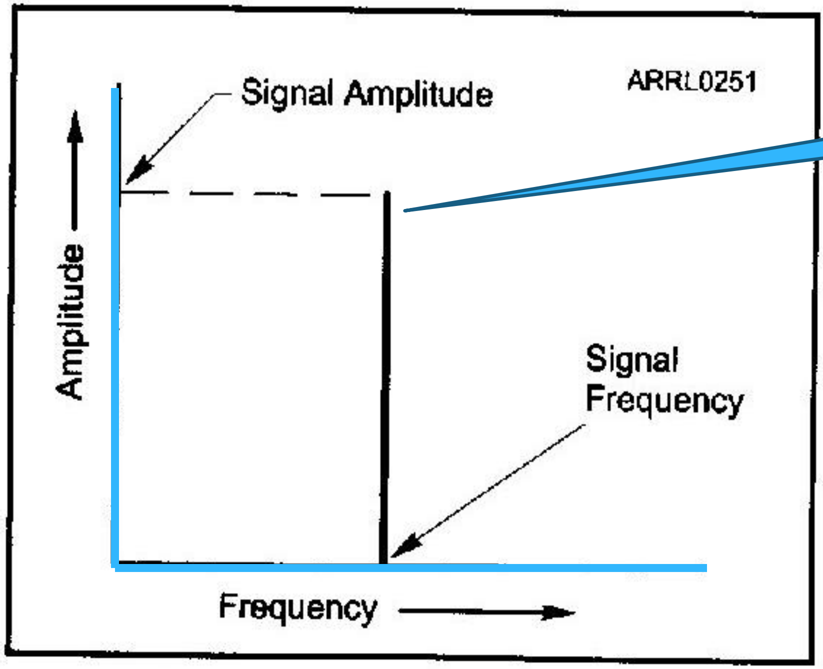
Sawtooth



Let’s Take a Spectral Look

Pg. 7-3

We can also look at Amplitude vs. Frequency (Frequency Domain)



Fundamental f

Fig 7-2

Sawtooth Wave (All Harmonics)

The **sawtooth** wave is made up of the fundamental and **all** the harmonics.

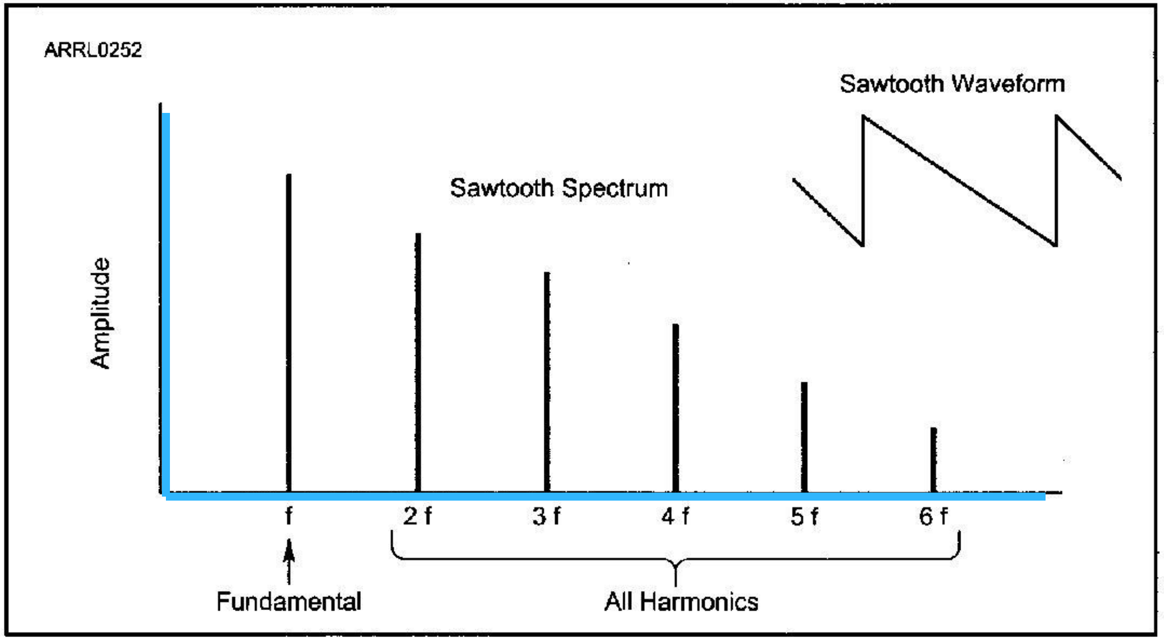


Figure 7-3 — The sawtooth waveform is made up of sine waves at the fundamental frequency and all of its harmonics. The amplitude of the harmonics decreases as their frequency increases.

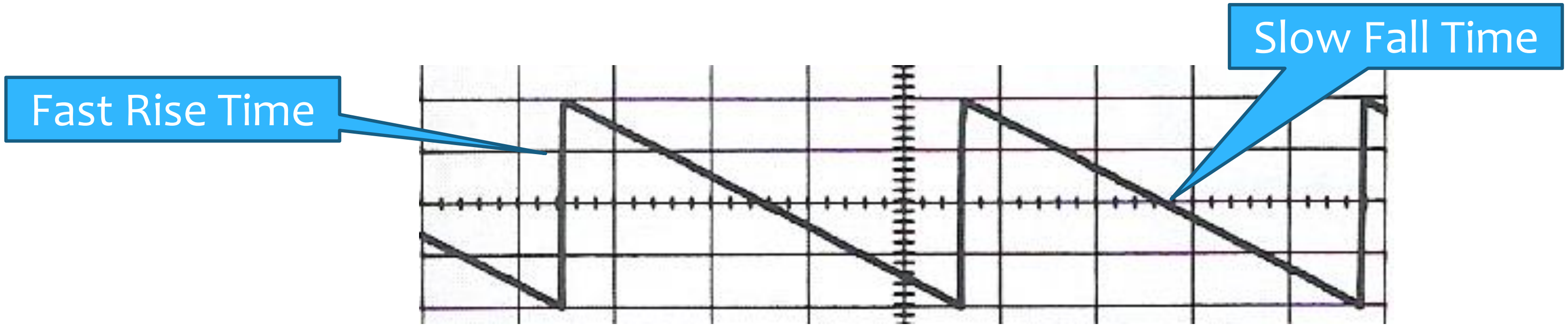
E8A03

A Fourier analysis shows a sawtooths wave is made up of sine waves of a given fundamental frequency plus all of its harmonics

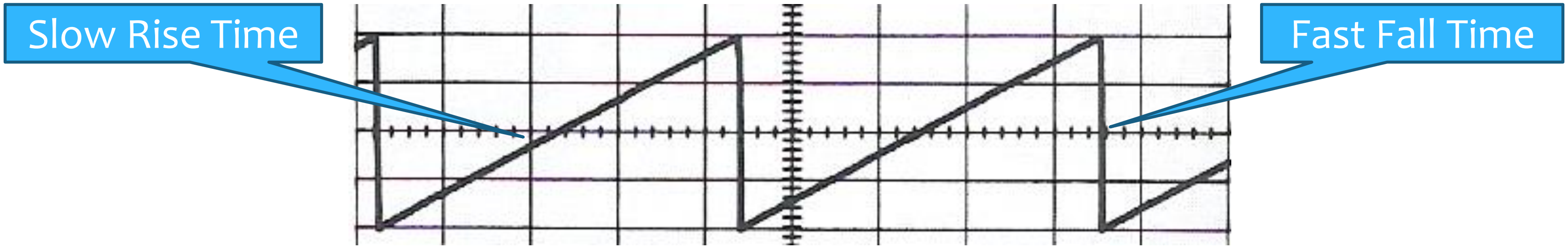
Sawtooth & Ramp Wave

Pg. 7-4

A ***sawtooth wave*** has a fast rise and slow fall time



A backward ***sawtooth wave*** can be called a ***ramp wave***



Square Wave (Odd Harmonics)

Pg. 7-4

The **square** wave is made up of the fundamental and the **odd** harmonics.

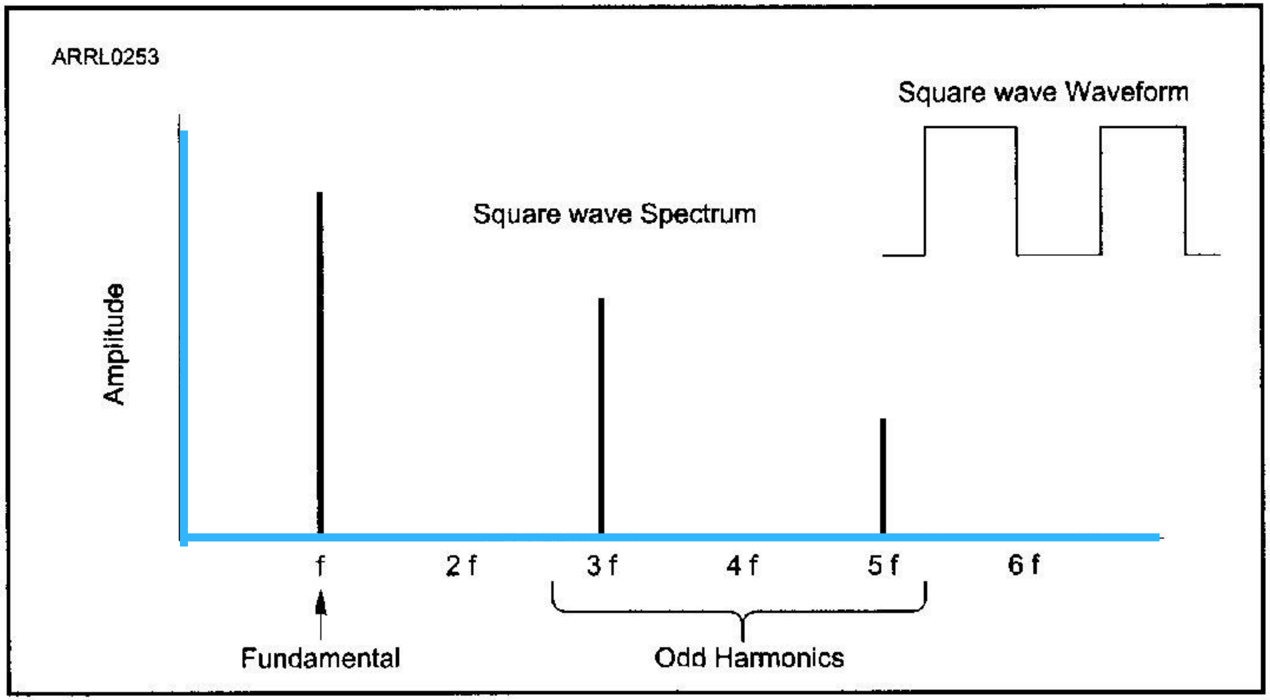


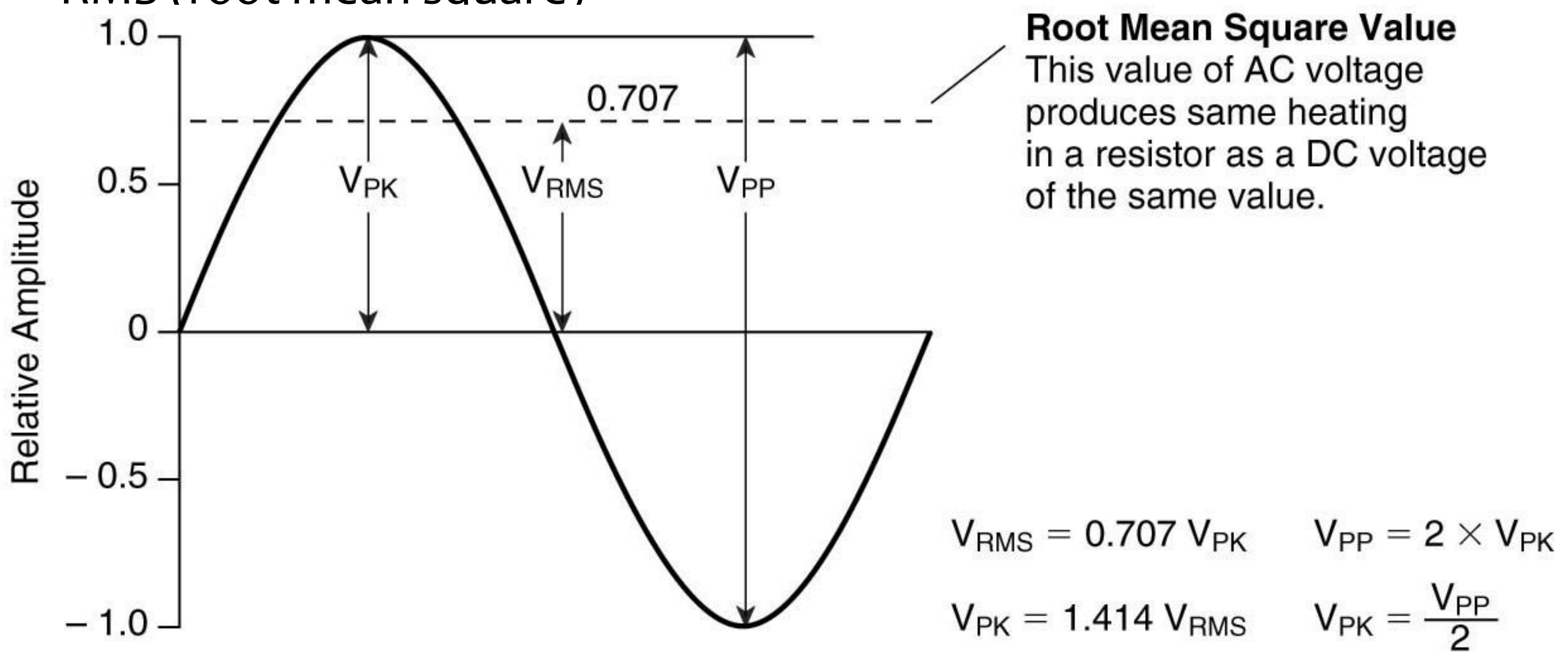
Figure 7-4 — The square wave is made up of sine waves at the fundamental frequency and only the odd harmonics. The amplitude of the harmonics decreases as their frequency increases.

…If you're ***square***, you're probably ***odd***.

Peak and RMS Voltage of a Sine Wave

Pg. 7-4

* AC Voltages can be specified several different ways:
  * Peak
  * Peak to Peak
  * RMS (root mean square)



Peak & RMS Voltage

Root Mean Square – The Heating Power

Pg. 7-4

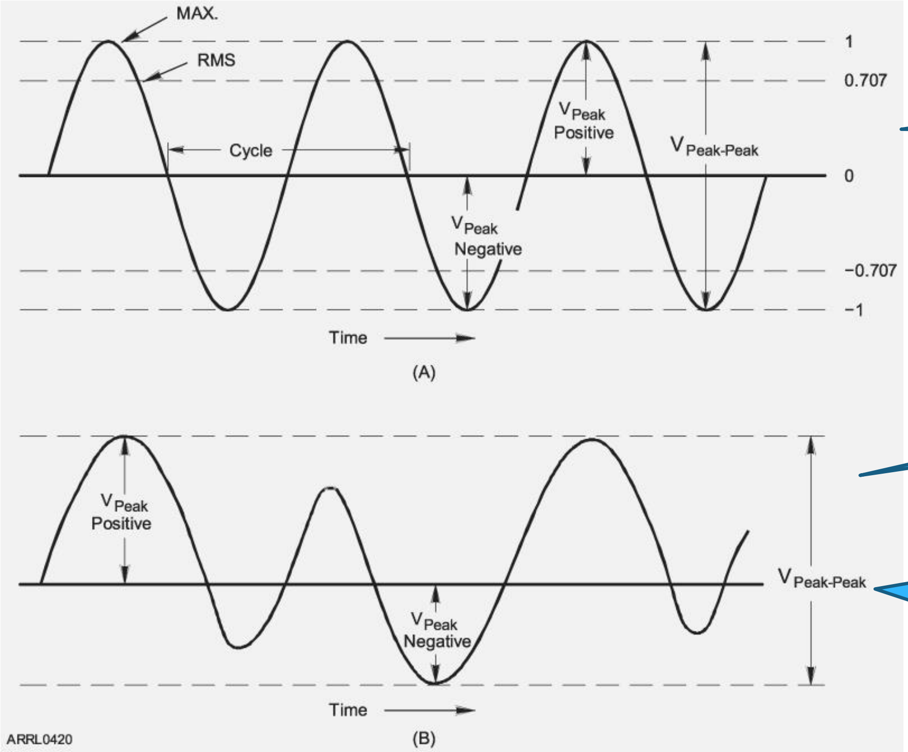


Fig 7-5

Symmetric waveform

Complex or irregular waveform

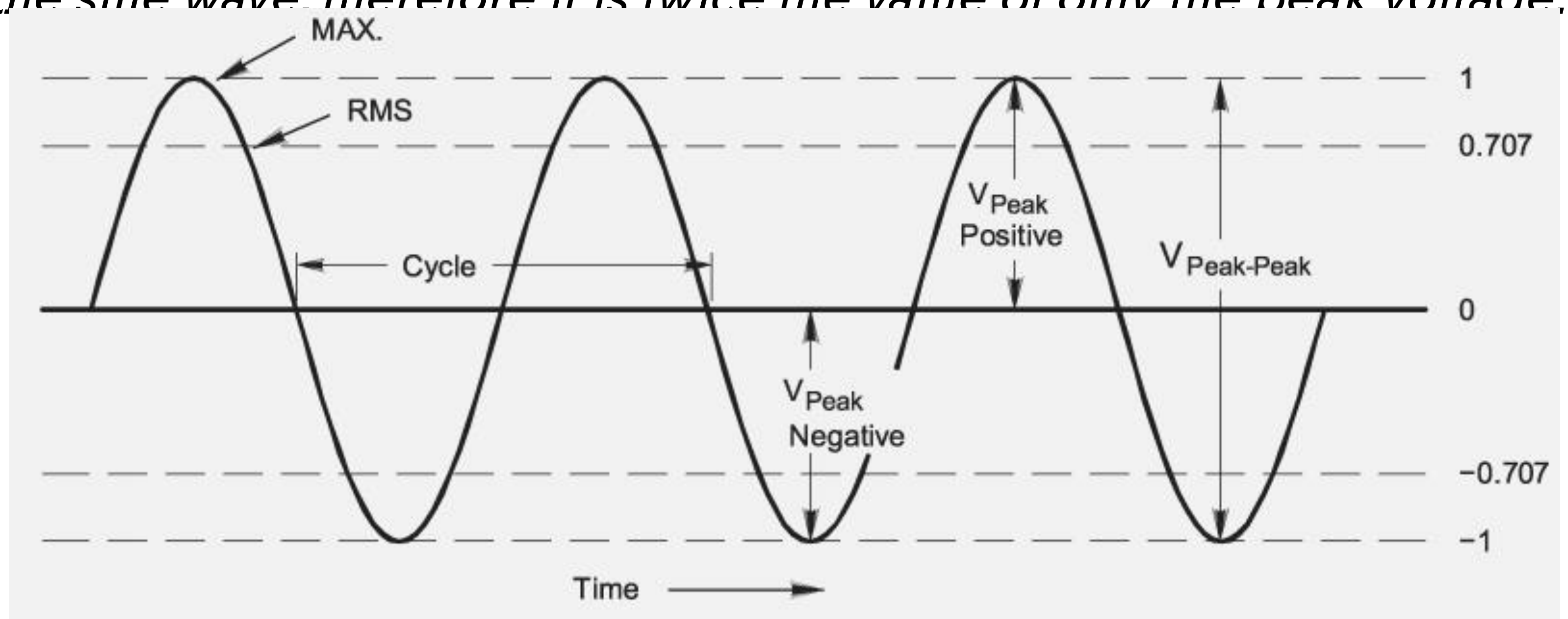
The best way to measure the RMS voltage of a complex waveform is by measuring the heating value into a resistor.

Peak to Peak

Pg. 7-4

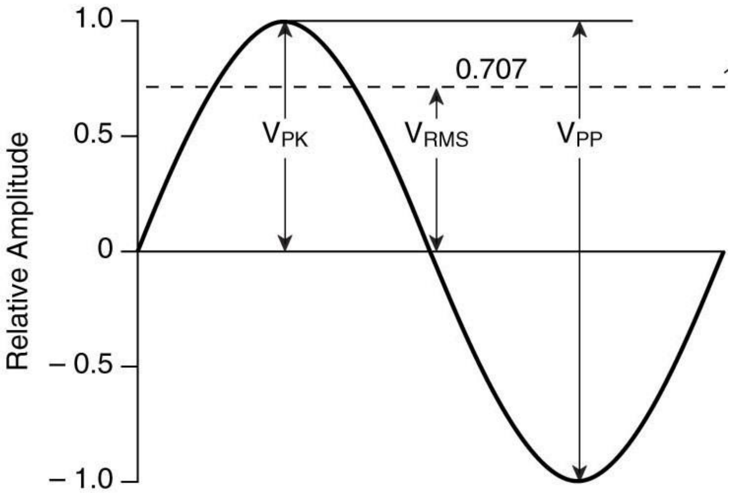
* ***The relationship between peak-to-peak voltage and peak voltage is 2:1***. It is important to realize that the waveform must be symmetrical – and a sine wave certainly is. $V_{PP} = 2V_P$.

The peak to peak includes both the positive and negative excursions of the sine wave, therefore it is twice the value of only the peak voltage.



(A)

An Everyday Example: 120 VAC



- Example
  - Common household voltage is 120 v RMS
  - V_p = 120 x 1.414 = 170 V
  - V_{p-p} = 2 x V_p = 2 x 170 V = 340 V_{p-p}

Peak & RMS Voltage

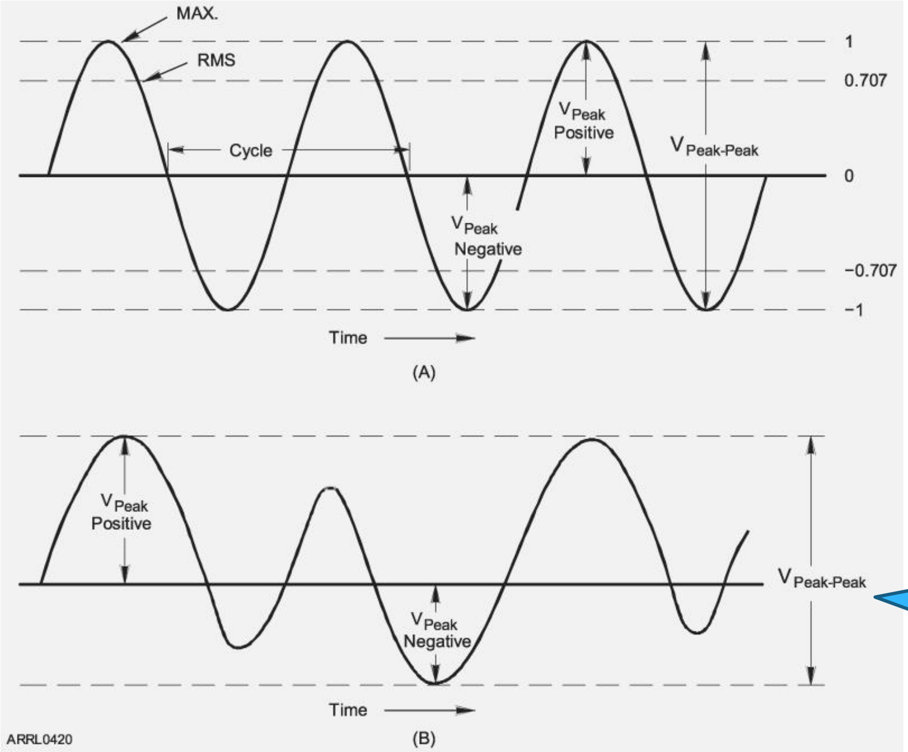


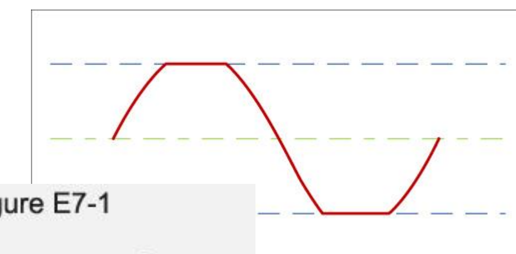
Fig 7-6

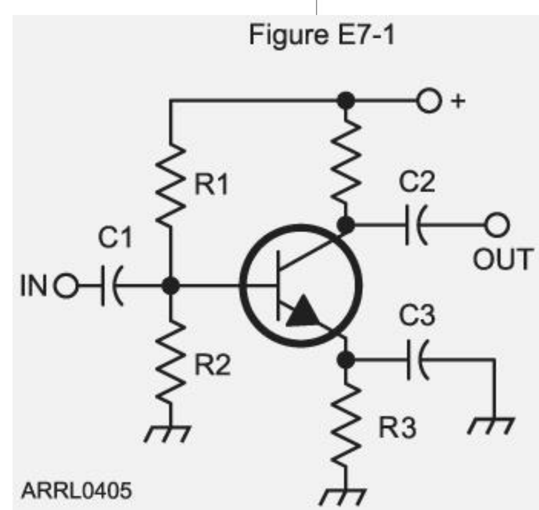
The maximum peak-to-peak input amplitude is an important parameter for evaluating linear amplifiers.

Why RMS? Why Pk-Pk?

