Chapter 7

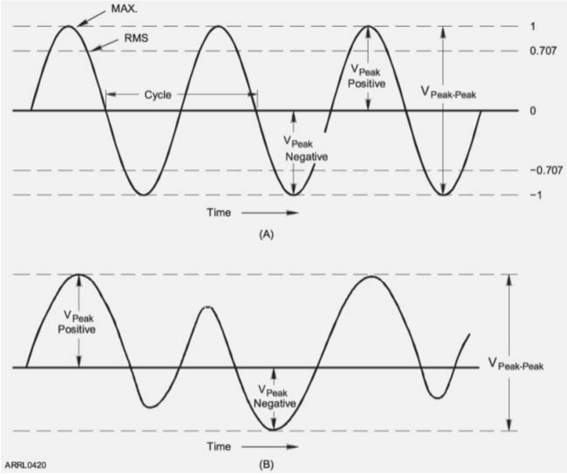
Radio Measurements and Performance

Feb 7, 2026

Jim Andera K0NK

We will Look at:

- 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

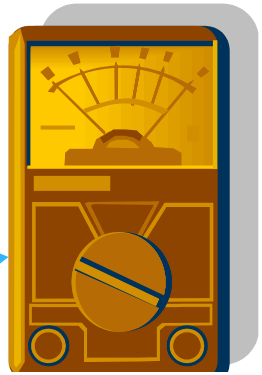
Test Equipment

Section 7-1

Multimeters

Pg. 7-1

Measures: Voltage, Current, Resistance …



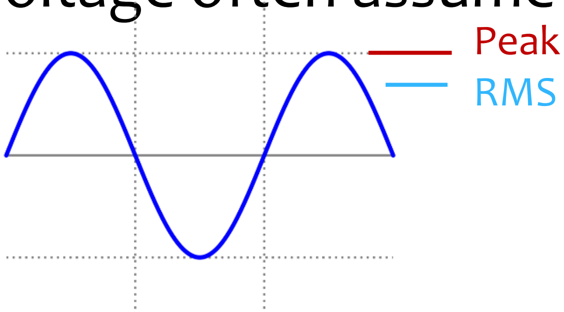
- One specification of an analog multimeter is the **Sensitivity** often specified in ohms-per-volt (Ω / V)
- Another specification of a multimeter is the **input impedance**, expressed in ohms
  - The input impedance can be obtained by multiplying the full-scale reading by the sensitivity
    Impedance = (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.

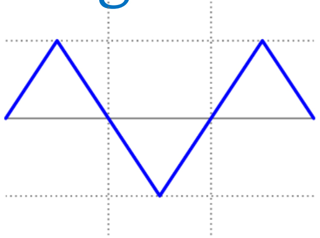
True RMS Meters

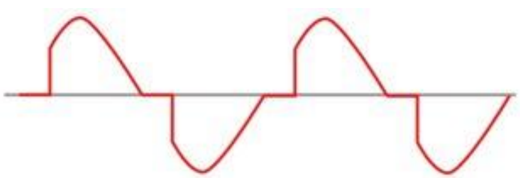
Pg 7-2

* AC voltmeters typically read RMS (root mean square) voltage, i.e.: the heating value compered to DC
* Voltmeters that read out in RMS voltage often assume that the waveform is a sine wave.



  * These meters may not be accurate on other waveforms
* **True RMS Calculating Meters** are the most accurate for measuring the value of any AC waveform