RMS

Peak - Peak

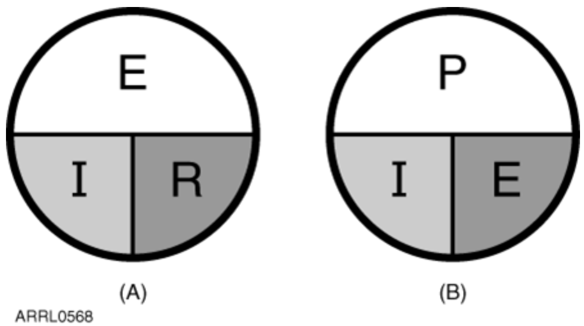




AC Power

Technician Review

* AC Power is the product of RMS voltage and RMS current
* **Remember from your Technician study of DC power :**
  * $\boldsymbol{P = I \times E}$
  * or $P = \dfrac{E^2}{R}$



* $\boldsymbol{P_{AVG}} = \dfrac{\mathbf{V_{RMS}}^2}{\mathbf{Z}}$ (Equation 7-6) where Z is the impedance

Peak Envelope Power (PEP)

Used in the power rating of a SSB transmitter

Pg. 7-5 & 7-6

* First Determine the Peak Envelope Voltage

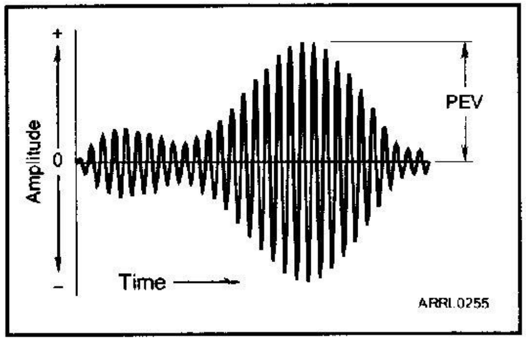


Figure 7-6 · An amplitude-modulated signal as an example of a complex signal. Peak envelope voltage (PEV) is an important parameter for determining the power of a complex waveform.

* Then convert the Peak Envelope Voltage to RMS voltage

Peak Envelope Power (PEP)

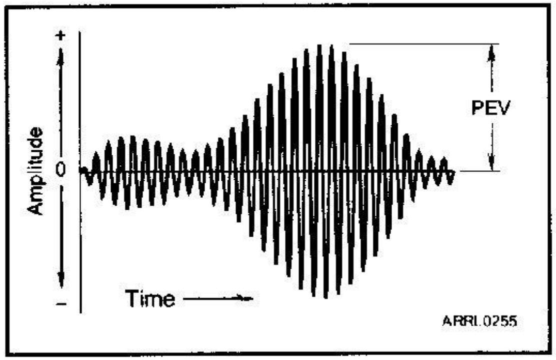
Pg. 7-5 & 7-6

To Determine the Peak Envelope Power

* $PEP = (PEV \times 0.707)^2 / R_{LOAD}$ (Equation 7-7)

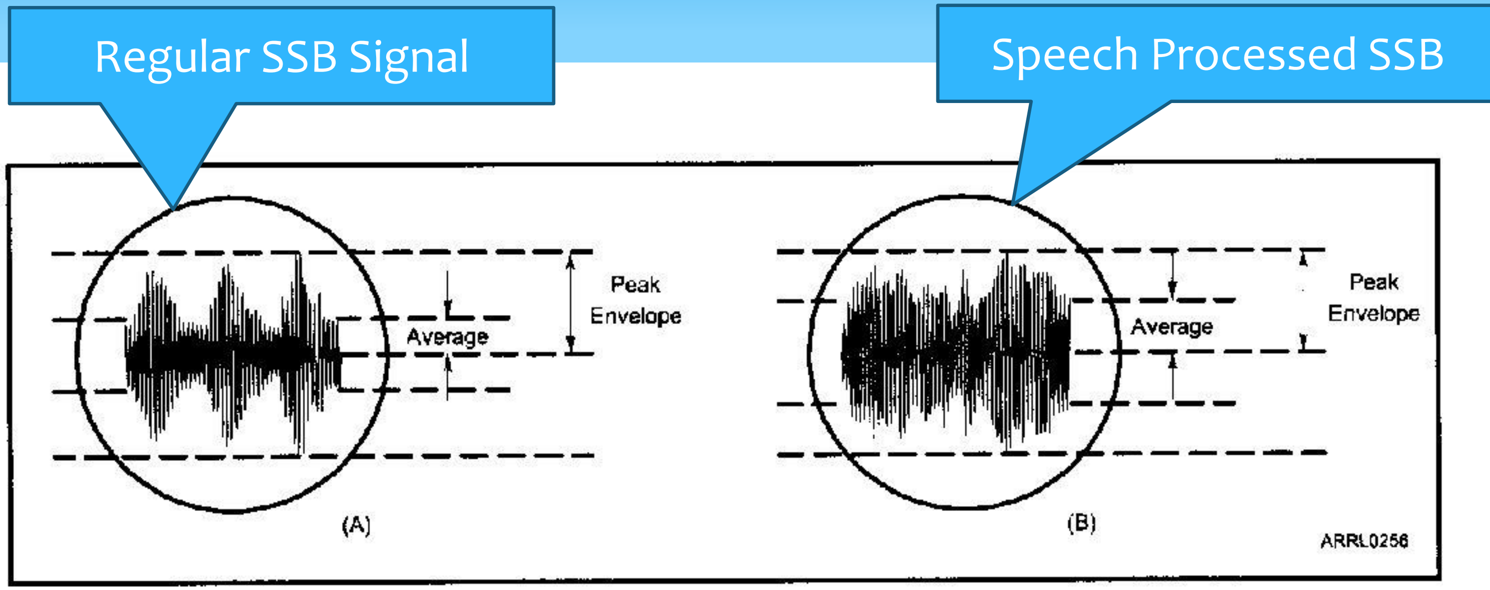
$P_{AVG} = V_{RMS}^2 / Z$

* Example 7-2
  - What is the PEP output power of a transmitter that has a PEV of 100 V across a resistive load of 50Ω?
    - $PEP = (PEV \times 0.707)^2 / R_{LOAD}$
    - $= (100 \times 0.707)^2 / 50$
    - $= (70.7)^2 / 50$
    - $= 4998 / 50 = 100$ W PEP



PEP in Voice SSB signals

Pg. 7-7



- The ratio of peak-to-average power in a SSB voice signal varies widely with voices of different characteristics.
- Typical ratios of PEP to average power are 2.5 : 1 (but may be more than 10:1).

Peak-reading Wattmeters

Pg. 7-7

If you use an amplifier in your station you may want to use a peak reading wattmeter in the feedline to your antenna to insure that you do note exceed the maximum allowable output power.

Peak-hold or Peak-reading wattmeter's are special meters used to display the peak value of the waveform.

Switch to select between Average (AVG) and Peak Envelope Power (PEP)

E8A03 What type of wave does a Fourier analysis show to be made up of sine waves of a given fundamental frequency plus all of its harmonics?

A. A sawtooth wave
B. A square wave
C. A sine wave
D. A cosine wave

E8A05 What would be the most accurate way of measuring the RMS voltage of a complex waveform?

A. By using a grid dip meter
B. By measuring the voltage with a D'Arsonval meter
C. By using an absorption wave meter
D. By measuring the heating effect in a known resistor

E8A07 What determines the PEP-to-average power ratio of a single-sideband phone signal?

A. The frequency of the modulating signal
B. The characteristics of the modulating signal
C. The degree of carrier suppression
D. The amplifier gain

Test Equipment

Section 7-2

Multimeters

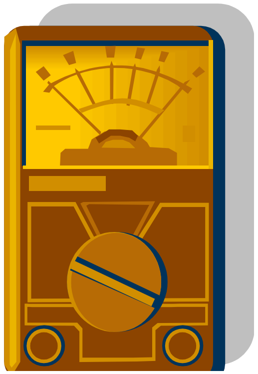
Pg. 7-7

- **Measures: Voltage, Current, Resistance …**
- One specification of a multimeter is the Sensitivity often specified in ohms-per-volt (Ω / V)
- The input impedance can be obtained by multiplying the full scale reading by the sensitivity

  Impedance = (voltage range) x (Ω / V)

  = (150 V range) x (10,000 Ω / V)

  = 1,500,000 or 1.5 MΩ

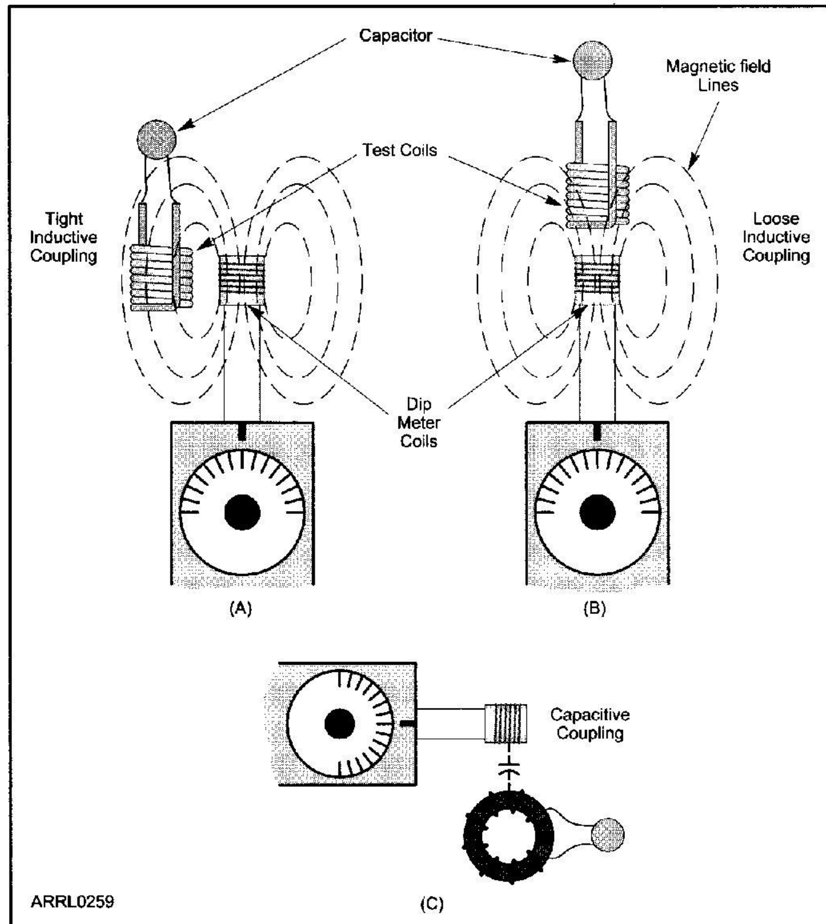


- Digital meters just specify the impedance directly
- Higher values in input impedance or Ω / V are generally good for both AC and DC measurements.

Grid Dip Meter

Pg. 7-13

* A Grid Dip Meter lets us "sniff" the resonant frequency of a circuit.
* Coupling too strong ("tight") will reduce the accuracy of the frequency measurement.



Impedance Bridges

Pg. 7-13

* Bridges are excellent instruments for measuring impedance because obtaining a null of the meter reading can be done precisely.
* SWR meters and antenna analyzers rely on the bridge principal.

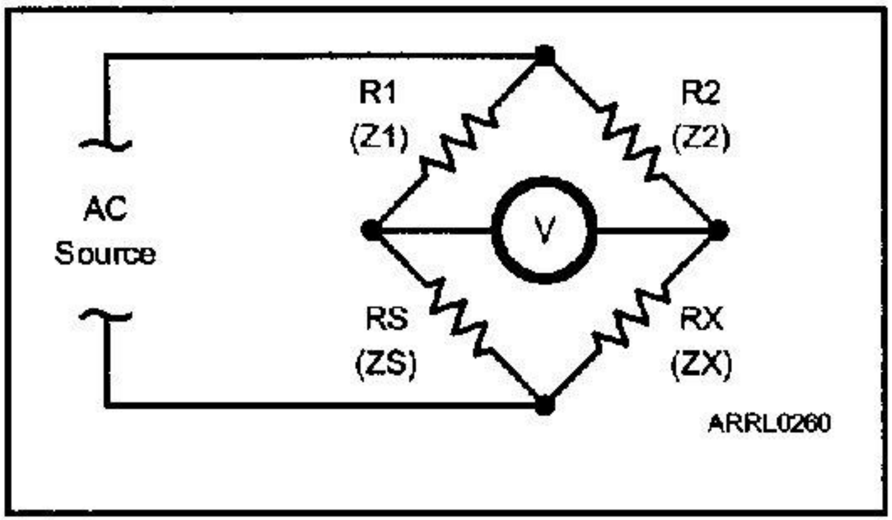
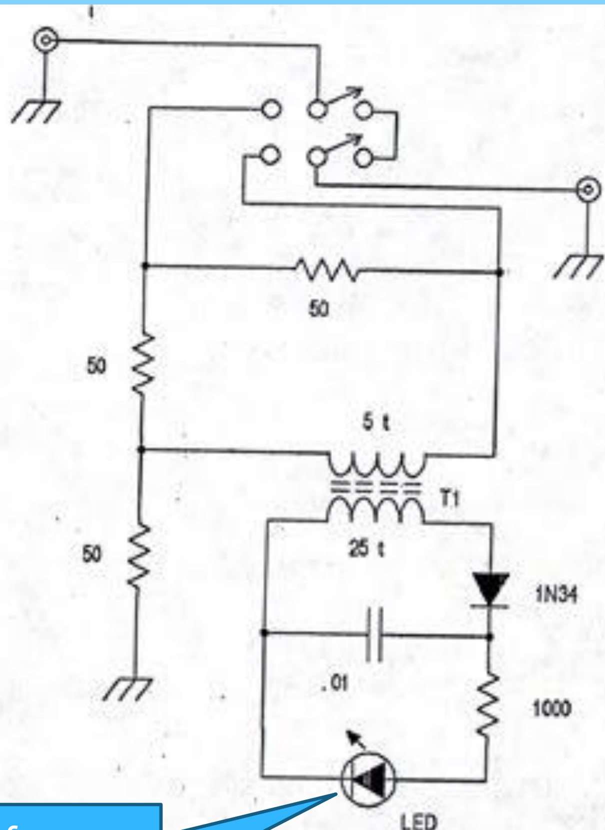


Figure 7-9 — This generalized bridge circuit works by balancing the two voltage dividers, Z1-ZS and Z2-ZX

LED SWR Bridge

KI6SN (N7VE)
http://www.adventure-radio.org/ars/pages/back_issues/1998_text/0998_text/bright.html



T1 -- 5 turn primary, 25 turn secondary,
on FT-37-61 or FT-50-61 core
#28 enamelled wire

LED -- clear lens (non-diffused), red.
20 ma. (RS # 276-309, wide angle,
or RS #276-307 or #276-066 will do.
Others, too, but avoid #276-045.)

W6JJZ, 10/23/97, SWR Indicator
Using LED. Modification
of Dan Tayloe (N7VE) design

Tune for minimum LED Brightness

Frequency Counter

Pg. 7-14

- The more accurate the **time base**, the more accurate the readings will be.
- Time base error is specified in PPM (parts per million)

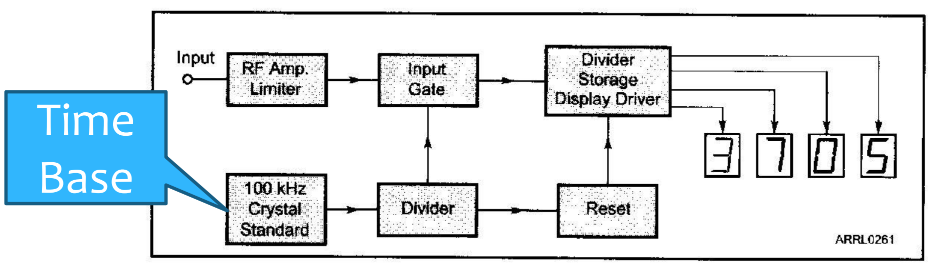


Figure 7-14 —This block diagram shows the basic parts of a frequency counter.

Understanding Frequency Counter Error

Pg. 7-14 & 15

$$\text{Error in Hz} = \frac{\text{f (in Hz) x counter error in ppm}}{1{,}000{,}000}$$

Equation 7-7

* If a frequency counter with a time base accuracy of ± 10 ppm reads 146,520,000 Hz, what is the most the actual frequency could differ from the reading?
* Error in Hz = 146,520,000 x 10 ppm / 1,000,000
* = 1465.20 Hz

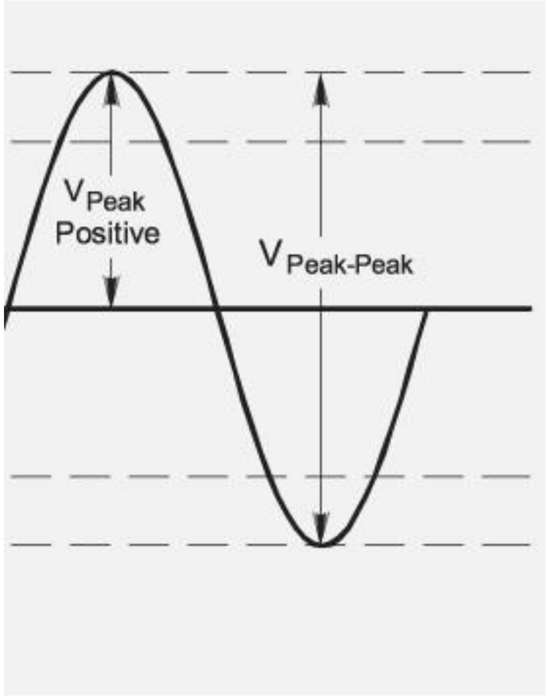
* **Better yet: Error in Hz = Freq (in MHz) x ppm**
* **= 146.52 MHz x 10 PPM**
* **= 1465.2 Hz**

There are 3 similar questions in the question pool

Oscilloscope

Pg. 7-16

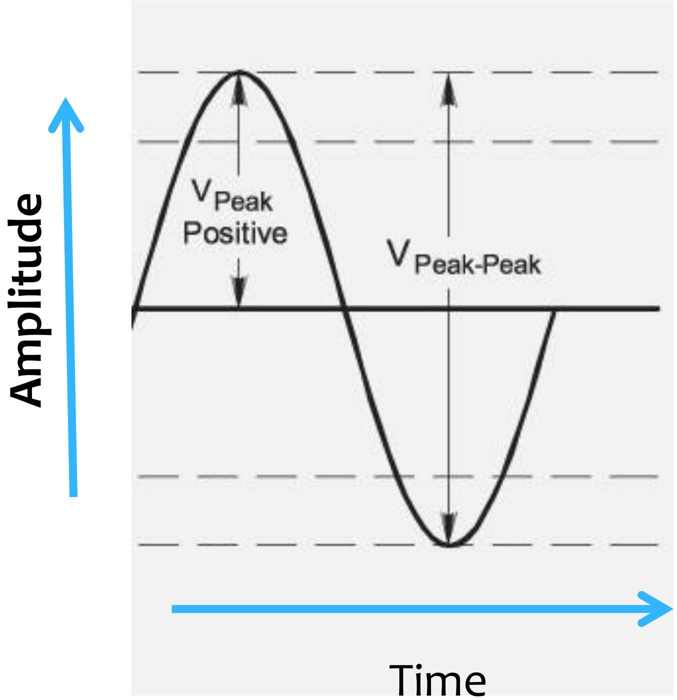
- The easiest amplitude measurement to make with an oscilloscope is an AC signal's **peak-to-peak voltage**



Oscilloscope

Pg. 7-16

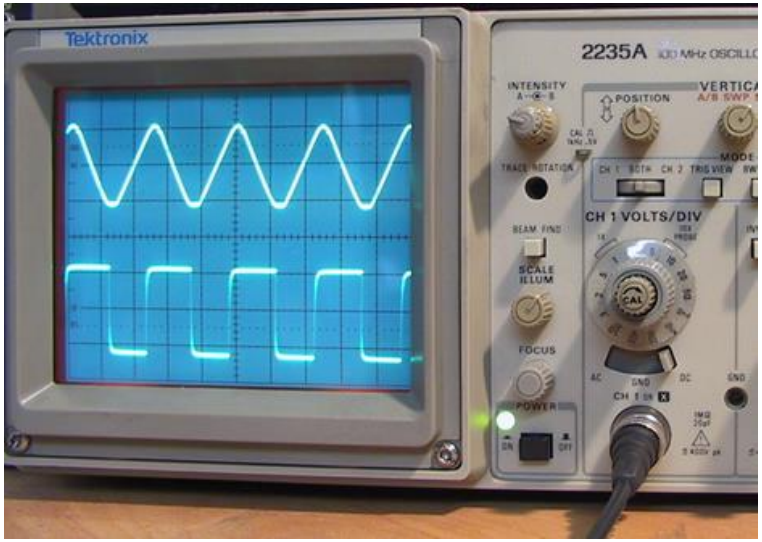
* The oscilloscope allows us to evaluate signals in the **time domain**



Oscilloscope

Pg. 7-16

- We can also measure the period of an AC signal



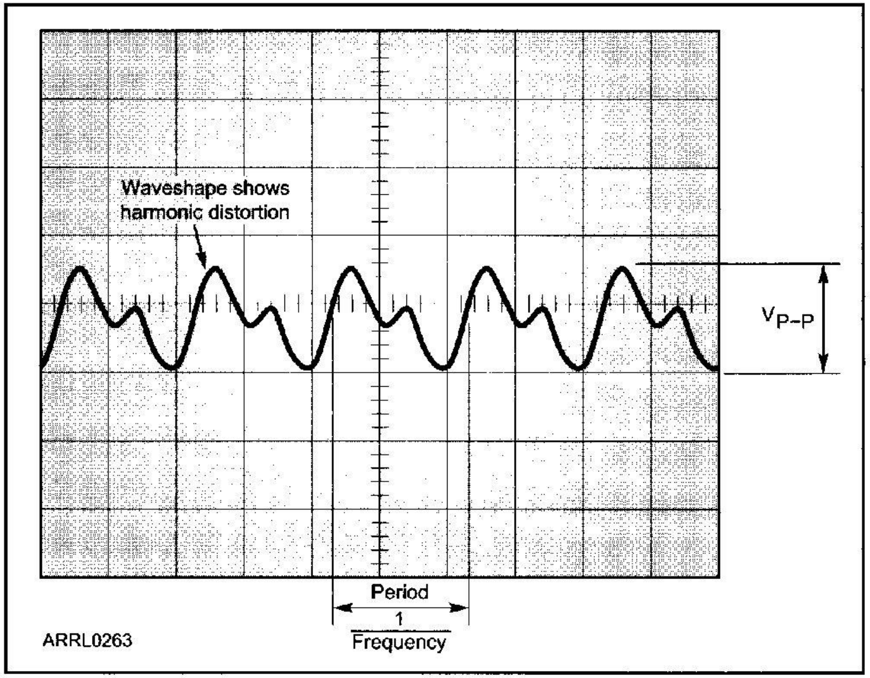
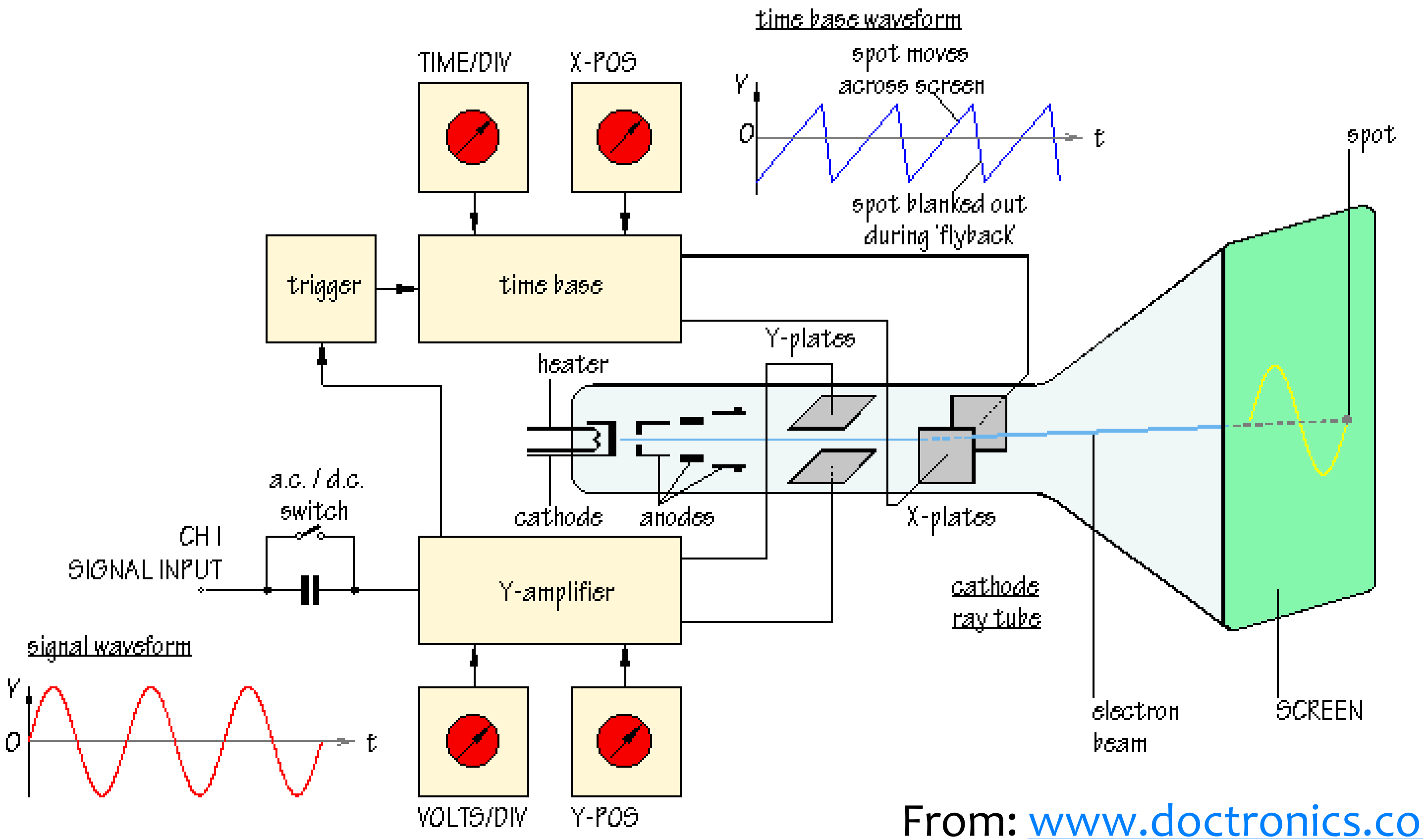


Figure 7-16 — This display shows how the peak-to-peak voltage and period of a complex waveform are measured using an oscilloscope. It can also be seen that the waveform contains enough harmonic energy to cause significant distortion.

Inside the Oscilloscope

* Simplified o'scope



From: www.doctronics.co.uk

Oscilloscope Probes

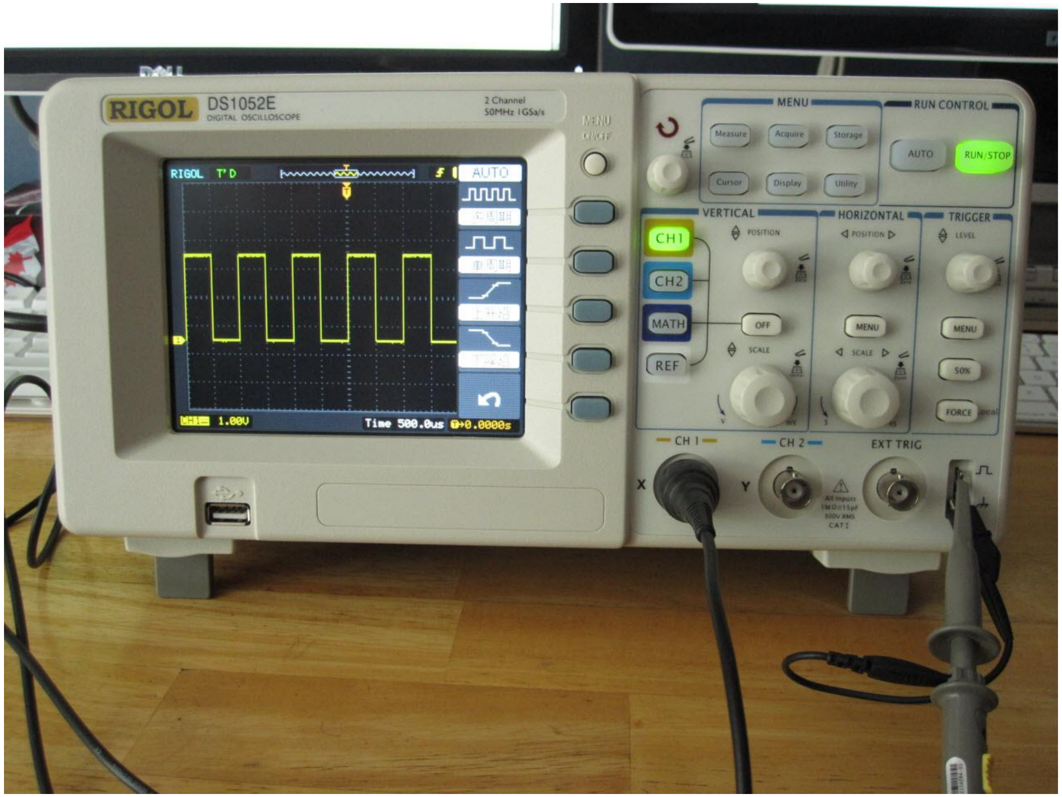
Pg. 7-12

- O'scopes use one or more probes
  - 10:1 divider probe is the most common
- For the most accurate measurements at high frequencies, it is important to **keep the ground connection as short as possible.**

Oscilloscope Probes

Pg. 7-13

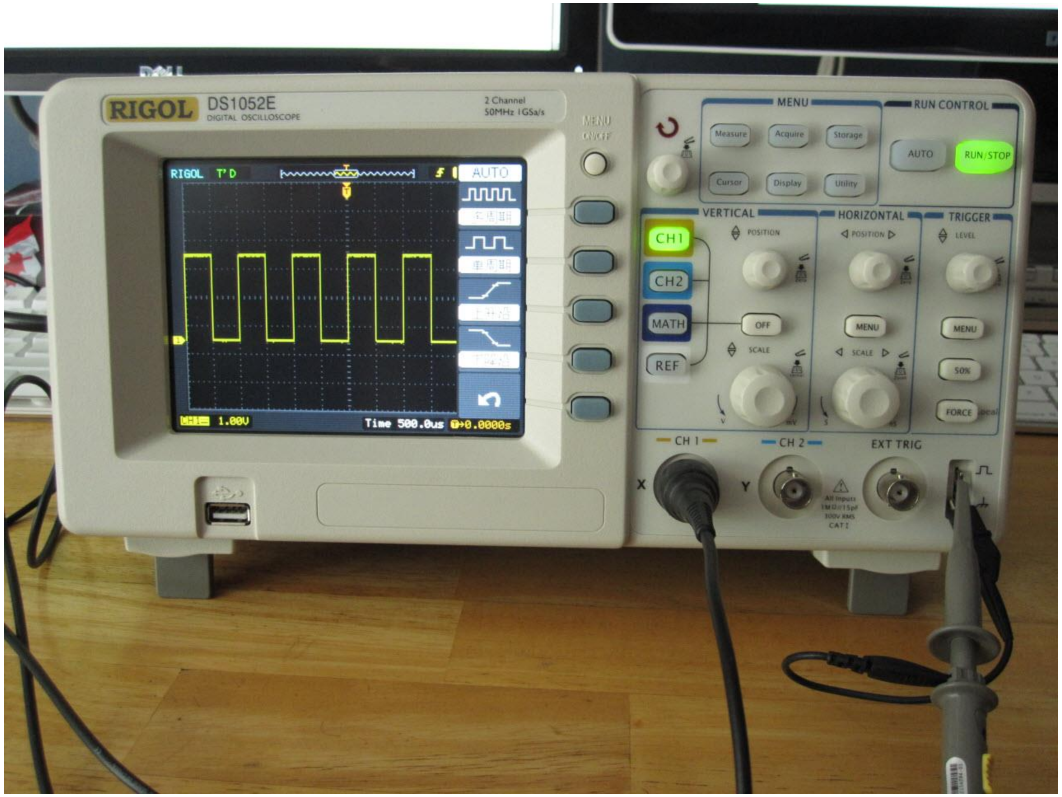
- The probes have to be frequency “compensated”.
- Most scopes provide a square wave calibration signal.
- The probe is connected to this signal and **adjusted until the square wave’s horizontal portions are flat and the corners are sharp.**



Digital Oscilloscopes

Pg. 7-13

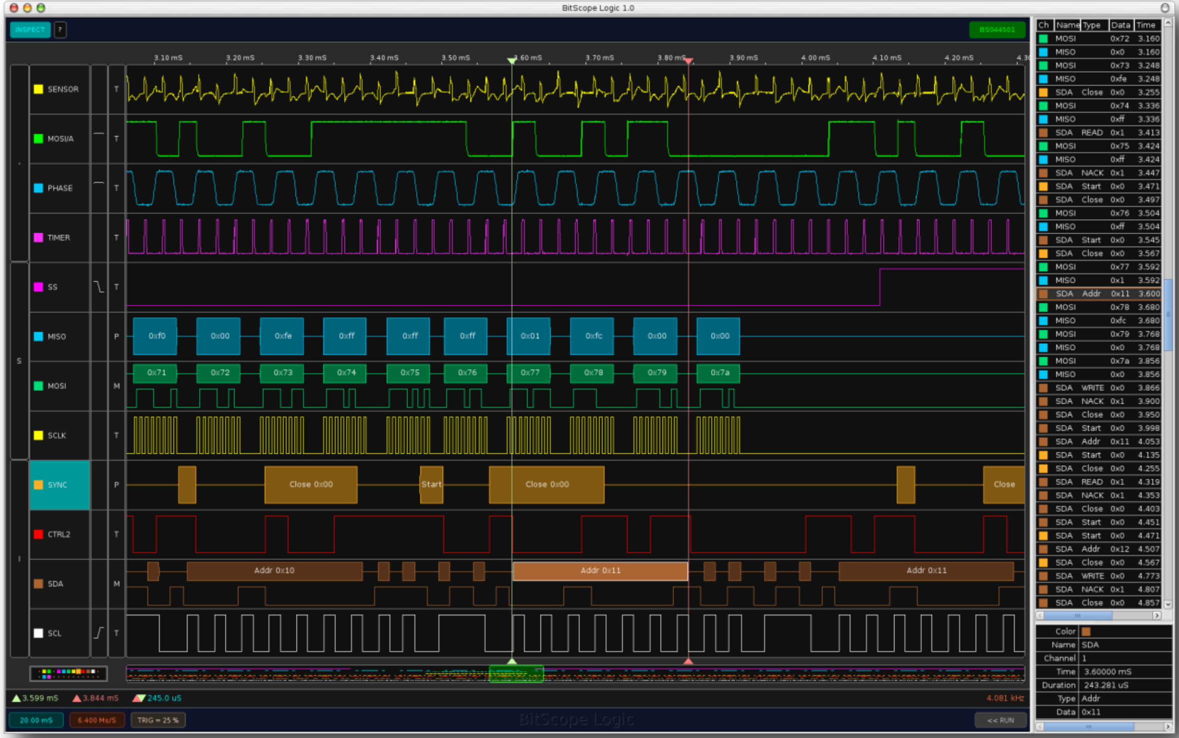
* Upper Bandwidth is determined by the sampling rate or analog to digital conversion card of a PC based scope.
* Highest frequency that can be digitized is ½ the sampling rate or there can be a "false" alias signal shown.
* With digital scopes, you can zoom in and out



Logic Analyzers

Pg. 7-13

* A Logic Analyzer is a special type of oscilloscope for observing digital signals.
* It may have 16 or more input channels.



Spectrum Analyzers

Pg. 7-14

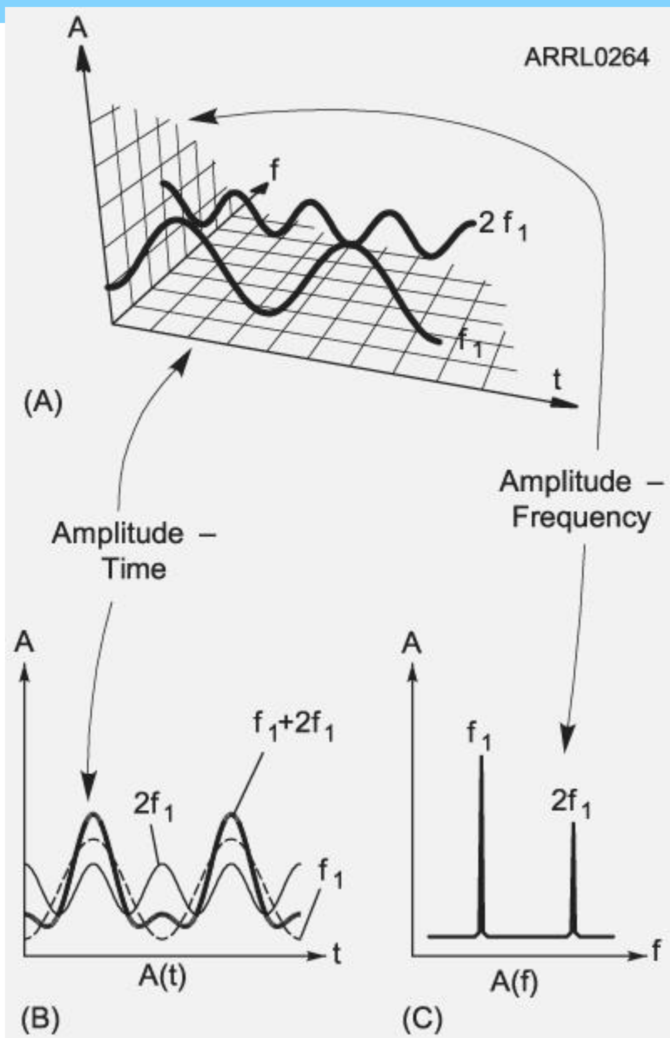


Fig 7-14

* If we look at a complex signal on an oscilloscope, the wave form becomes difficult to distinguish.
* A spectrum analyzer may give us a more meaningful display.

Simplified Spectrum Analyzer

Pg. 7-14

- The spectrum analyzer displays the amplitude vs the frequency.
- We say that the spectrum analyzer allows us to evaluate signals in the frequency domain

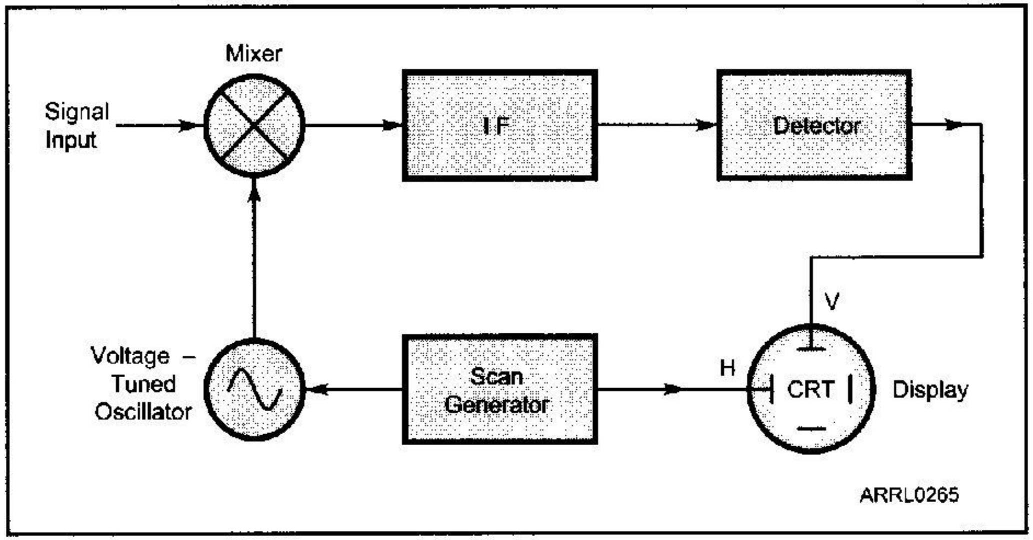
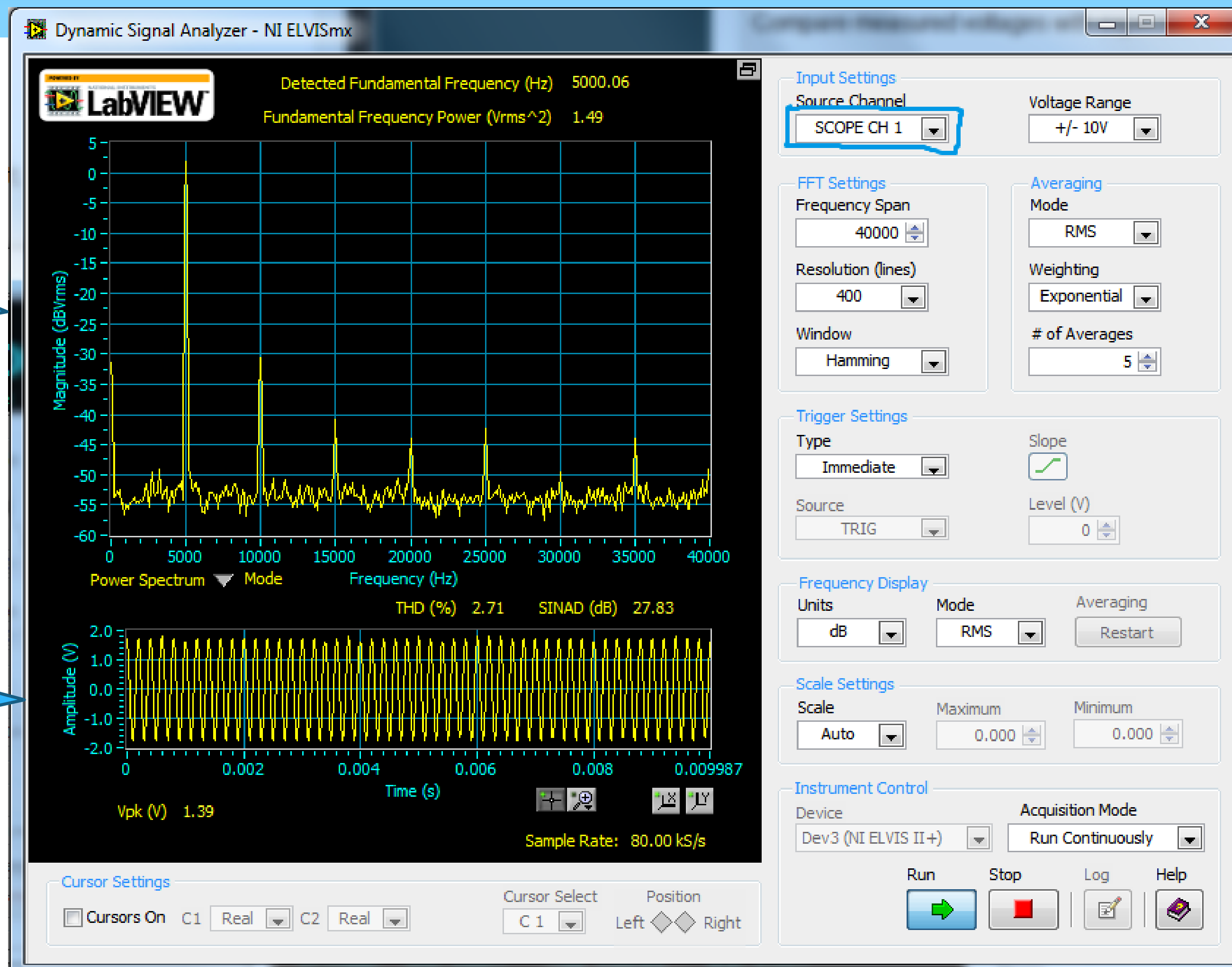


Figure 7-18 — This simplified block diagram illustrates the operation of swept-superheterodyne spectrum analyzer. It is basically an electronically tuned, narrow-band receiver with a CRT display of signal amplitude and frequency.

Looking at a Signal with Harmonics

Frequency Domain Display (Spectrum Anlz)

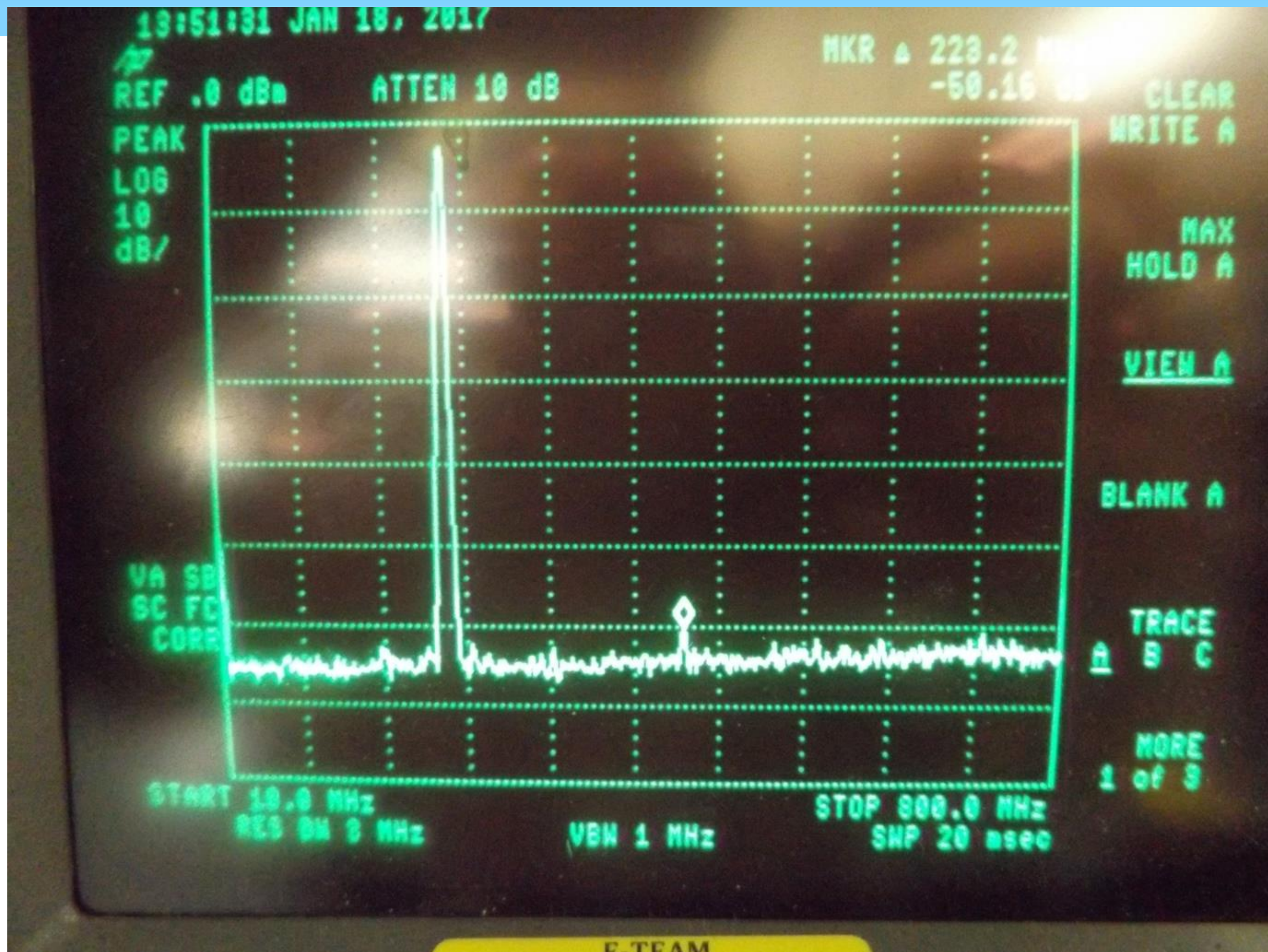
Time Domain Display (Oscilloscope)



http://www.eng.auburn.edu

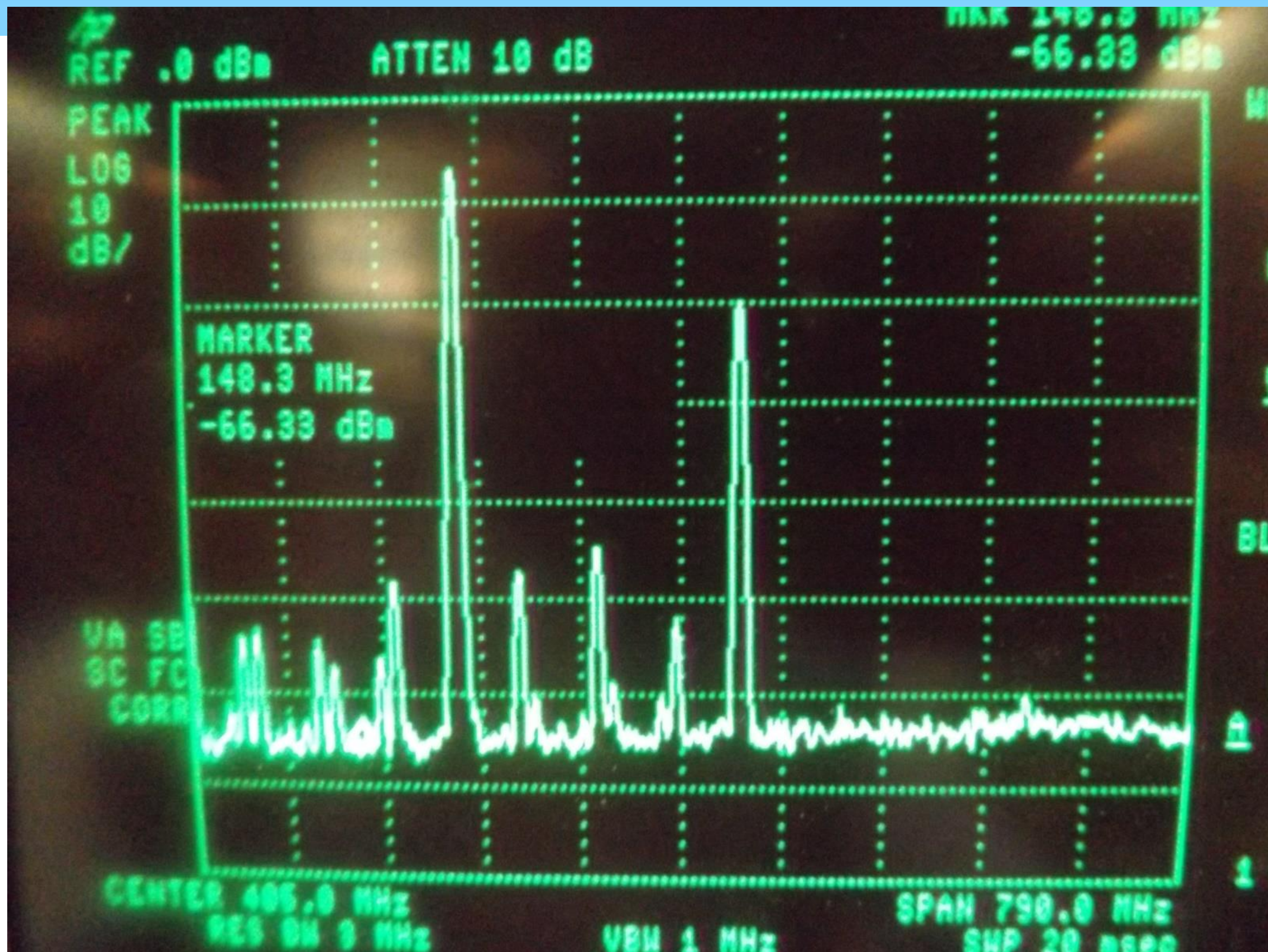
Kenwood TH-F6A

* 224.78 MHz



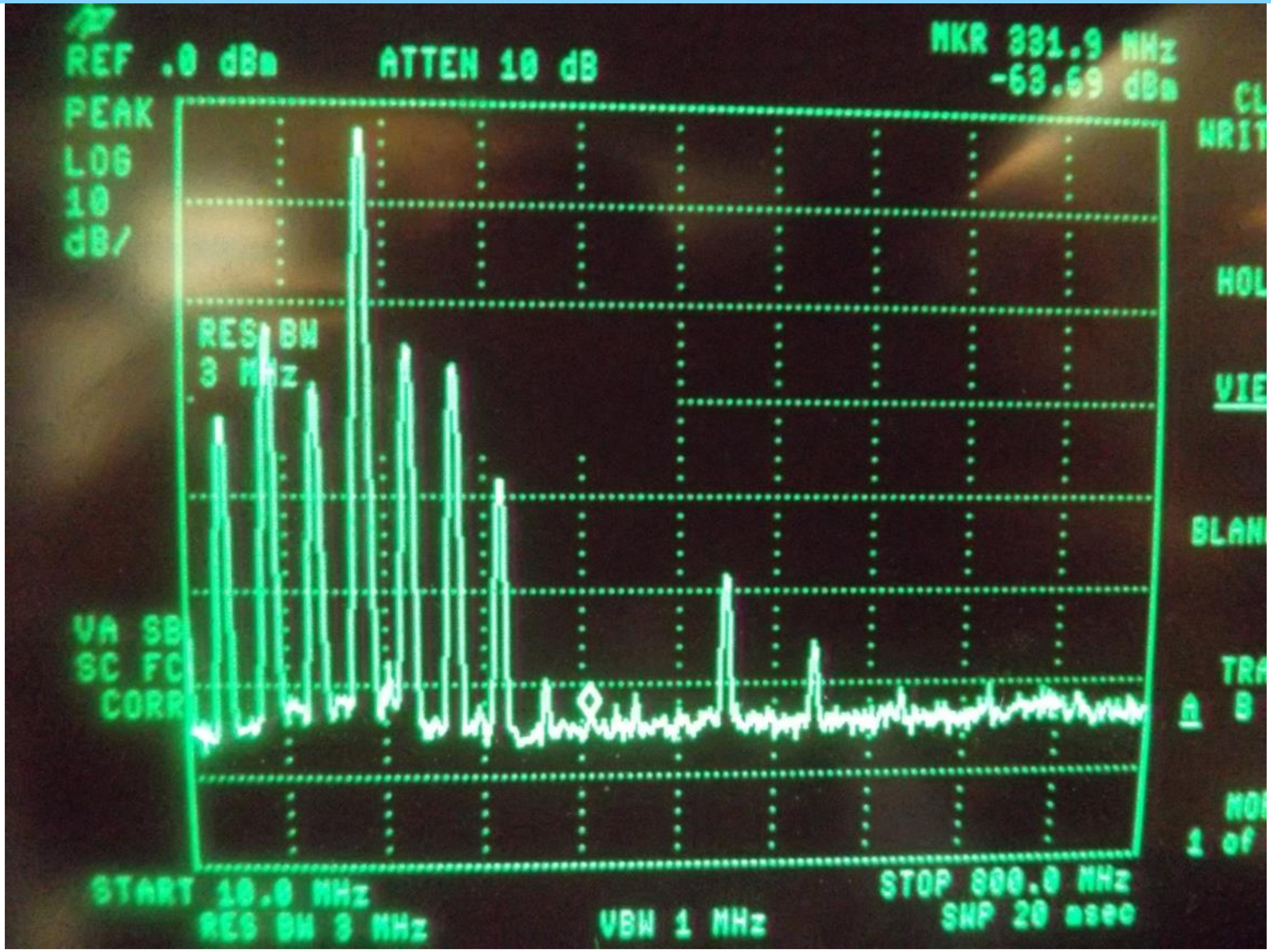
Baofeng UV-82X

* 224.78 MHz



Baofeng UV-82X

* 146 MHz



Using a Spectrum Analyzer

Pg. 7-18

* You can easily see spurious signals from a transmitter on a spectrum analyzer.
* The transmitter output must be reduced to a safe level before it is applied to the spectrum analyzer by either:
  * A line sampler
  * A power attenuator

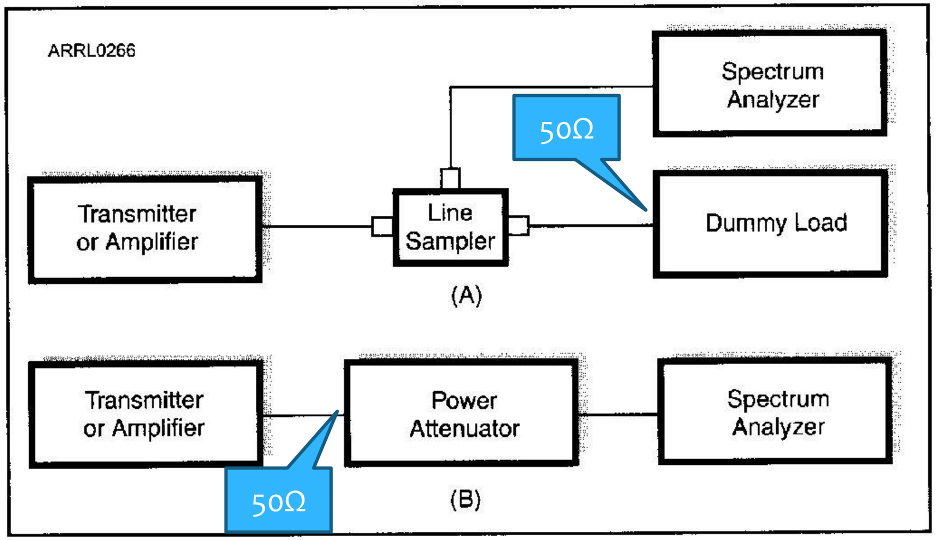


Figure 7-19 — These diagrams show two commonly used test set-ups to observe the output of a transmitter or amplifier on a spectrum analyzer. The system at A uses a transmission line power sampler to obtain a small amount of the transmitter or amplifier output power. At B, the majority of the transmitter output power is dissipated by the power attenuator, leaving a small amount to be measured by the spectrum analyzer.

HF Transceivers

with Built-in Spectrum Analyzer and Oscilloscope

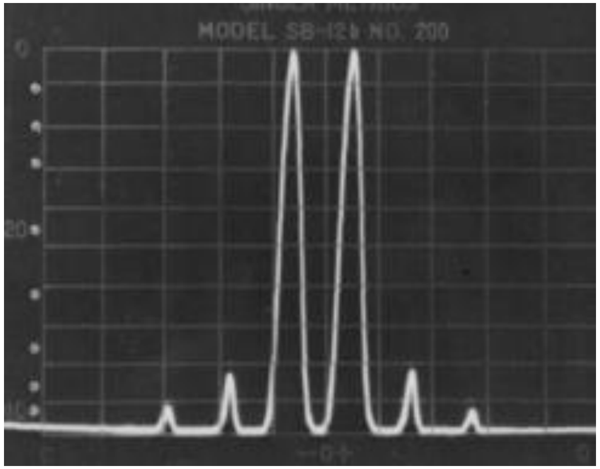
Icom IC-756 Pro

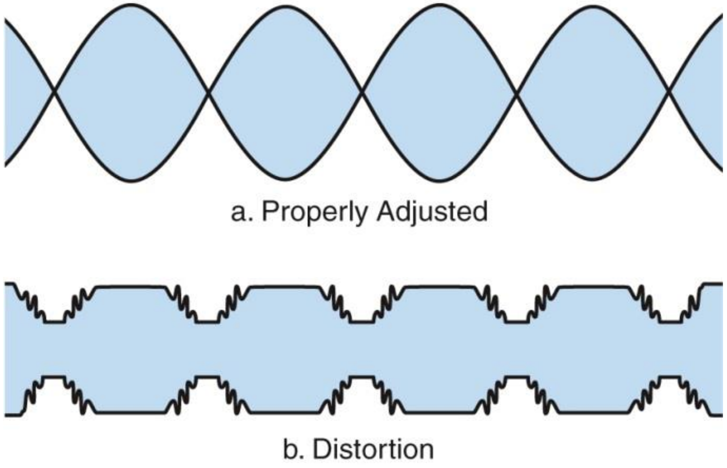
Two Tones

General Review

Two-Tone Test Signal for Transmitters

- One test that is often run on a SSB transmitter is the two-tone test. A two-tone test analyzes the **linearity** of a transmitter. (G4B15)
- **Two non-harmonically related audio signals** are used to conduct a two-tone test. (G4B16)





Understanding Linearity vs. Non-linearity

* **Linear:** The sled follows smoothly. Its movement is proportional to the force I am exerting on it.
* **Non-Linear:** The sled pulls and jerks and pushes, often erratically

Two-Tone Test

Pg. 7-16

Two equal-amplitude, but not harmonically related, audio tones are applied to the transmitter.

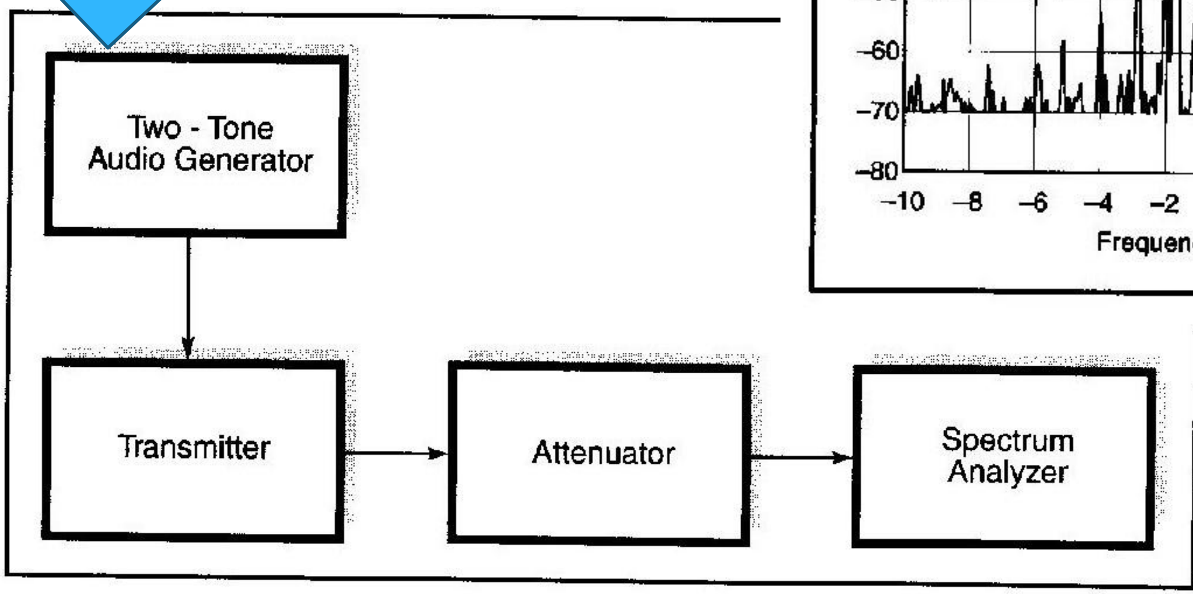


Figure 7-17 - This diagram illustrates the test setup used in the ARRL Laboratory for measuring the IMD performance of SSB transmitters and amplifiers.

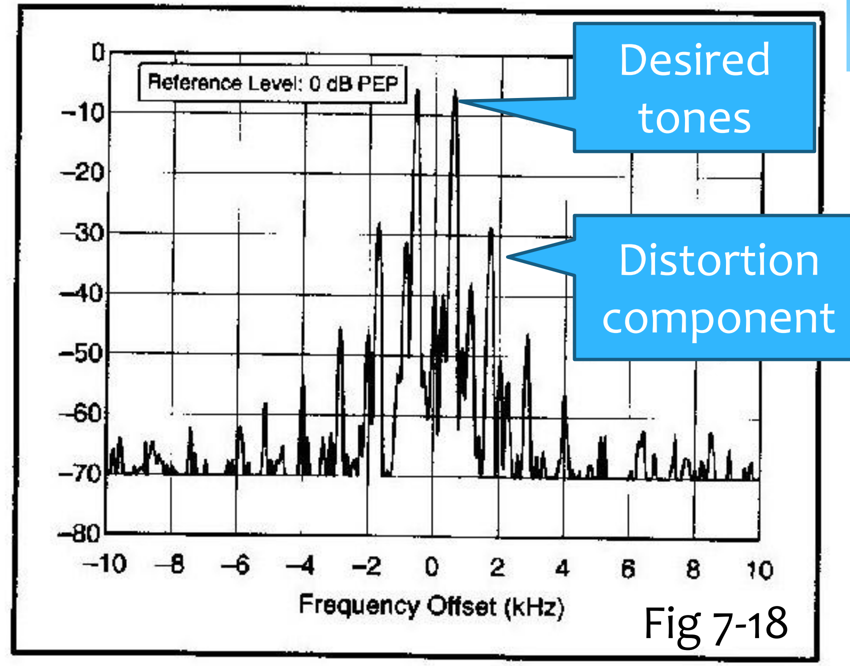


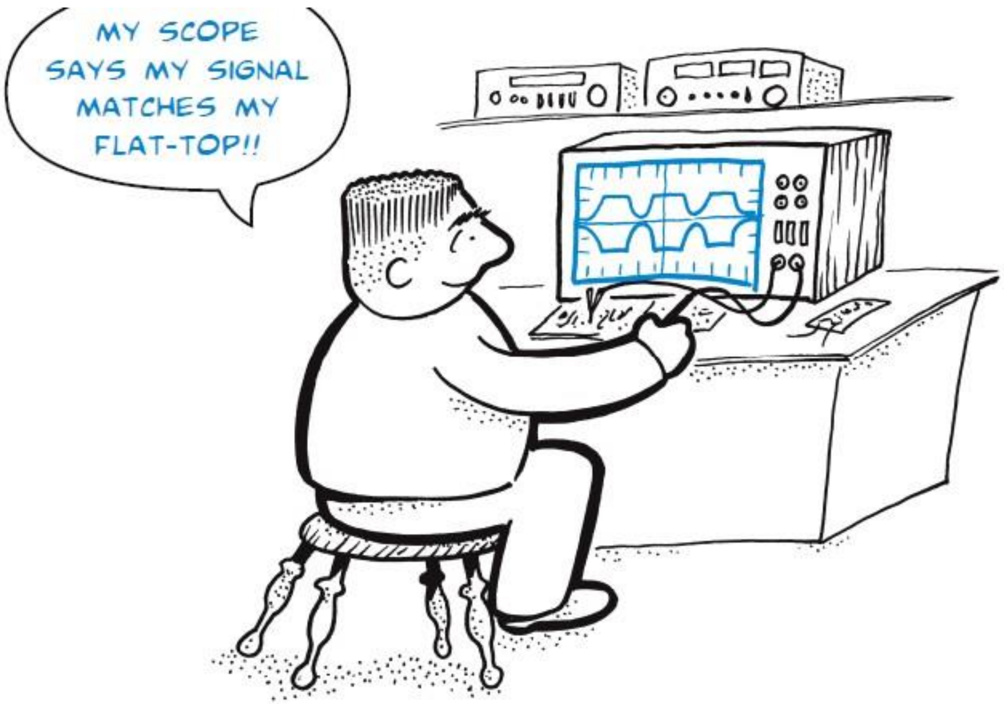
Fig 7-18

This two-tone intermodulation distortion (IMD) test is a common method of measuring transmitter linearity.

Common Uses for a Spectrum Analyzer

- Transmitter spectral output
  - Harmonics and spurs
- IMD (amplifier linearity)
- Crystal oscillator operation
  - Fundamental or overtone
- Amount of isolation (dB) between the input and output ports of a 2m duplexer

Let's Look at Some Questions



E4B02 What is an advantage of using a bridge circuit to measure impedance?

A. It provides an excellent match under all conditions
B. It is relatively immune to drift in the signal generator source
C. The measurement is based on obtaining a signal null, which can be done very precisely
D. It can display results directly in Smith chart format

E4A12 Which of the following procedures is an important precaution to follow when connecting a spectrum analyzer to a transmitter output?

A. Use high quality double shielded coaxial cables to reduce signal losses

B. Attenuate the transmitter output going to the spectrum analyzer

C. Match the antenna to the load

D. All of these choices are correct

E4B03 If a frequency counter with a specified accuracy of +/- 1.0 ppm reads 146,520,000 Hz, what is the most the actual frequency being measured could differ from the reading?

A. 165.2 Hz
B. 14.652 kHz
C. 146.52 Hz
D. 1.4652 MHz

E4A13 How is the compensation of an oscilloscope probe typically adjusted?

A. A square wave is displayed and the probe is adjusted until the horizontal portions of the displayed wave are as nearly flat as possible
B. A high frequency sine wave is displayed and the probe is adjusted for maximum amplitude
C. A frequency standard is displayed and the probe is adjusted until the deflection time is accurate
D. A DC voltage standard is displayed and the probe is adjusted until the displayed voltage is accurate

E4A11 Which of the following is good practice when using an oscilloscope probe?

A. Keep the signal ground connection of the probe as short as possible
B. Never use a high impedance probe to measure a low impedance circuit
C. Never use a DC-coupled probe to measure an AC circuit
D. All of these choices are correct

E4A03 Which of the following test instrument is used to display spurious signals and/or intermodulation distortion products in an SSB transmitter?

A. A wattmeter
B. B. A spectrum analyzer
C. C. A logic analyzer
D. D. A time-domain reflectometer

Receiver Performance

7-3

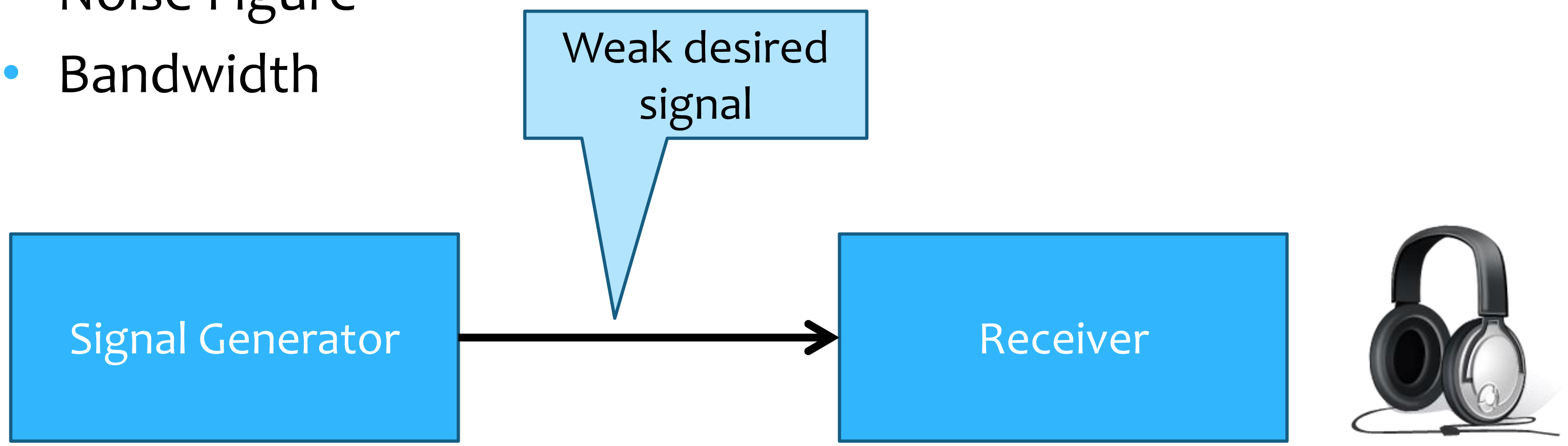
Bang for Your Buck

- Next to your antenna, your receiver is the most important item that determines the performance of your station.
- The receiver is a good place place to put your time, effort, money and ***understanding***.

Minimum Discernible Signal (MDS)

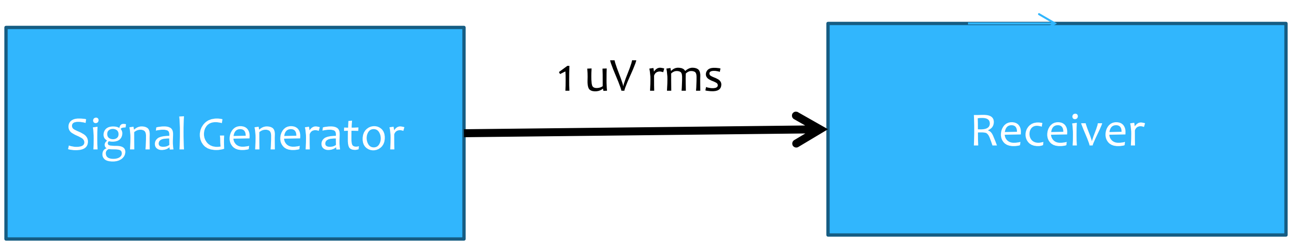
Pg. 7-17

- The **MDS** is the smallest discernable input signal (also called the receiver noise floor)
  - Noise Figure
  - Bandwidth



Receiver Input Voltage

* The level (strength) of an input signal to a receiver is often specified in microvolts (uV).



dB (Decibels)

Technician – General Review

- The decibel is a measure of change
  - Often the change of power

Decibel	Change in Power	Observed Effect
1 dB	Only 20%	Hardly perceivable
3 dB	Factor of 2	Just noticeable
6 dB	Factor of 4	Readily noticeable
10 dB	Factor of 10	Quite significant
15 dB	Factor of 32	A bit more significant
20 dB	Factor of 100	Very significant
30 dB	Factor of 1,000	Very-very significant
60 dB	Factor or 1,000,000	Extremely significant

dB (Decibels)

General Review

* The decibel is calculated as:
* **dB = 10 log P2 / P1**
* If you reduced your power from 100 W to 50 W:
* dB = 10 log 50 / 100 = 10 log 0.5 = 10 (-.3)
* = - 3 dB

dB and dBm

Pg. 7-17

- dB is a unit of **change**
- dBm is a unit of **power**

Decibels with respect to a power of 1 mW (usually into 50 ohms)

1 mW = 0 dBm
2 mW = 3 dBm
4 mw = 6 dBm

0.5 mW = -3 dBm
.0001 mw = -40 dBm

dBm and uV

- $dBm = 20 \log (V / 0.224 \text{ V})$
- $V = 0.224 (\text{antilog} (dBm / 20))$

0.224 V across a 50 ohm resistor dissipates 1 mW of power

The conversion would be different if you are using dBm in an audio application that is based on a 600 ohm impedance.

dBm to uV Conversion Charts

* http://wa8lmf.net/miscinfo/dBm-to-Microvolts.pdf

dBm TO MICROVOLTS CONVERSION CHART (For 50 Ω System)

dBm	uV	dBm	uV	dBm	uV
0	224,000	-47	1,000	-94	4.47
-1	200,000	-48	891	-95	3.99
-2	178,000	-49	795	-96	3.55
-3	159,000	-50	709	-97	3.17
-4	141,000	-51	633	-98	2.82
-5	126,000	-52	563	-99	2.52
-6	112,000	-53	501	-100	2.24
-7	100,000	-54	447	-101	2.00
-8	89,100	-55	399	-102	1.78
-9	79,500	-56	355	-103	1.59
-10	70,900	-57	317	-104	1.41

The Noise Floor

Pg. 7-17

* **- 174 dBm** is considered the theoretical best (lowest) noise floor that any receiver can have at room temperate.
* The strength of any signal would have to be at least -174 dBm to be heard.
* This is calculated with a **1 Hz** bandwidth.

1 Hz is a ridiculously narrow BW

You Built a Perfect Receiver

Pg. 7-17

* Your receiver has a MDS of -174 dBm in a 1 Hz BW.
* But you want to use a 400 Hz filter to work CW. What is the actual MDS?

Calculate the BW ratio in dB:

$$BW_{\text{RATIO dB}} = 10 \log (BW2/ BW1)$$
$$= 10 \log (400 \text{ Hz} / 1 \text{ Hz})$$
$$= 10 \log (400)$$
$$= 10 \times 2.6$$
$$= 26 \text{ dB}$$

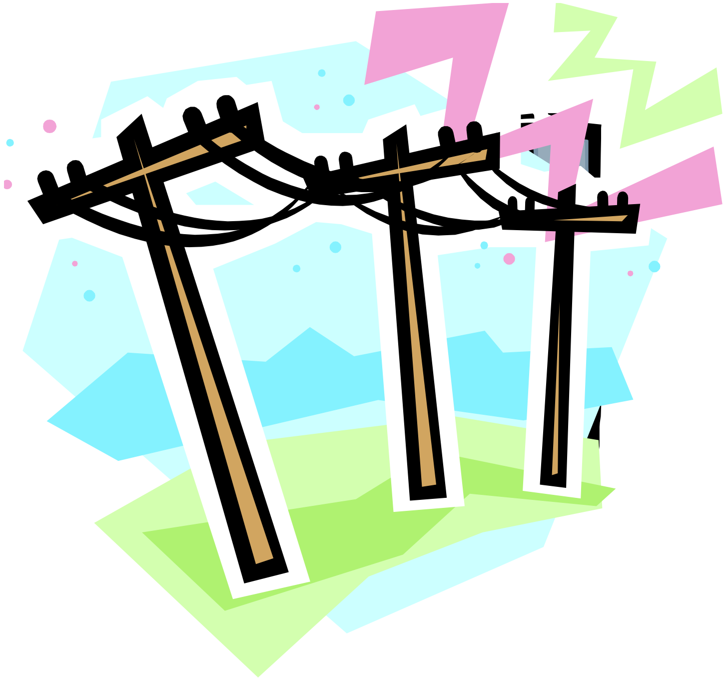
MDS = -174 dBm + 26 dB = -148 dBm

Remember:
dB = 10 log (P2 / P1)

As a practical matter …

- Atmospheric noise is the limiting factor for sensitivity on the HF bands.

- So is power line noise



Noise Figure

Pg. 8-20

* Noise figure is the "figure of merit" for the receiver. It is the ratio in dB of the noise generated by the receiver to the theoretical MDS.
* The higher the noise figure, the more noise is generated in the receiver.
* For a UHF receiver, noise figure is more important than for a HF receiver. A low noise preamplifier at UHF might have a noise figure of **2 dB**.
* Actual Noise Floor = Theoretical MDS + noise figure.
* With a lower noise figure, a weak signal will be easier to copy.

Signal to Noise

Pg. 7-18

- **SNR** = Signal to Noise Radio
  - The desired signal power compared to the noise power
  - Expressed in dB
- **SINAD** = Signal to Noise and Distortion
  - This also taken in any ***distortion*** generated in the receiver.
  - Expressed in dB

Selectivity

Pg. 7-18

The ability of a receiver to:

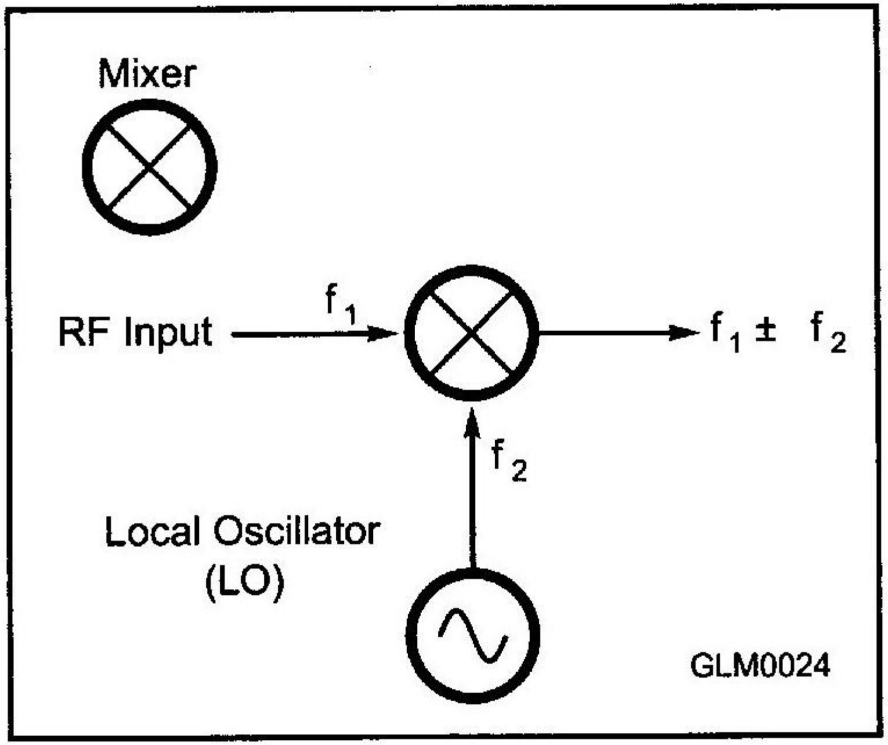
- Pass (receive) the desired signal with good fidelity

- Reject all undesired signal
  - There could be literally millions of undesired signals

Mixer

General Review

7 MHz

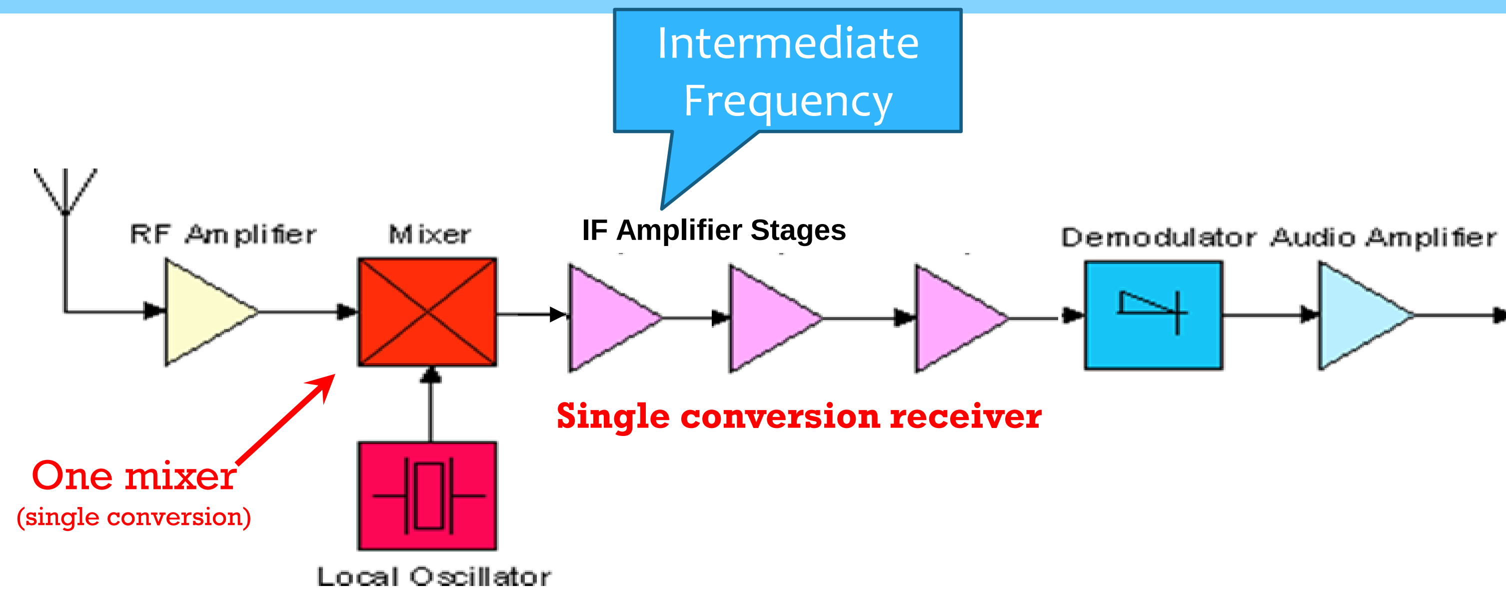


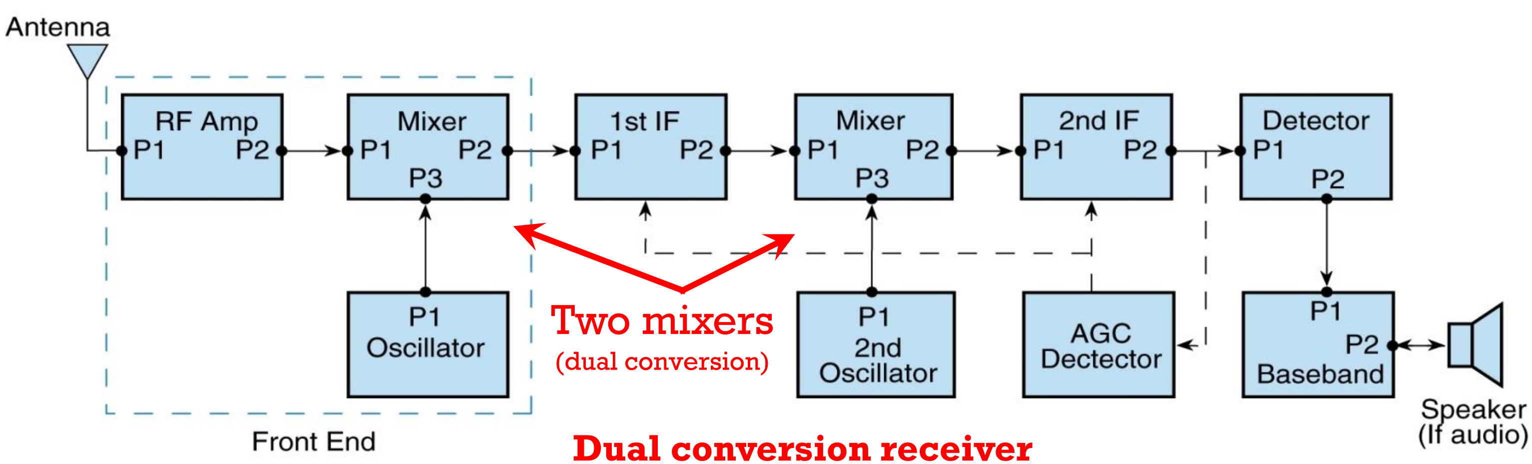
4 MHz
10 MHz

3 MHz

Receivers

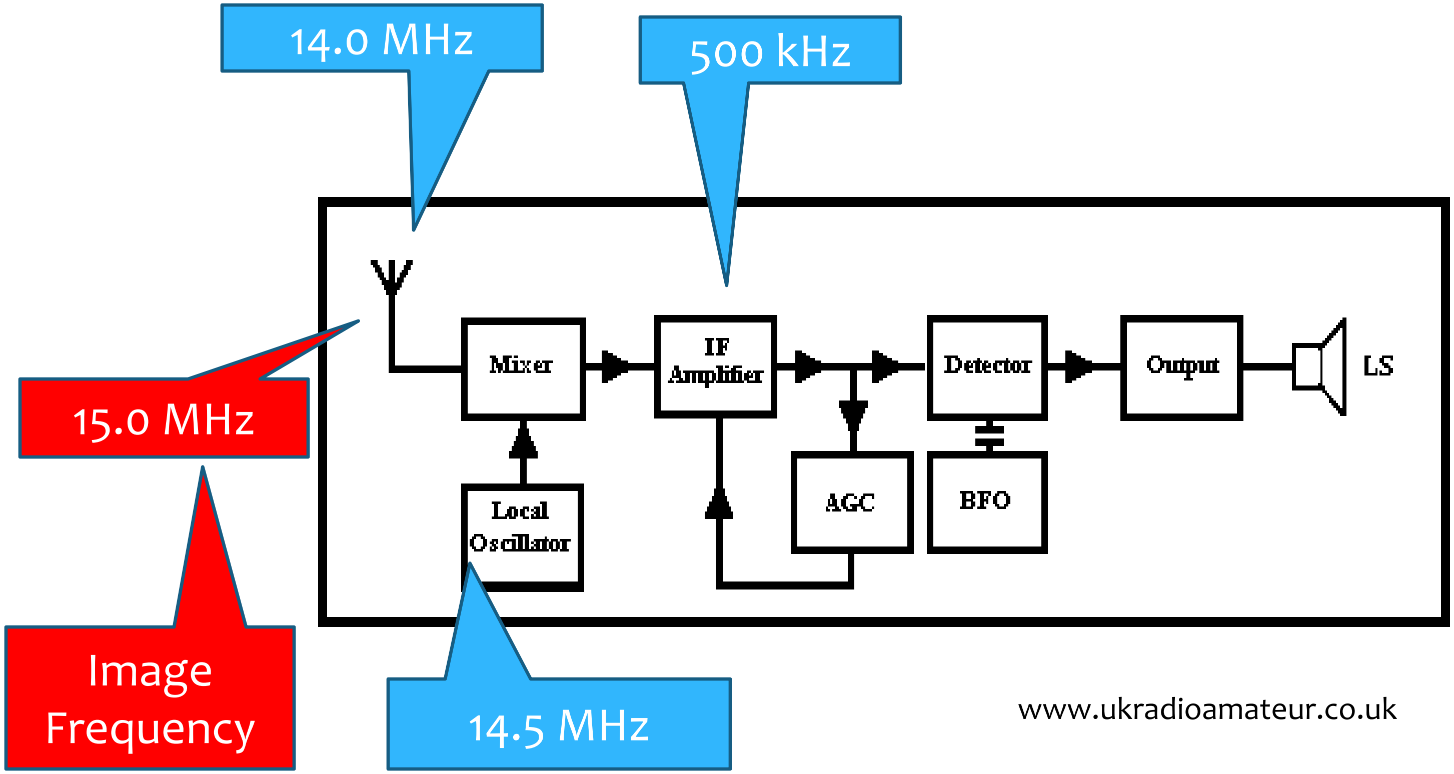
General Review





Superheterodyne Receiver

500 kHz IF

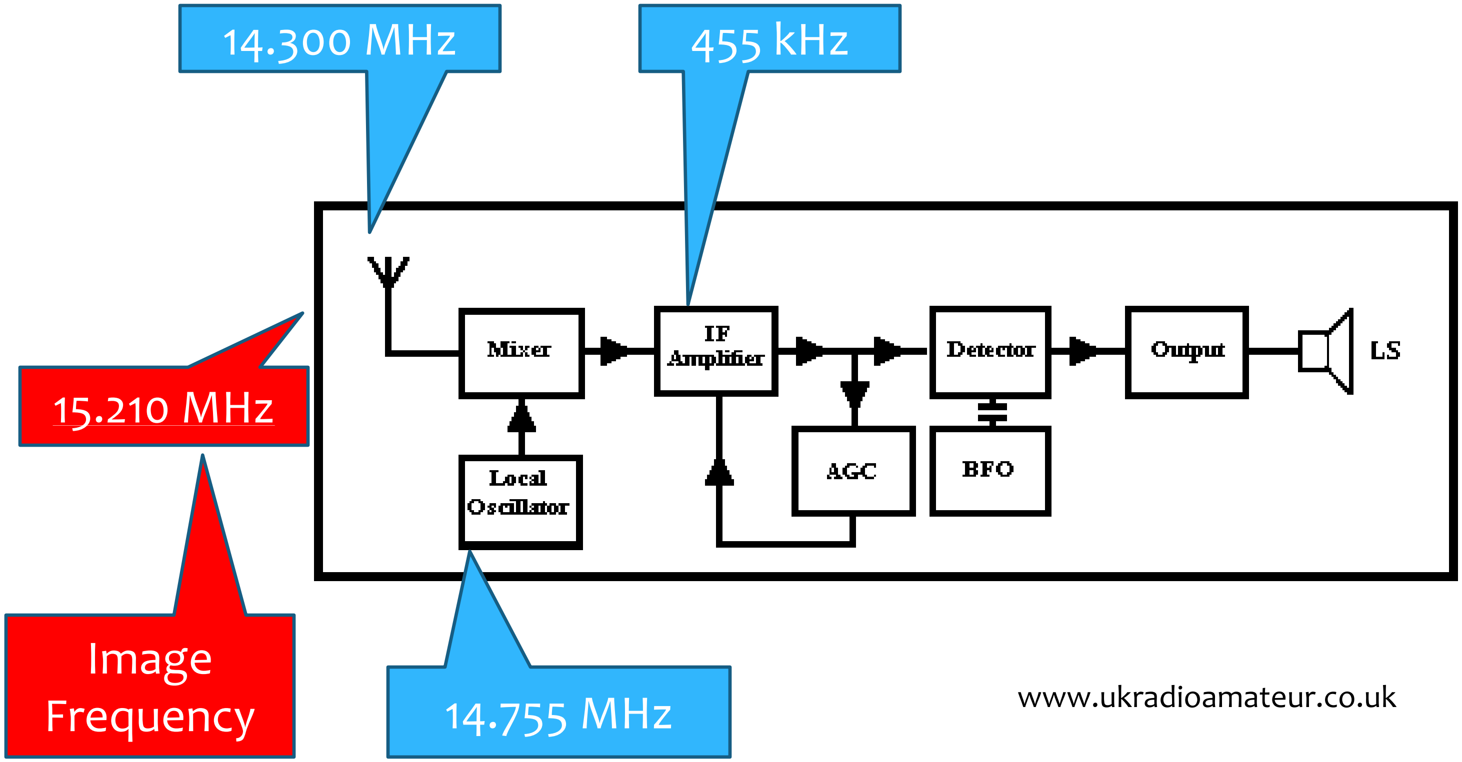


www.ukradioamateur.co.uk

Superheterodyne Receiver

455 kHz IF

Pg. 7-19

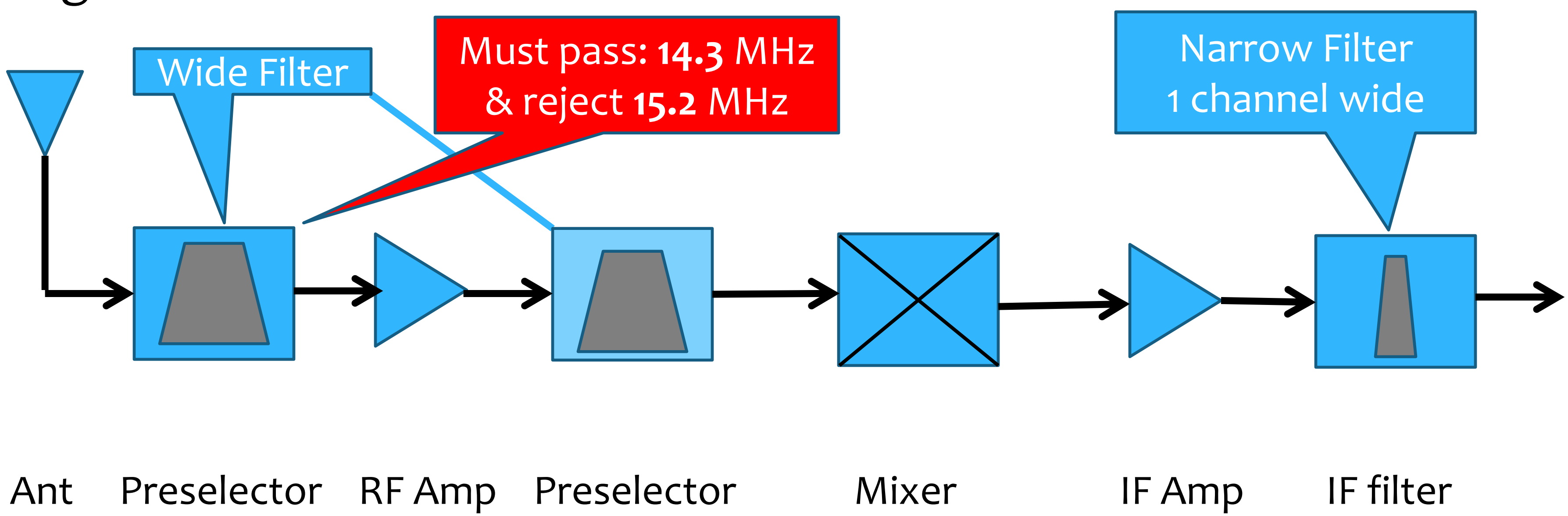


www.ukradioamateur.co.uk

Let's Add Some Filters

Pg. 7-19

A preselector is a tunable input filter adjusted to pass the desired frequencies and reject out-of-band unwanted signals.



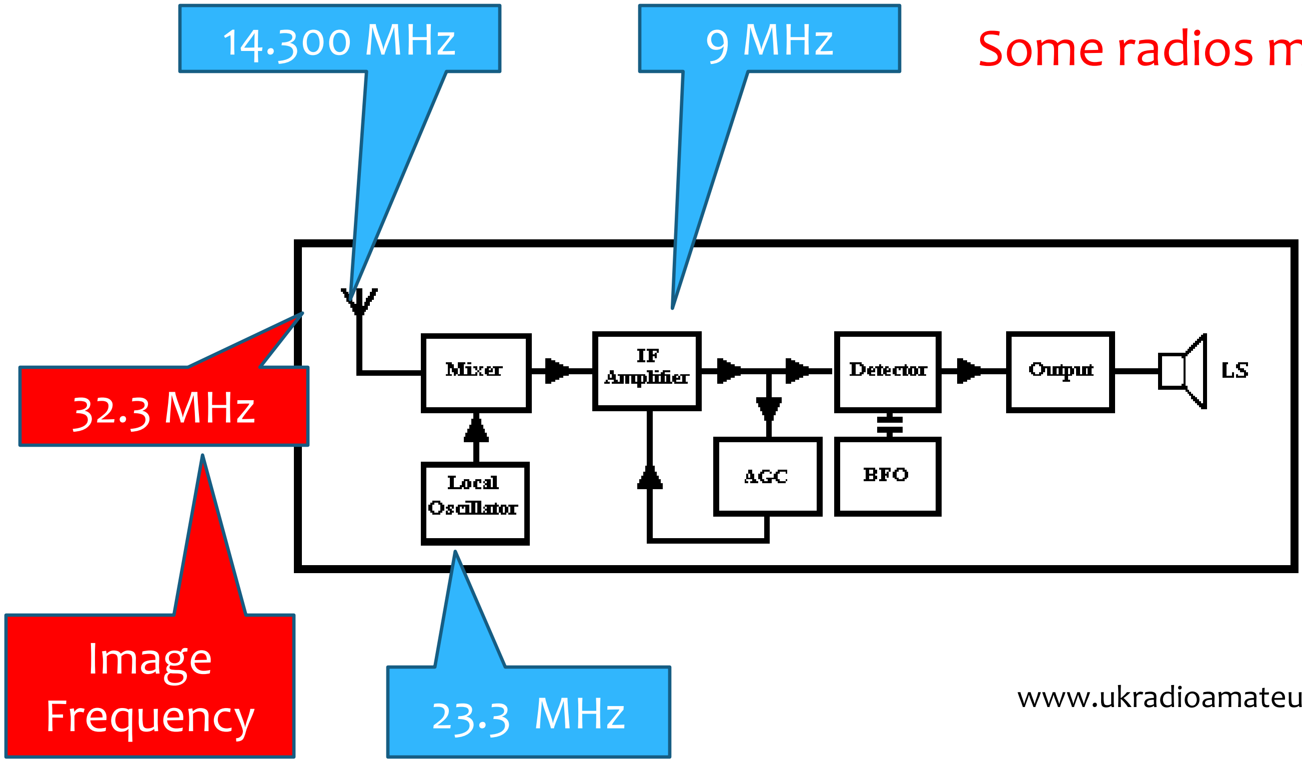
Superheterodyne Receiver

9 MHz IF

Pg. 7-19

As the IF is increased, the frequency of the image response moves further away and is easier to filter out.

Some radios may have a 45 MHz IF



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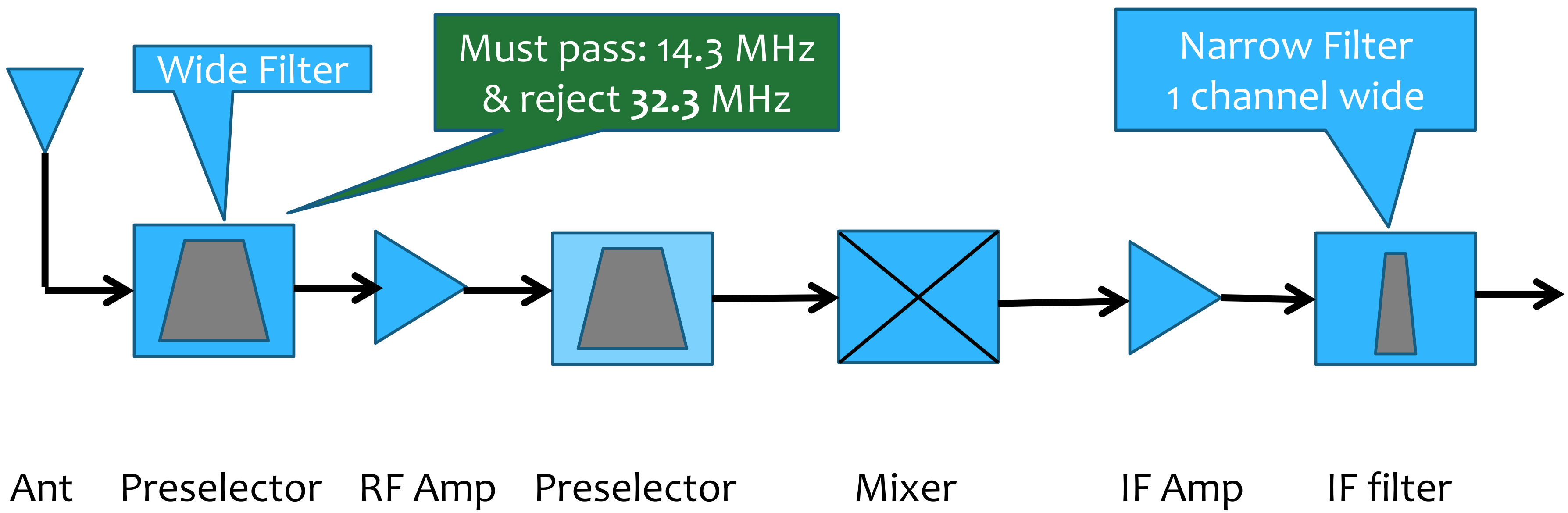
Let's Move that Image far Away

Pg. 7-19

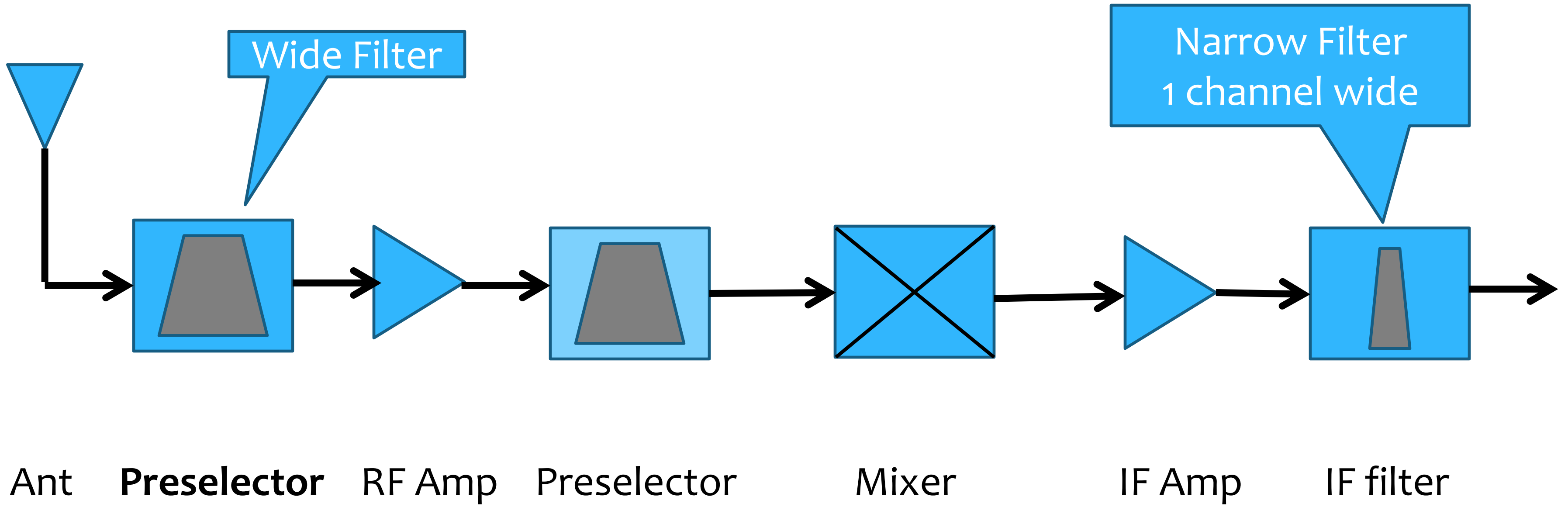
As the IF is increased, the frequency of the image response moves further away and is easier to filter out.



Reject that Image Response

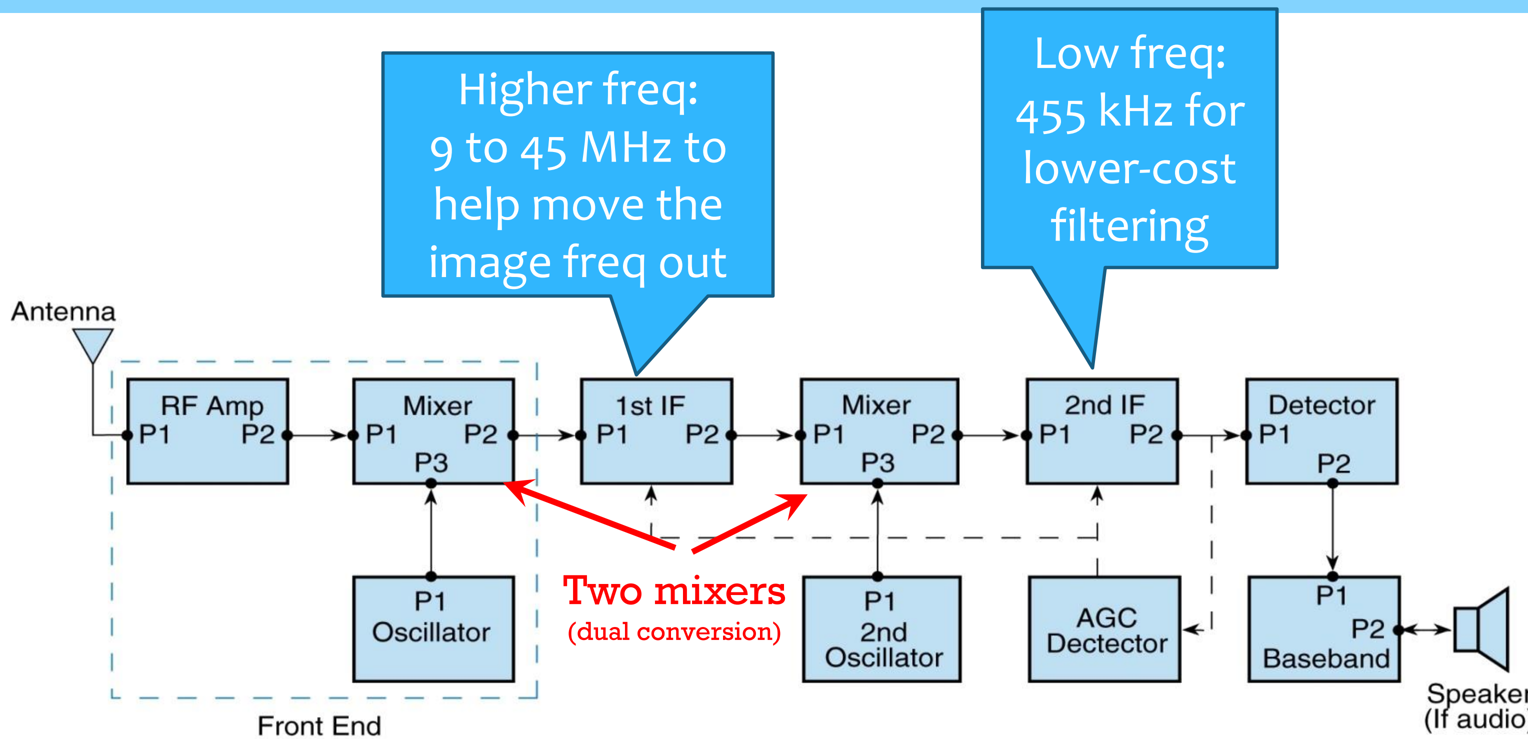
Pg. 7-19

The **Preselector** rejects the image response of the receiver and other unwanted signals.



An advantage of Dual Conversion

Practical Information

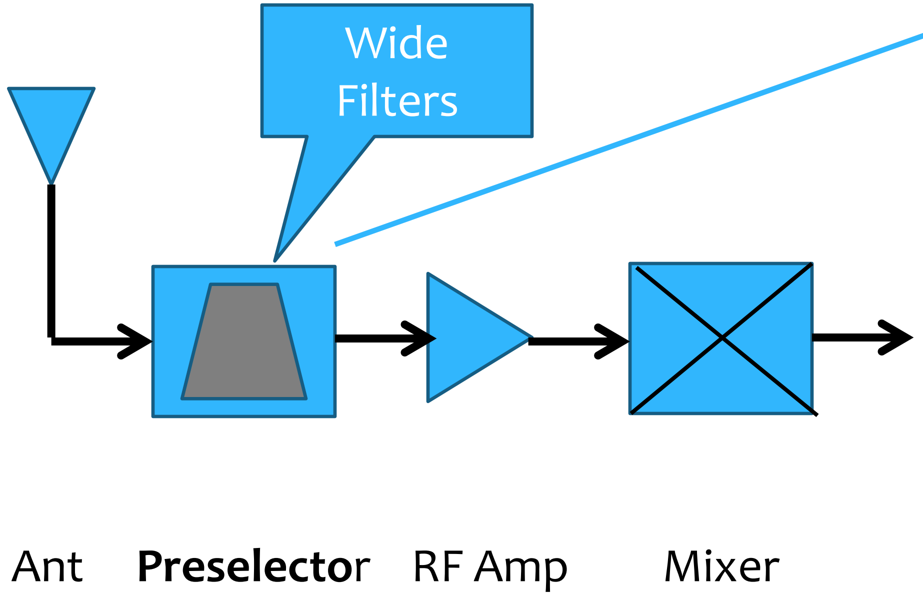


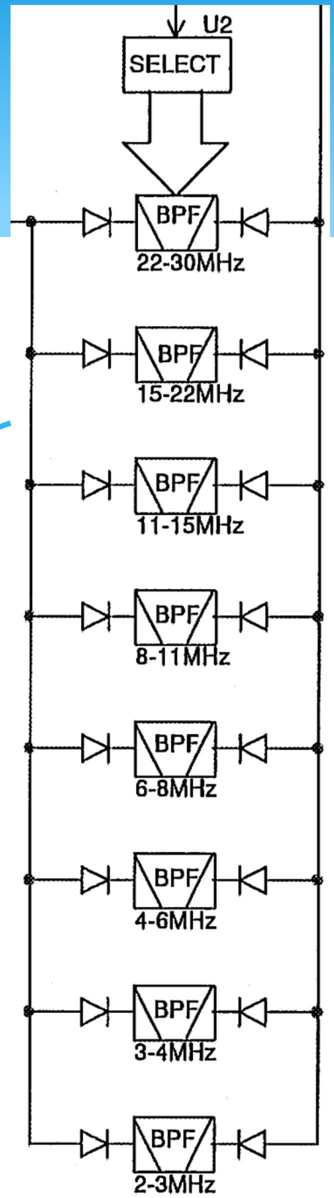
Dual conversion receiver

In DSP radio, more and more of the filtering is done digitally in the 2nd IF *or even in a 3rd IF.*

A Bank of BPF Filters

The **Preselector** rejects the image response of the receiver.





Let's Look at the Narrow Filter

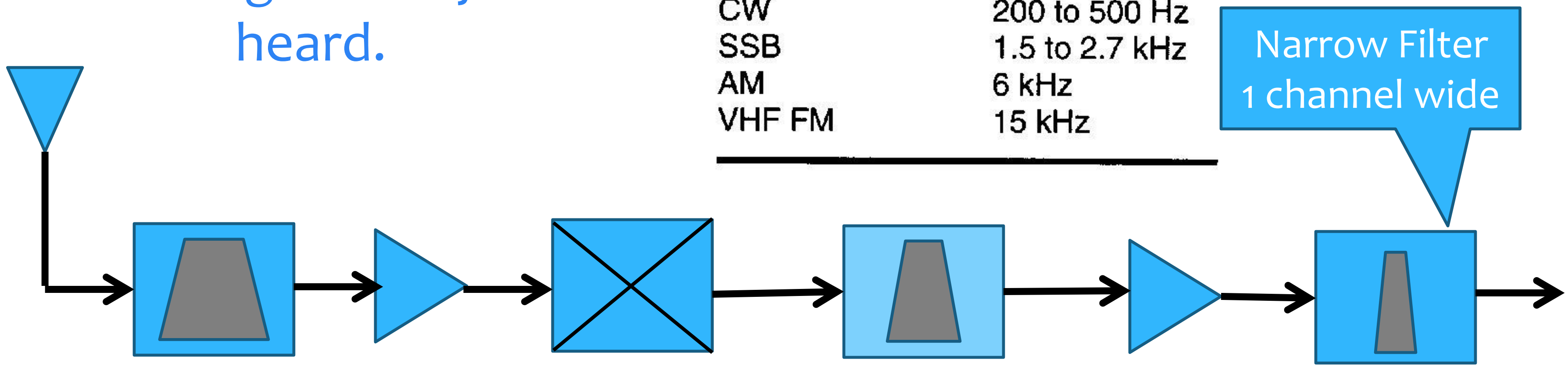
Pg. 7-19
& 20

The wider the filter, the more natural the audio, but undesired signals may also be heard.

7-2

Table 8-5
IF Filter Bandwidths by Signal Type

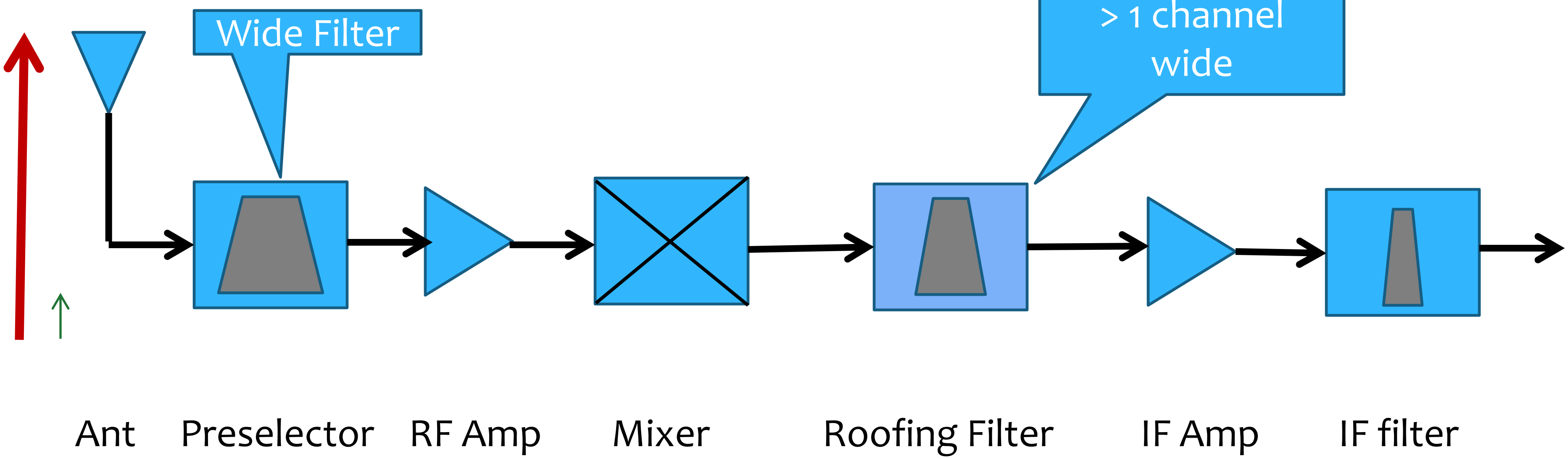
RTTY or digital	300 Hz
CW	200 to 500 Hz
SSB	1.5 to 2.7 kHz
AM	6 kHz
VHF FM	15 kHz



Ant Preselector RF Amp Mixer Roofing Filter IF Amp **IF filter**

Let's Look at the Roofing Filter

The purpose of a roofing filter is **to reject as many strong signals as possible on nearby frequencies, improving the dynamic range.**



Roofing Filter

The view looking down the "throat" of a receiver Pg. 7-19

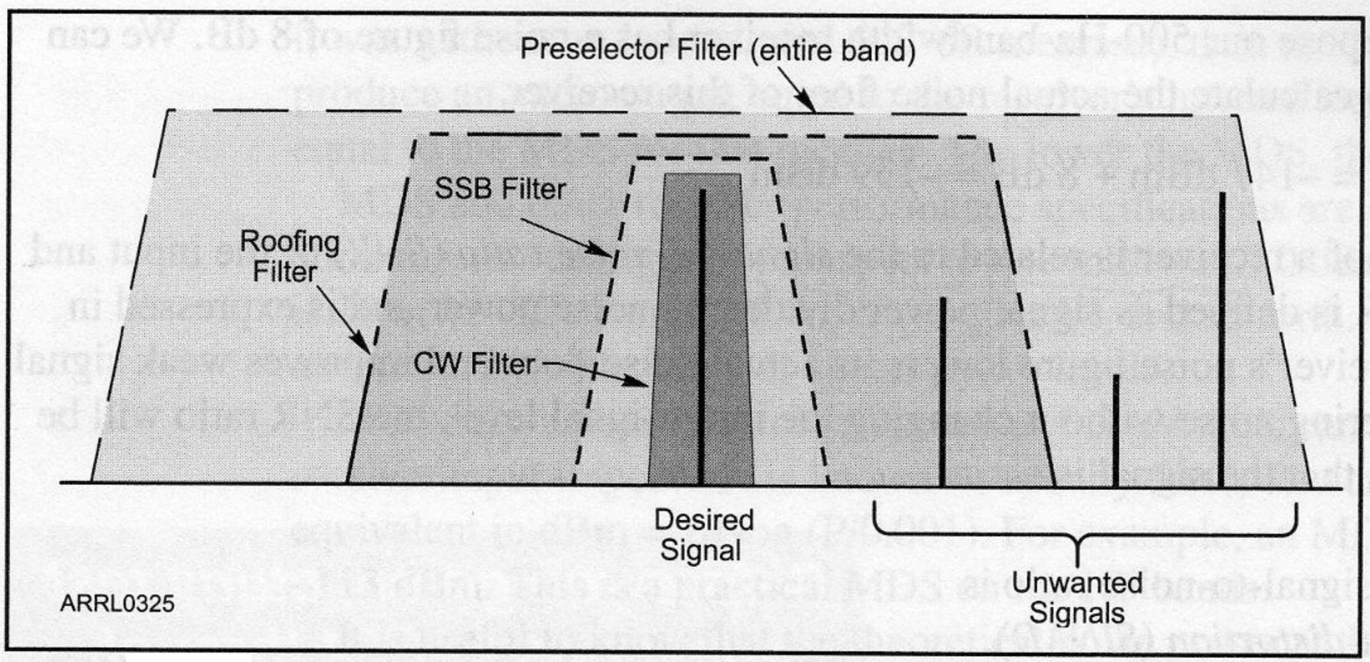
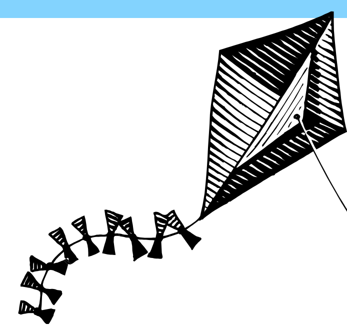


Figure 7-19 A typical multiple-conversion superheterodyne receiver has several stages of filtering. Preselector filters reject out-of-band signals. Roofing filters at the input to each IF further restrict receiver bandwidth, attenuating strong in-band signals that might overload the IF amplifiers. In the final IF stage, single-signal filters are used to select just the desired signal.

Dynamic Range

Pg. 7-20



Blocking Dynamic Range

* Strong adjacent channel signals can overwhelm the receiver causing weaker signals to appear to fade.
* The fading is due to gain compression (a reduction in gain)
* This results in a reduction of sensitivity called **Desensitization**

Gain Compression

Pg. 8-23

* Blocking Dynamic Range (BDR) is the difference between the level of the receivers MDS and the blocking level

* When the Blocking Dynamic Range (BDR) is exceeded, the receiver loses its ability to amplify weak signals.

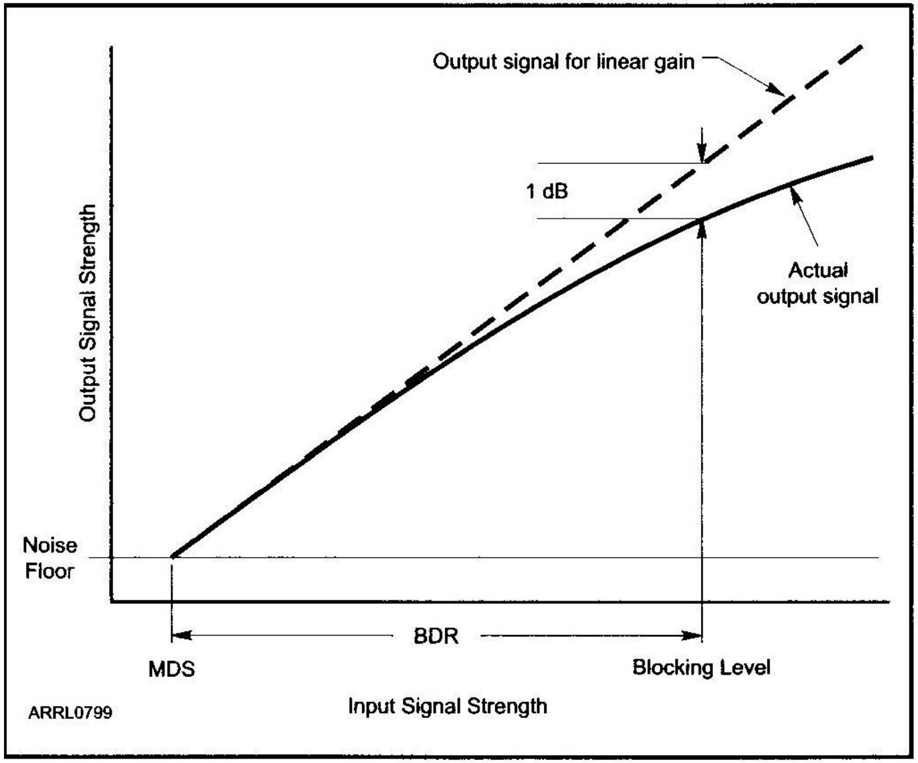


Figure 8-11 — Gain compression occurs when the input signal is too strong for the receiver to develop full gain. Blocking Dynamic Range (BDR) is measured in dB from MDS to a level at which the input signal strength causes a 1 dB drop in receiver gain, called the blocking level.

Blocking Dynamic Range

Pg. 8-23

* Blocking Dynamic Range (BDR) is the difference in dB between the **noise floor** and the **level of an incoming signal that causes 1 dB compression**.
* Remember:
  * The noise floor represents the **very weak** signal performance
  * And the 1 dB Compression point represents the **maximum** input signal before we "choke" the receiver (blocking level).
* We my be able to reduce the desensitization by reducing the RF bandwidth of the receiver. (Use narrower filters).
* Or by switching in Attenuation or reducing the RF Gain.

SDR -- Software Defined Radio

* Require an analog-to-digital converter
* Digital values are processed in a DSP (Digital signal Processor)
* This minimizes the traditional analog radio circuitry

Dynamic Range of a SDR Radio

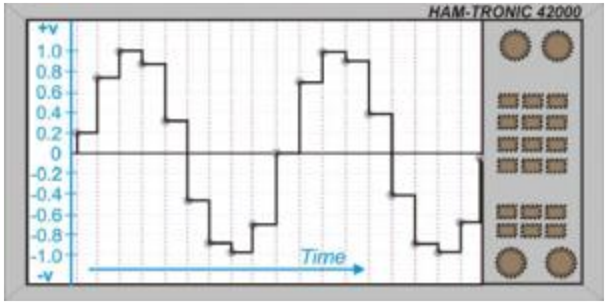
Pg. 8-23

Strong-signal performance

* Sample Width – the number of bits in each sample of the input signal to the DSP.
* If the input signal exceeds the analog-to-digital converter's maximum count. The DSP chokes!

Source of distortion

* Missing Code -- the analog to digital converter can not generate a particular value. Manufacturing defect inside the DSP.



Receiver Intermodulation (IMD)

Pg. 7-21 to 23

- 3rd order IMD products can be created within a receiver.
- Two very strong in-band undesired signals can cause IMD products that are also in band. These are particularly problematic. E4D11
- Pg 7-21 thru 7-23 give you the math that explains it.

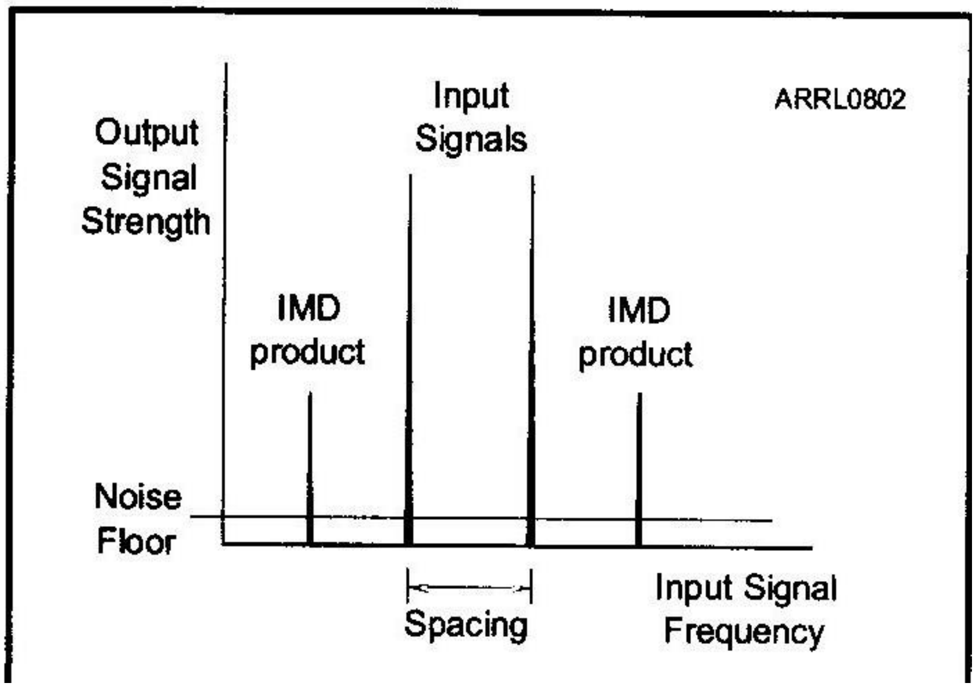


Fig 7-21

Intermodulation (IMD)

Pg. 7-22 & 23

* Take the difference between your frequency and the known interfering frequency:
* 146.70 – 146.52 = **0.18 MHz**

* Take the difference and subtract it from the known interfering signal:
* 146.52 – 0.18 = <u>**146.34 MHz**</u>

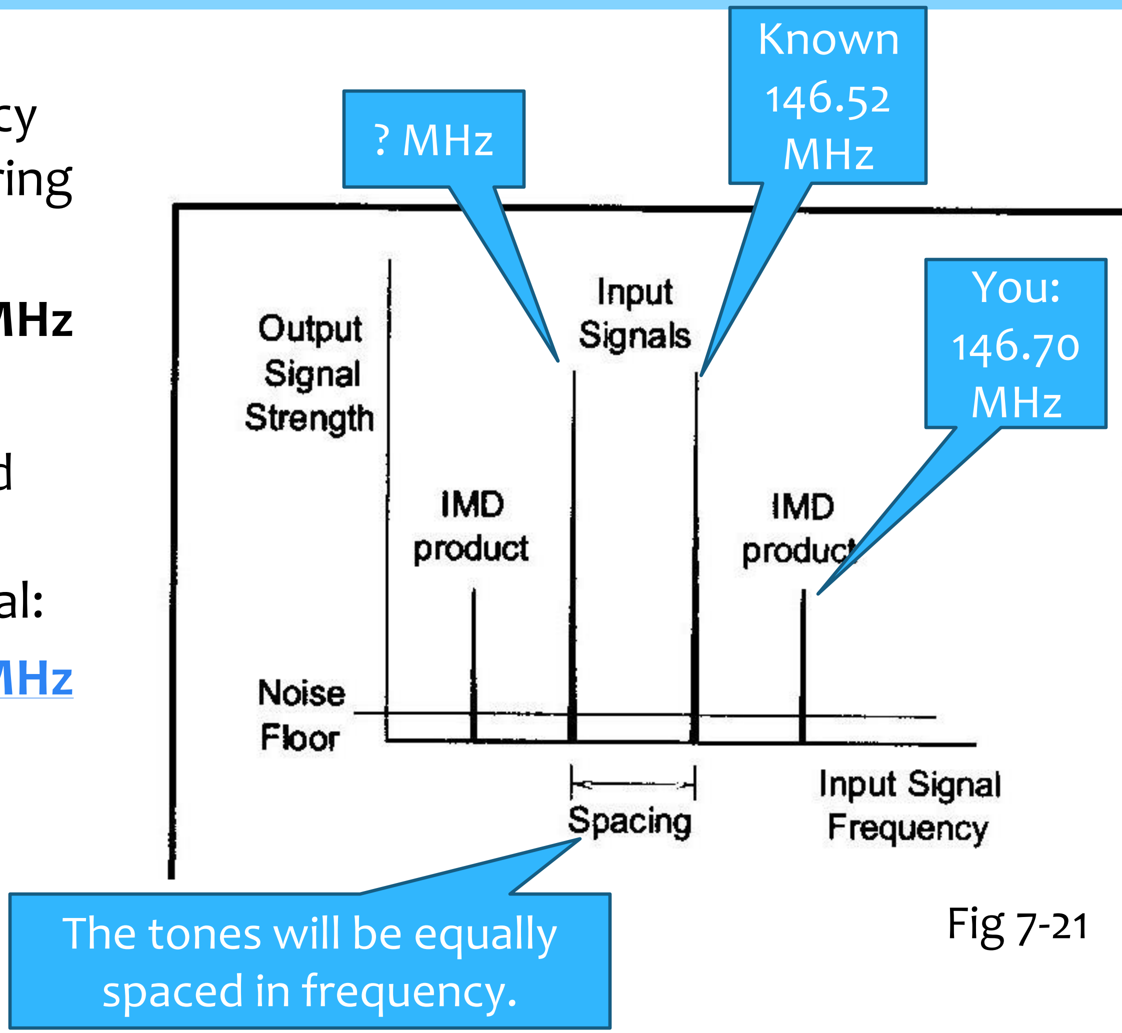


Fig 7-21

Intermodulation (IMD)

Pg. 7-21 & 24

Let's take a look at the levels:

* If both strong signals increases 1 dB
* The "3rd order products" will increase 3 dB.

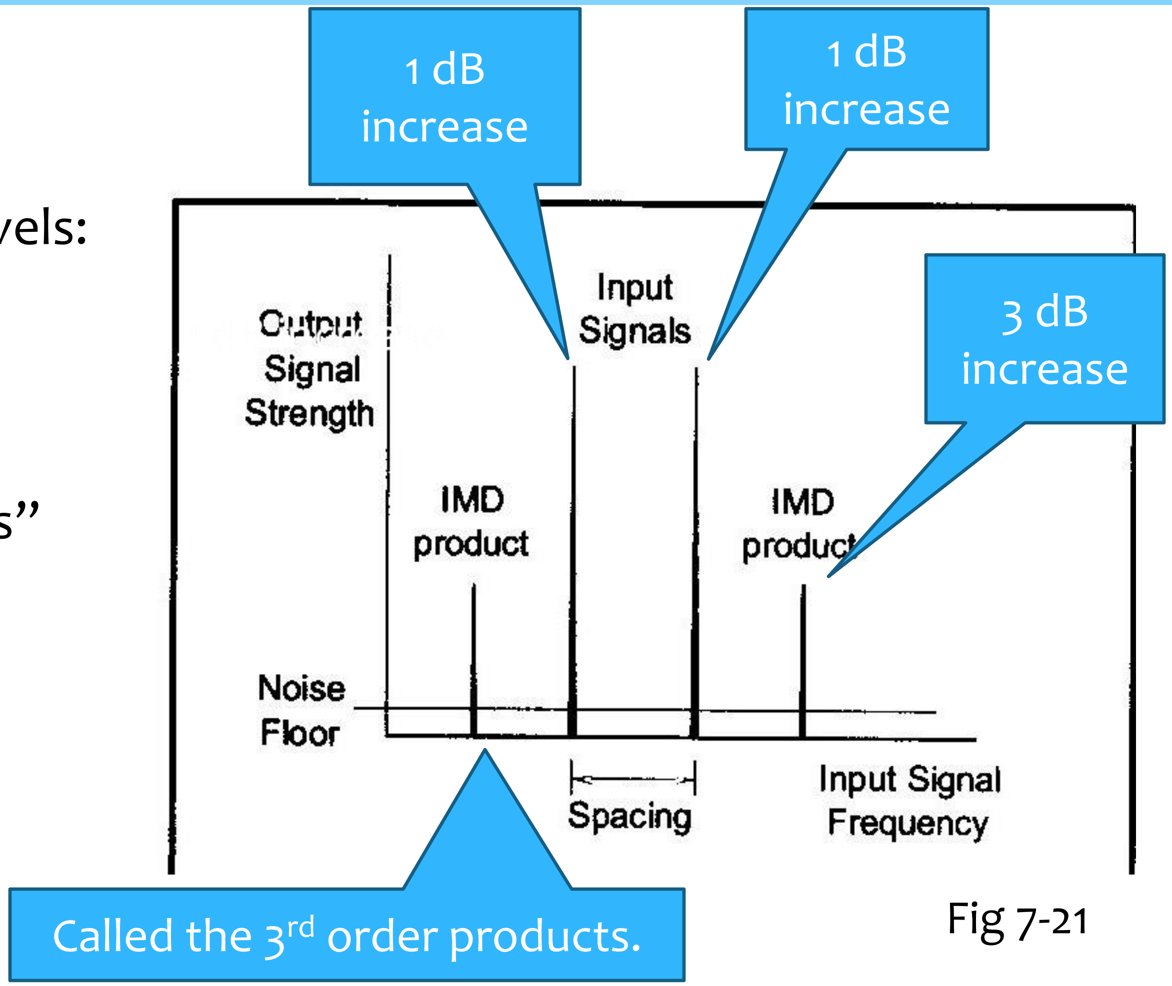
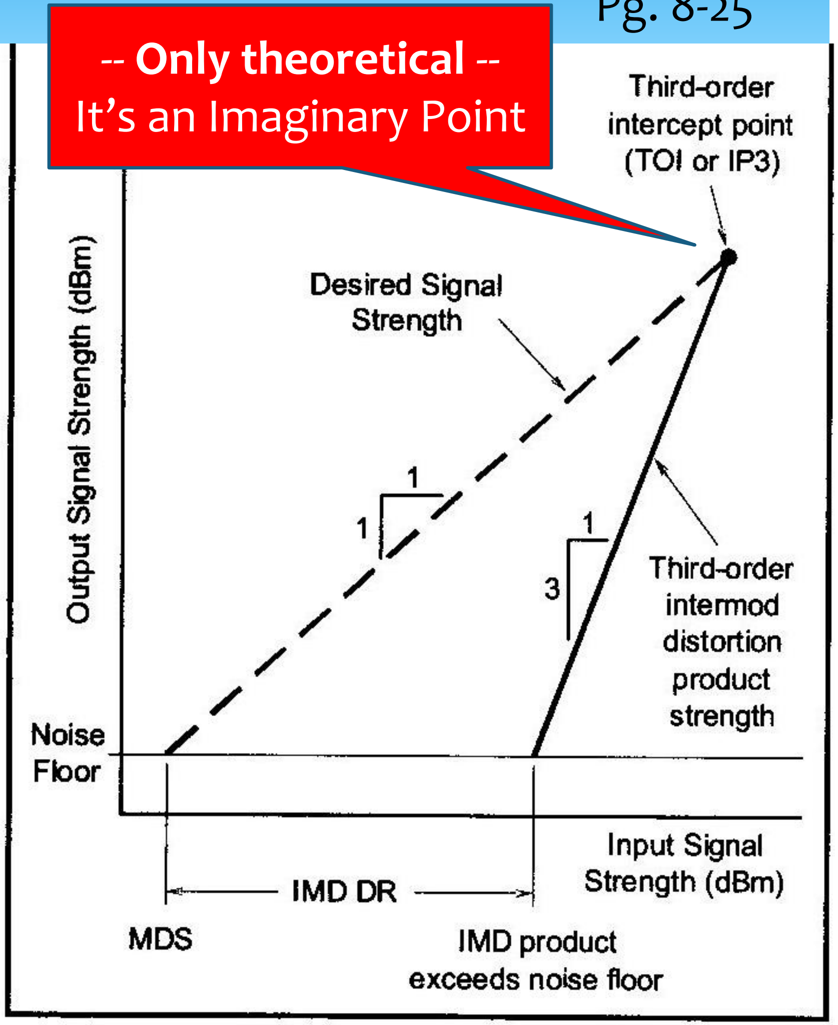


Fig 7-21

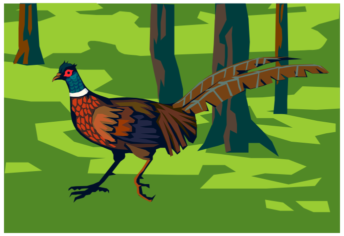
3rd Order Intercept Point

Pg. 8-25

* The level of an input signal at which the level of the 3rd order distortion products are *theoretically equal* the level of the input signals is the receivers **intercept point.**



Shooting at an Imaginary Point



www.hunter-ed.com

Third Order Intermodulation Distortion

Pg. 8-25

* A 40 dBm third order intercept point means that a pair of 40 dBm input signals would produce IMD products of a 40 dBm level.
* The higher the 3rd order intercept point, the better.

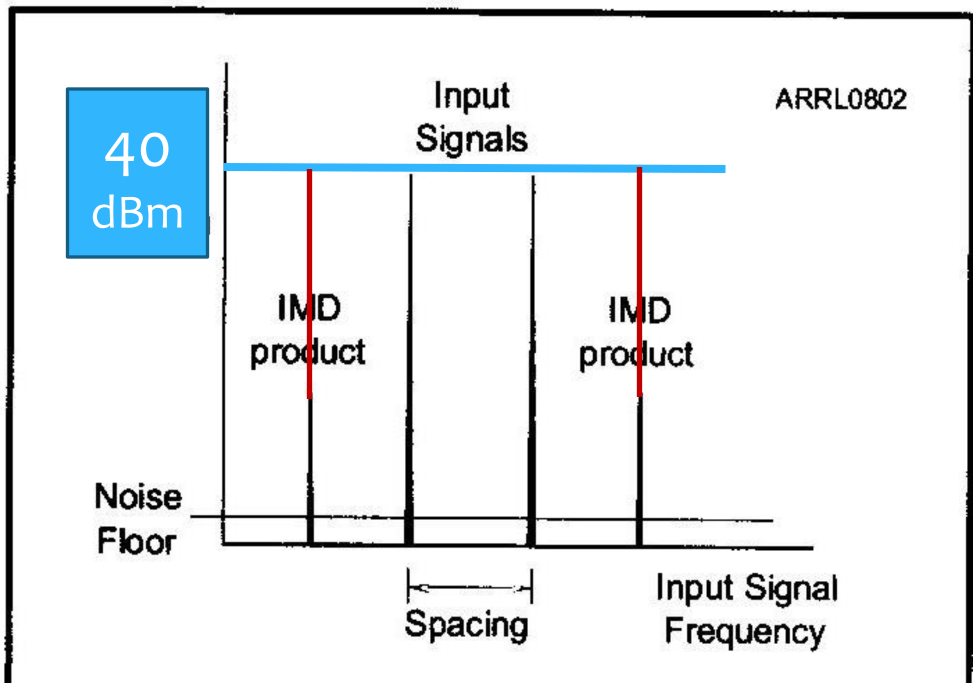


Fig 7-21

Example of a Rx IMD Spec

* Yaesu FT DX 5000MP example -- $5000
* Better IP3 is shown with a greater separation between the signals.
* Many radio do not specify the IP3 in advertising

SUPERB 3rd-Order Dynamic Range & 3rd-Order Intercept Point (IP3)

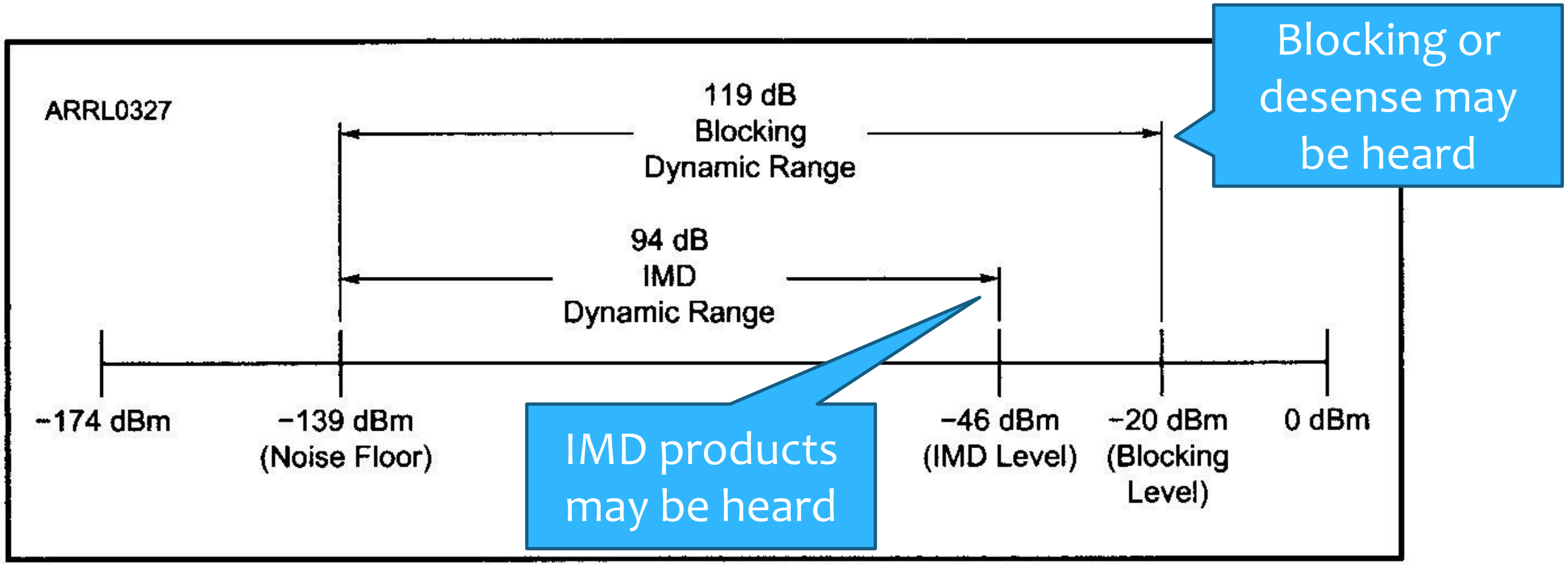
SSB (2.4kHz BW)
10 kHz SEP.:106 dB, IP3 +40 dBm

CW (500Hz BW)
10 kHz SEP:112 dB, IP3 +40 dBm
2 kHz SEP. :105 dB, IP3 +36 dBm
1 kHz SEP. : 99 dB, IP3 +25 dBm

Dynamic Range

Pg. 7-24

* If a receiver has poor dynamic range, cross modulation or IMD products will be generated and desensitization from strong signals can occur.



Phase Noise

PG 7-25

* Phase noise is generated by circuitry internal to the receiver. (Digital VFO)
* It can cause strong signals on nearby frequencies to interfere with the reception of weak signals.

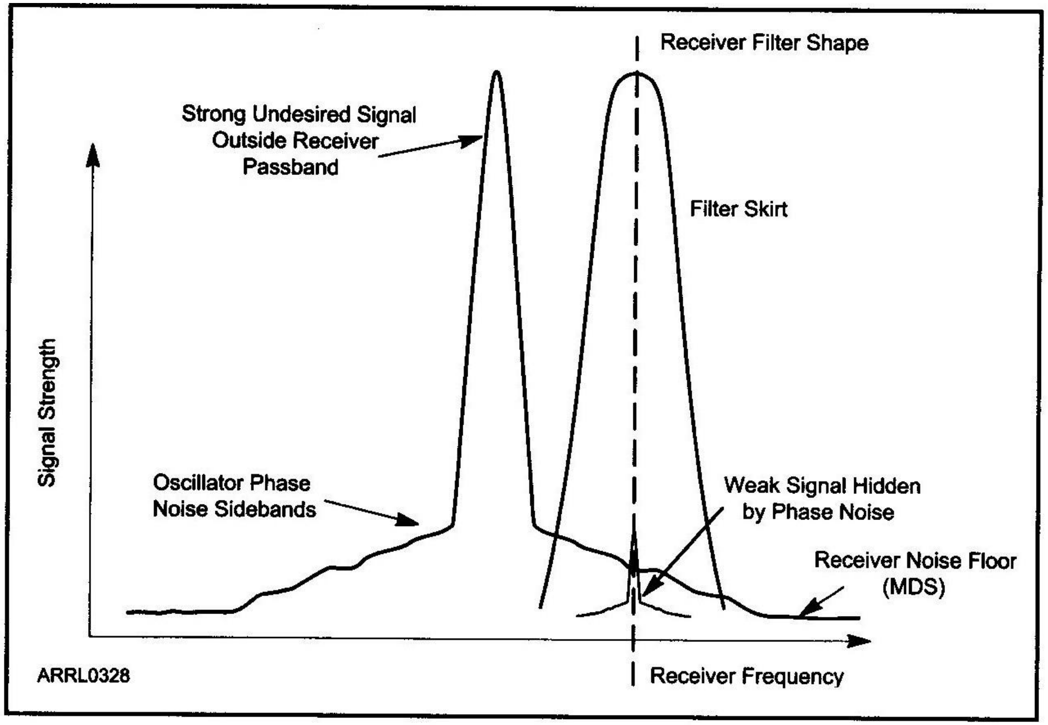


Figure 7-23 In a receiver with excessive phase noise, a strong signal near the receiver passband can raise the apparent receiver noise floor in the passband. This increased noise can cover a weak signal that you are trying to receive.

FM Capture Effect

Pg 7-25

* *FM voice receivers exhibit a characteristic known as* ***capture effect where a strong signal blocks the reception of all weaker signals***.

* The strongest signal received will be the only signal heard, even if it is only a few dB stronger.

Some Strong-Signal Terms

* **Intermod** (IMD) will occur only with certain frequency combinations.
* **Desense** can occur with any strong signal and makes the desired signal weaker.
* **Crossmod** can occur with any strong signal and when the undesired signal's modulation is imposed on to of the desired signal.

E4C04 How is the noise figure of a receiver defined?

A. The ratio of atmospheric noise to phase noise
B. The ratio of the noise bandwidth in Hertz to the theoretical bandwidth of a resistive network
C. The ratio of thermal noise to atmospheric noise
D. The ratio in dB of the noise generated by the receiver to the theoretical minimum noise

E4C03 What is the term for the blocking of one FM phone signal by another, stronger FM phone signal?

A. Desensitization
B. Cross-modulation interference
C. Capture effect
D. Frequency discrimination

E4D14 Which of the following is a way to reduce the likelihood of receiver desensitization?

A. Decrease the RF bandwidth of the receiver
B. Raise the receiver IF frequency
C. Increase the receiver front end gain
D. Switch from fast AGC to slow AGC

E7E08 What are the principal frequencies that appear at the output of a mixer circuit?

A. Two and four times the original frequency
B. The sum, difference and square root of the input frequencies
C. The two input frequencies along with their sum and difference frequencies
D. 1.141 and 0.707 times the input frequency

E4C01 What is the effect of excessive phase noise in the local oscillator section of a receiver?

A. It limits the receiver ability to receive strong signals
B. It reduces the receiver sensitivity
C. It decreases the receiver third-order intermodulation distortion dynamic range
D. It can cause strong signals on nearby frequencies to interfere with reception of weak signals

Interference and Noise

Section 7-4

Intermodulation from Transmitters

Interfering with a Receiver

Pg. 7-26

* A specific frequency relationship must exist

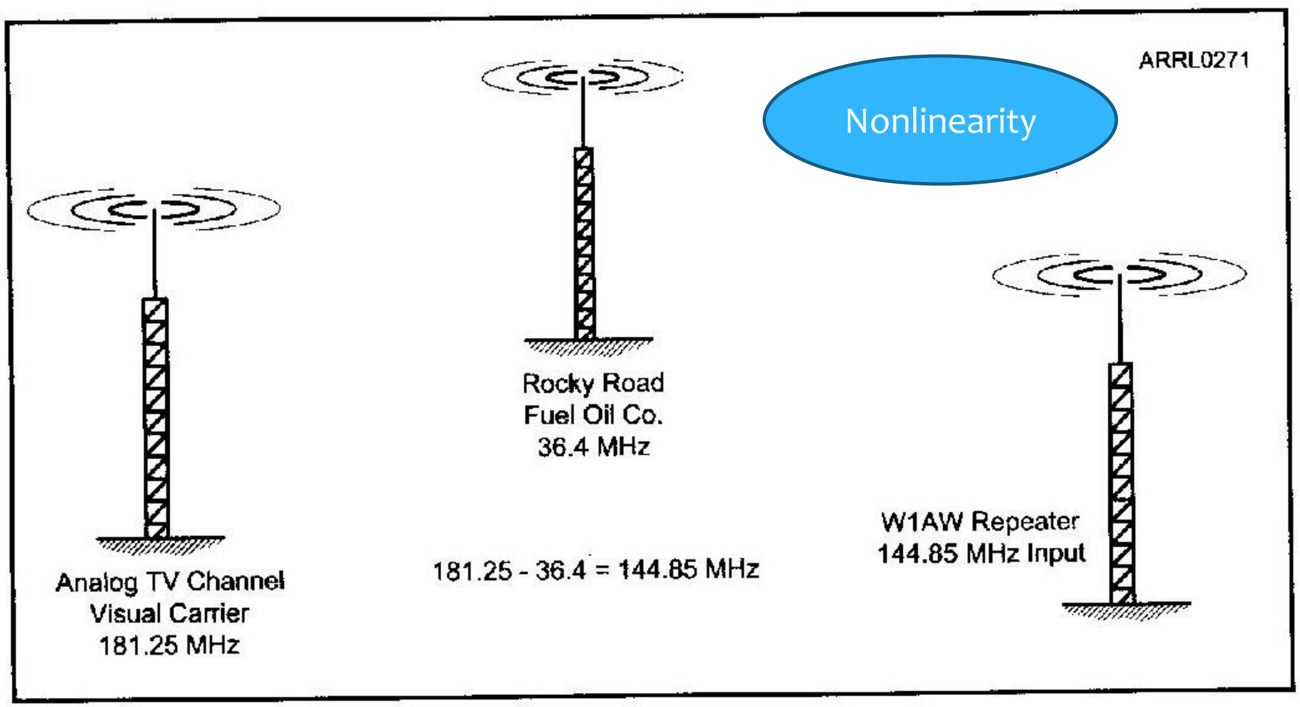


Fig 7-24

Correction in the second paragraph under Transmitter Intermodulation

Pg. 7-26

Nonlinear circuits or devices can cause intermodulation distortion in just about any electronic circuit. IMD (also ~~called *cross-modulation*~~) often occurs when signals from several transmitters, each operating on a different frequency, are mixed in a nonlinear manner, either by an active electronics device or a passive conductor that happens to have nonlinear characteristics. [E4D08] The mixing, just like in a mixer circuit, produces UNWANTED mixing products that may cause severe interference in a nearby receiver. Harmonics can also be generated and those frequencies will add to the possible mixing combinations. The *intermod*, as it is called, is radiated and received just like the transmitted signal. [E4D06] It is a clue that an interfering signal is ~~intermod~~ because the modulation from the off-frequency signal is combined with that of the desired signal in the interfering product signal. [E4D07]

crossmod?

Intermodulation Distortion - IMD

Pg. 7-26

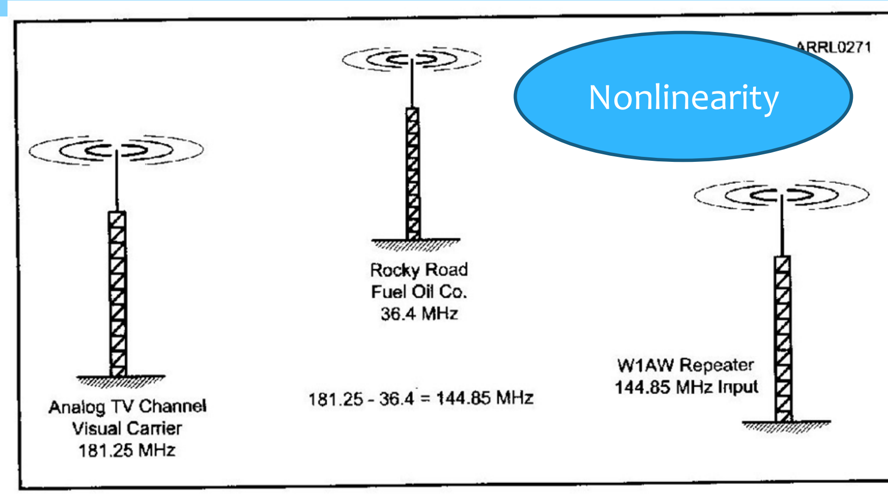


Fig 7-24

If we have:

* A specific frequency relationship
* And we have a nonlinearity

We can get

* A mixing of two or more signals that produce unwanted mixing products
* These mixing products interfere with reception, because the receiver hears it as if it is a valid signal.

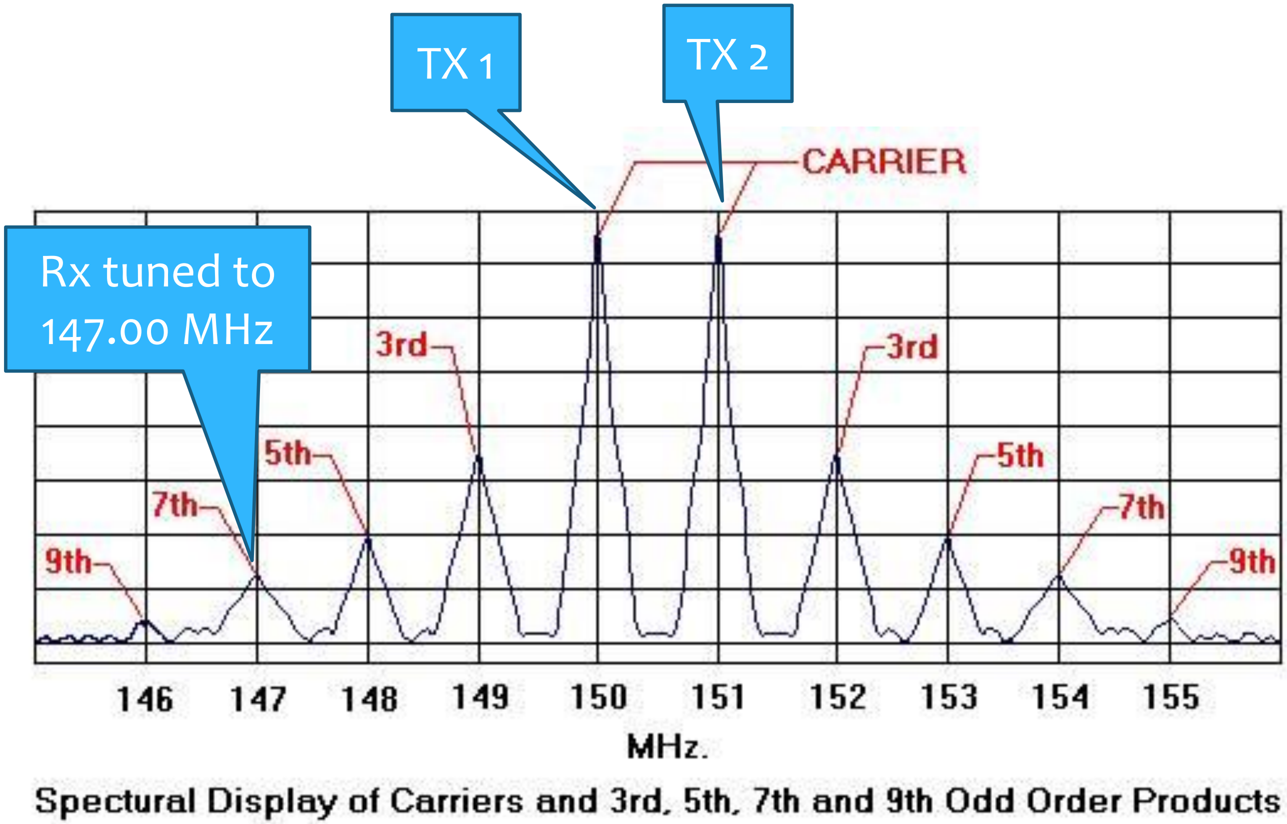
Nonlinearities Cause IMD Products

A mixing action occurs in nonlinear devices

Pg. 7-28

Nonlinearities can occur in:

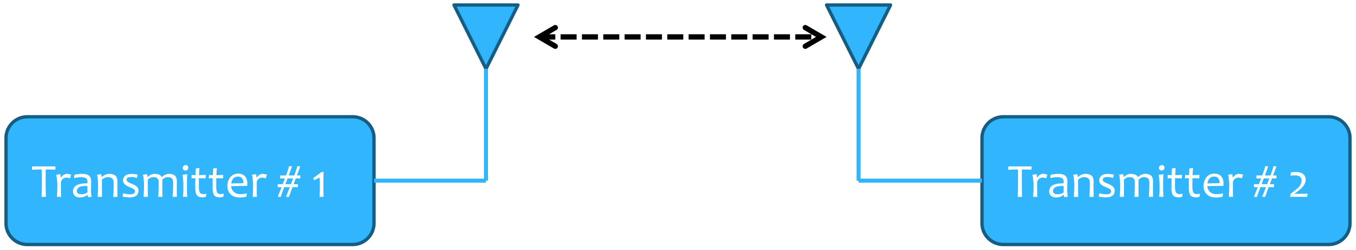
- Receivers
- Transmitters
- Other electronic devices
- Passive connections



www.midians.com/html/intermod-explained.php

Repeater Sites With Multiple Repeaters are at Risk of IMD Pg. 7-26

* IMD can be produced when two transmitted signals mix in the final amplifier of one or both of the transmitters.



Circulators and Isolators

Pg. 7-27

* **Circulators and isolators** can effectively **reduce intermod problems**

Circulators permit the RF signal to flow through them in only one direction.

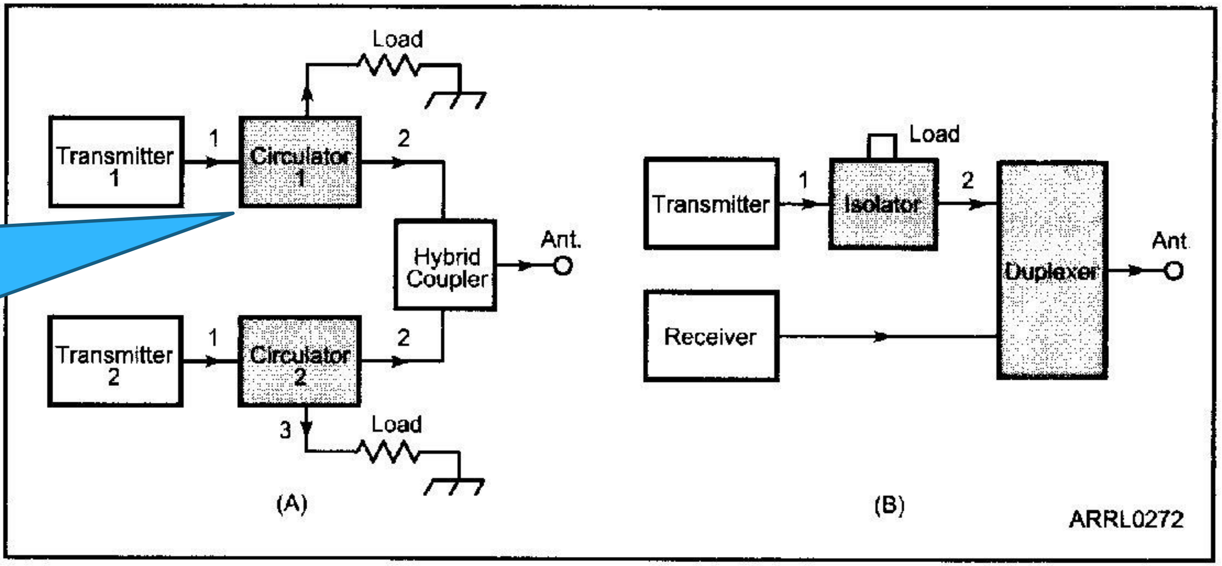


Figure 7-25 — This block diagram shows the use of circulators and an isolator. Circulators may be used to share one antenna with two transmitters, as in A, particularly at multi-transmitter sites. Duplexers are also used along with the circulators. In B, an isolator is placed between the transmitter and duplexer to reduce intermodulation.

Nonlinear Connections

Pg. 7-27

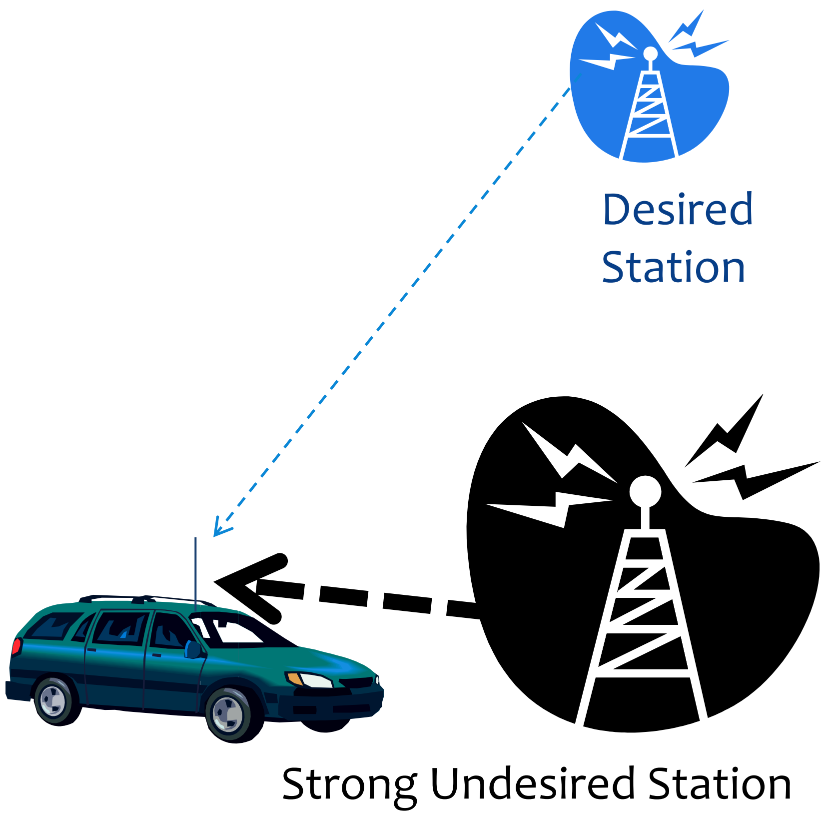
* Corroded metal joint are very nonlinear.
* If two strong AM broadcast stations are nearby, the signals can mix at the joint and generate IMD products across a wide range of frequencies.

Nonlinear connection

Cross Modulation

Pg. 7-27

- Unlike IMD, **Crossmod does not require** a specific frequency relationship
- A strong undesired transmitter simply overwhelms the receiver's front end.
- The modulation of the strong undesired signal is combined with that of the desired signal.
- The off-frequency unwanted signal is heard in addition to the desired signal. E4D07



Atmospheric Static Noise

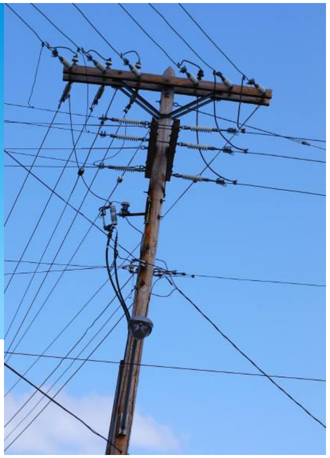
Pg. 7-28

* The most common form of static noise is caused by the buildup and discharge of static electricity in the atmosphere, mostly during thunderstorms
* Tends to be worse on 160, 80 and 40 meters
* We can also hear snow static or rain static

K0GY

AC Line Noise

Pg. 7-28



- An electrical arc generates varying amounts of energy across the radio spectrum.

- Common Arcing Sources:
  - Power line connections or insulators
  - Thermostatically controlled devices
  - Blinking adverting displays
  - Doorbells and doorbell transformers

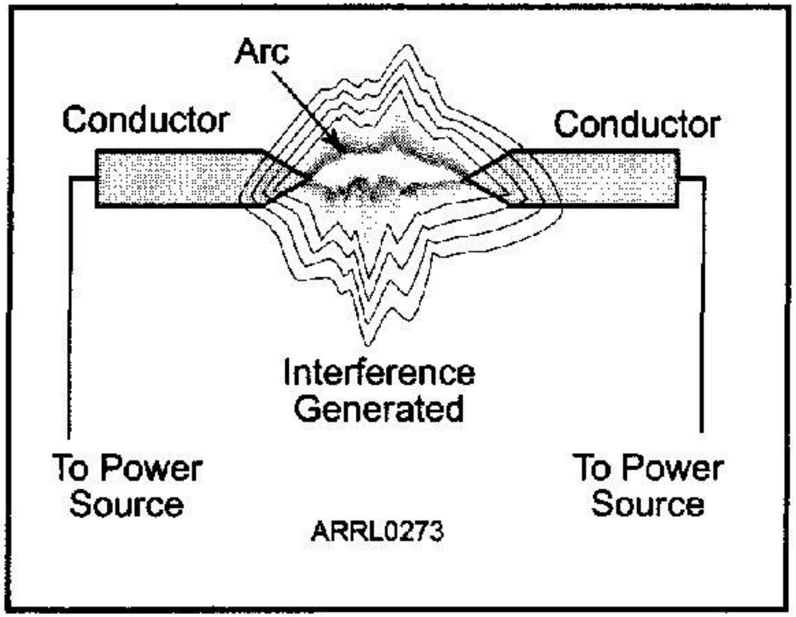


Figure 7-26 — An electrical arc can form through the air gap between conductors. Arcs radiate noise across a wide RF spectrum.

Brute Force

Pg. 7-30

- A “**brute force**” AC line filter can reduce electrical noise produced by an electric motor.
- Install the filter in series with the power leads of the motor.

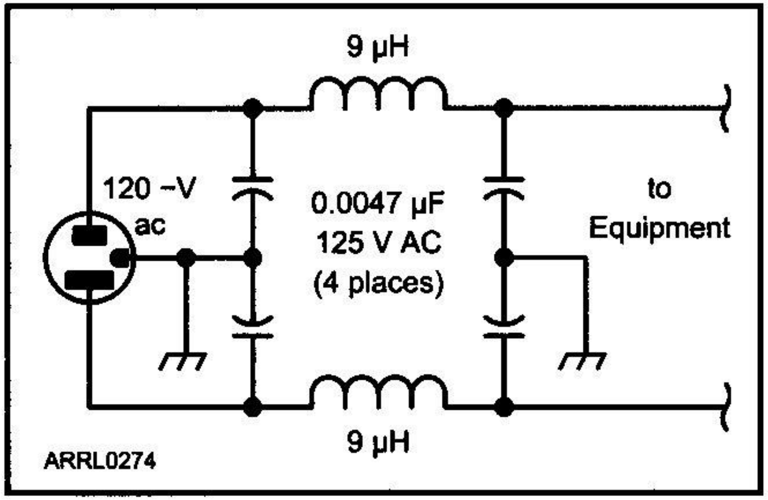
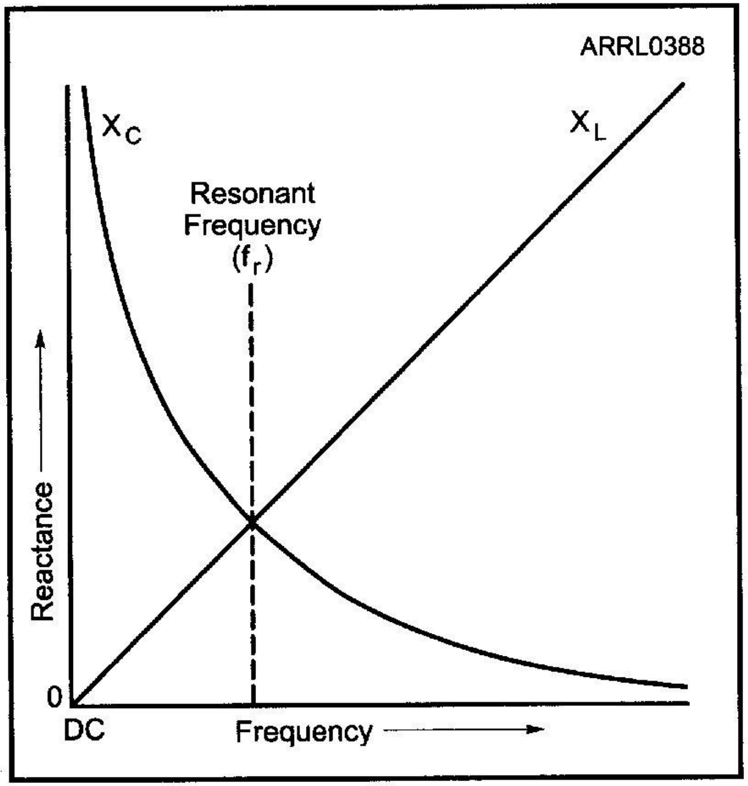


Figure 7-27 — A “brute force” ac line filter may reduce or eliminate line noise when installed in the power leads to an ac brush-type motor.

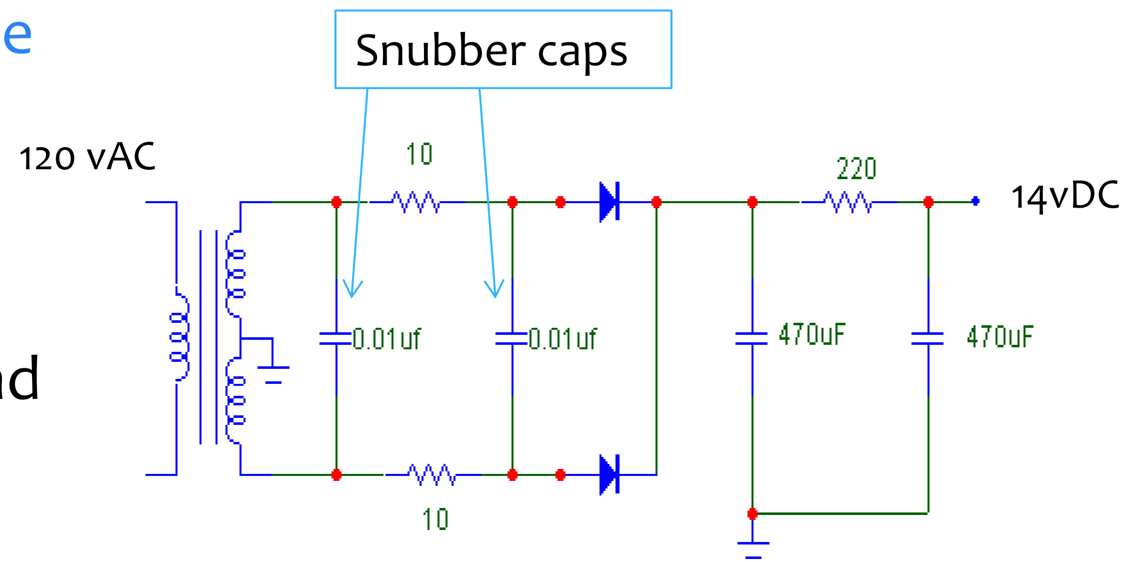
Remember Fig. 4-24 ?

- Capacitive reactance decreases at higher frequencies.
- Inductive reactance increases at higher frequencies.
- At 14 MHz:
  - 0.0047 uf Xc = 2.4Ω
  - 9 uH X_L = 791Ω



Snubber Capacitor

* A snubber capacitor across a low-voltage secondary of a transformer help absorb transient voltage spikes or noise energy instead of allowing it to travel through the power supply.



http://diyparadise.com

Noise Hunting

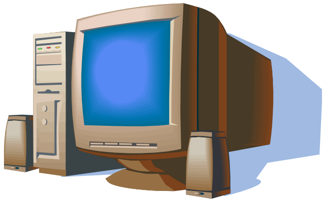
Pg. 7-39 & 30

Track it Down

* Open the main breaker to your house, while listening for the noise on a battery powered radio.
* If it goes away– it is likely in your house.
* Selectively turn off individual circuit breakers or electrical appliances to isolate the source.
* If the noise source is outside your house, try hunt it down with a portable receiver.

Noise, Noise and More Noise

Pg. 7-30



* **Interference can be generated by computers and switching power supplies.**
* This noise is usually **unstable modulated (buzz) or unmodulated signals at multiple specific frequencies** spaced at regular intervals over a wide spectrum.
* **"Touch controlled" devices** (such a lamps) can generate noise that:
  - **Sounds like AC hum**
  - **Drifts in Frequency**
  - **May be several kHz wide.**

Your Transmitter May Cause Interference to Other Electronics

Pg. 7-31

- Your transmitted signal can cause **common mode** interference to devices such as TV, radio or telephone.
- The AC and telephone **wiring near the antenna may pick up your signals and conduct it to the devices.**
- **Even shielded cables can receive or radiate interference.**

Automotive Noise

Pg. 7-31

Ignition Noise

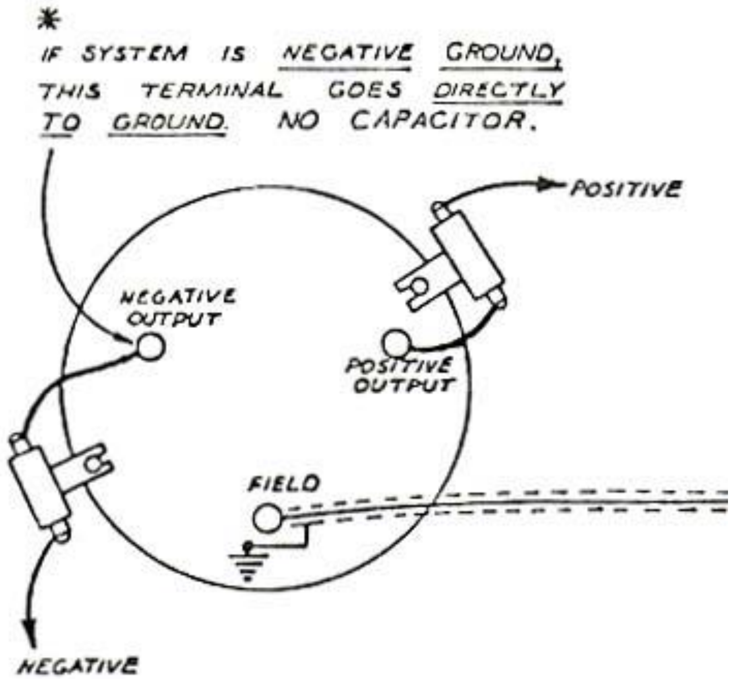
* Radiated from the ignition wires into your antenna
* Attempts to reduce the interfere can adversely affect engine performance.
* Ferrite beads and cores are one means of suppressing the noise.
* The coil-on-plug technology does not solve the ignition noise problem.

Automotive Noise

Pg. 7-32

Charging System Noise

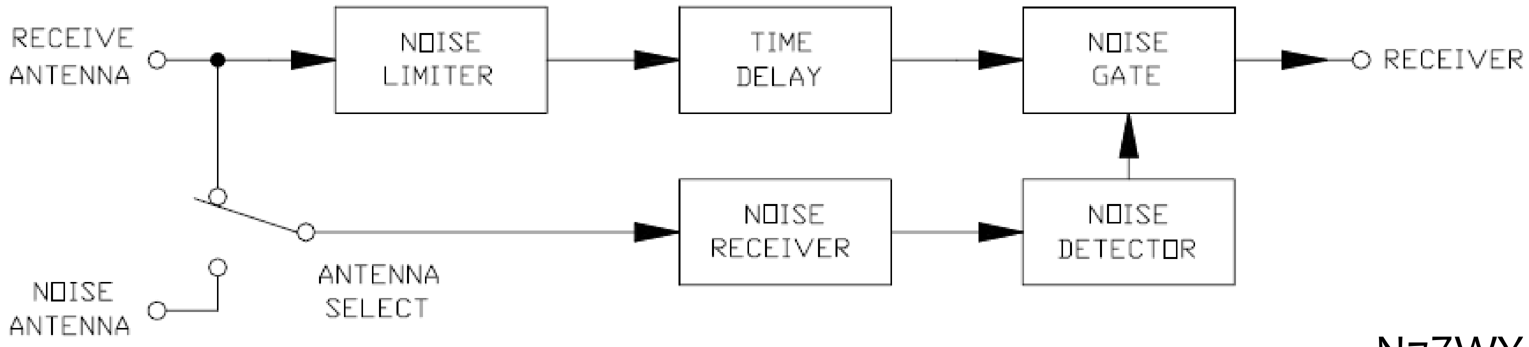
* Alternator whine is a common form of conducted interference and can affect both transmitting and receiving.
* Standard fixes:
  * **Connect both positive and negative power leads of the radio directly to the battery.** Fuse each lead.
  * **Install coaxial capacitors in series with the alternator.**



Noise Blankers

Pg. 7-32

* Noise blanking works by detecting noise pulses and muting the receiver when they are present.
* This technique, called gating, **is particularly effective on impulse noise such as ignition noise** or line noise.

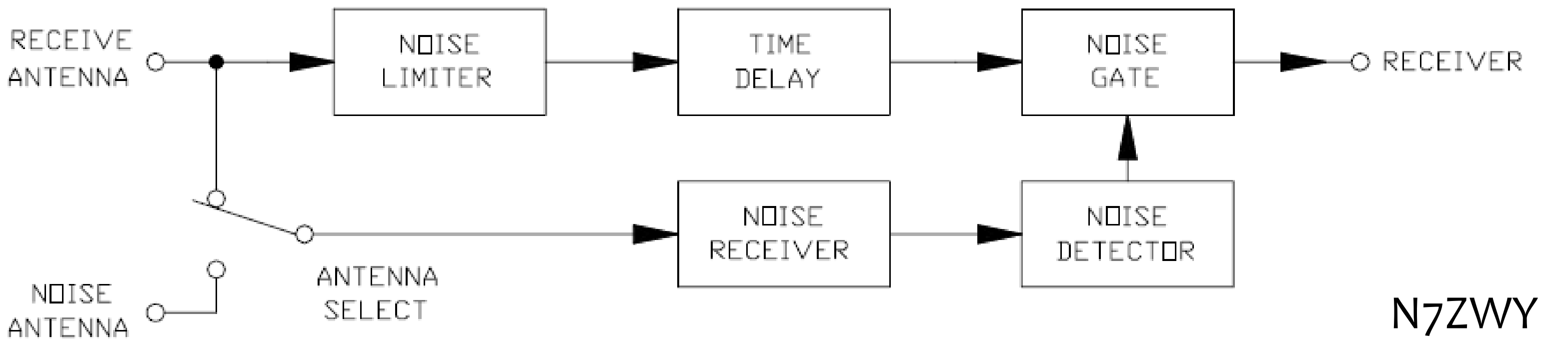


N7ZWY

Noise Blankers

Pg. 7- 32 & 33

- **The noise blanker must detect signals that appear across a wide bandwidth.**
- A noise blanker can be fooled by strong signal, shutting down the receiver as is they were noise pulses. **A nearby strong signals may appear to be excessively wide (splattering) when it is indeed clean!**



N7ZWY

DSP Noise Reduction

Pg. 7-33

* DSP noise reduction filters operate by using adaptive filter techniques in the software
* **While DSP noise reduction is most effective on "white noise" it may also work for ignition noise and power line noise.**

* **Automatic notch filters** can track and remove interfering tones.
* However **they can mistake a CW** or low-rate data signal for **noise and attempt to remove the desired signal** as well.

E4E13 What might be the cause of a loud roaring or buzzing AC line type of interference that comes and goes at intervals?

A. Arcing contacts in a thermostatically controlled device
B. A defective doorbell or doorbell transformer inside a nearby residence
C. A malfunctioning illuminated advertising display
D. All of these choices are correct

E4E14 What is one type of electrical interference that might be caused by the operation of a nearby personal computer?

A. A loud AC hum in the audio output of your station receiver

B. A clicking noise at intervals of a few seconds

C. The appearance of unstable modulated or unmodulated signals at specific frequencies

D. A whining type noise that continually pulses off and on

E4E03 Which of the following signals might a receiver noise blanker be able to remove from desired signals?

A. Signals which are constant at all IF levels
B. Signals which appear across a wide bandwidth
C. Signals which appear at one IF but not another
D. D. Signals which have a sharply peaked frequency distribution

E4E12 What is one disadvantage of using some types of automatic DSP notch-filters when attempting to copy CW signals?

A. The DSP filter can remove the desired signal at the same time as it removes interfering signals
B. Any nearby signal passing through the DSP system will overwhelm the desired signal
C. Received CW signals will appear to be modulated at the DSP clock frequency
D. Ringing in the DSP filter will completely remove the spaces between the CW characters

E4E10 What is a common characteristic of interference caused by a touch controlled electrical device?

A. The interfering signal sounds like AC hum on an AM receiver or a carrier modulated by 60 Hz FM on a SSB or CW receiver
B. The interfering signal may drift slowly across the HF spectrum
C. The interfering signal can be several kHz in width and usually repeats at regular intervals across a HF band
D. All of these choices are correct

Next Week – Chapter 8

* **Modulation**
  * FM/PM
  * Multiplexing
* **Digital Protocols**
  * Symbol and Data rates and Bandwidth
  * Digital modes and Spread Spectrum
* **Amateur Television**
  * Fast scan and Slow scan