Peak, P2P and RMS

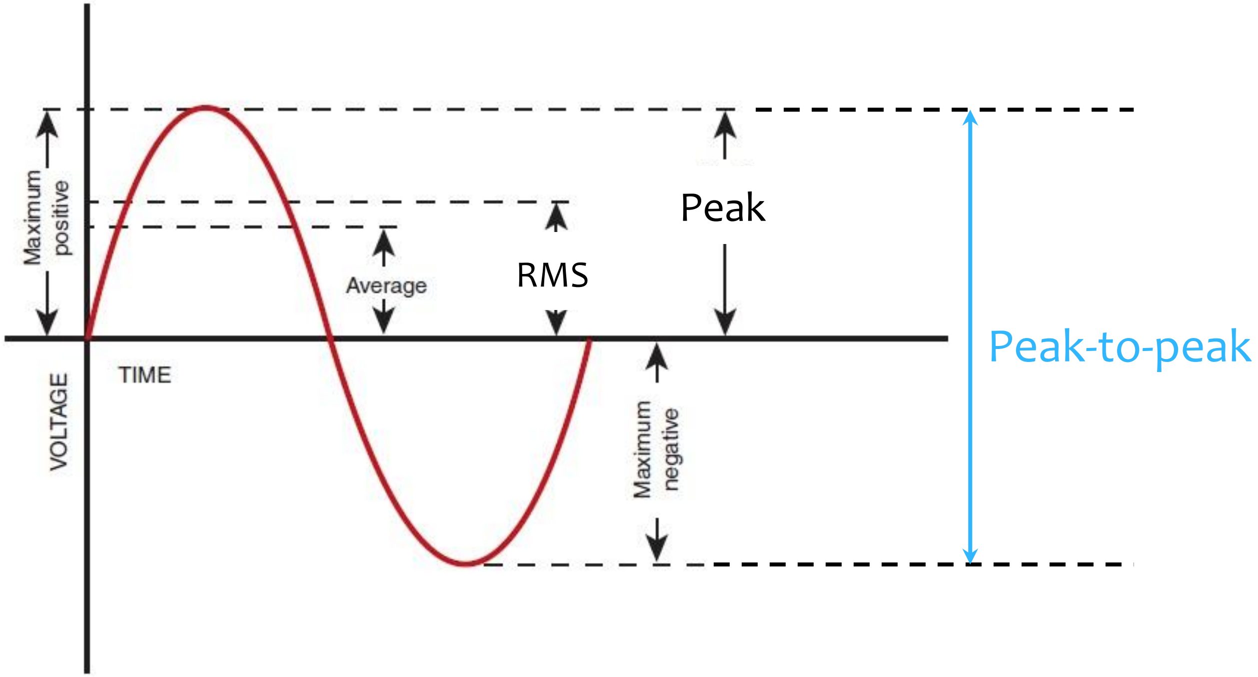
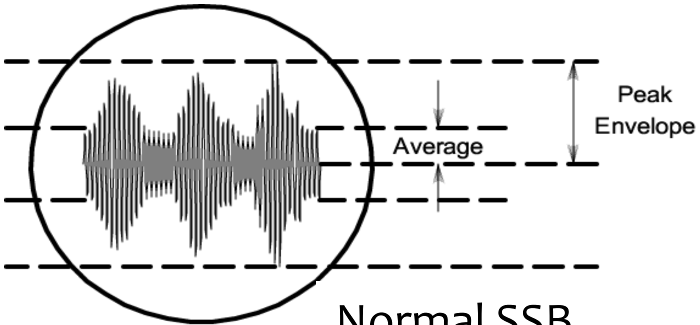


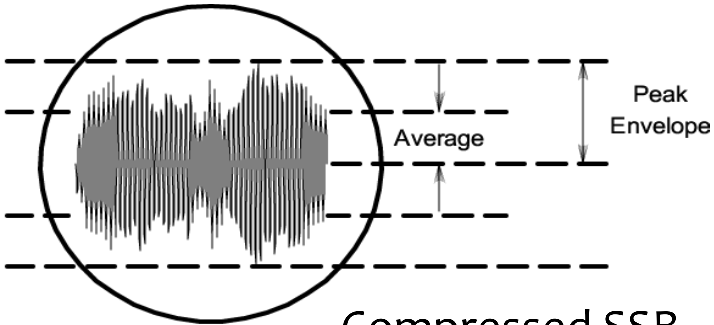
Table 7.1

- Peak-to-peak = 2 x Peak
- RMS = 0.707 x Peak
- Peak = 1.414 x RMS

SSB Peak vs Average Power



Normal SSB

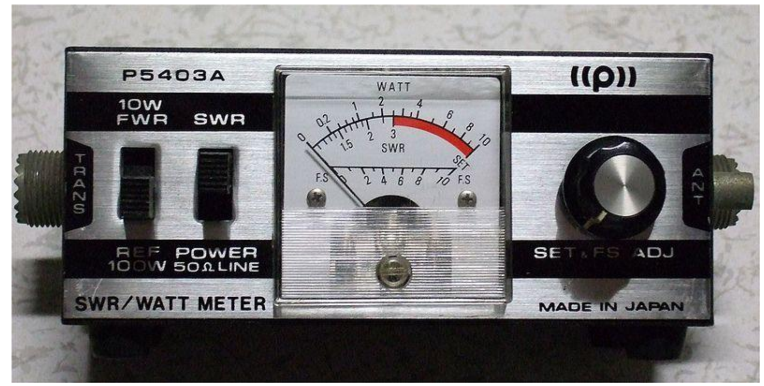


Compressed SSB

* In a normal SSB voice signal, the peak envelope power (PEP) can be 10 times greater than the average power.
* With a compressed SSB voice signal, the PEP may be 2.5 times the average power.
  - The peak-to-average power ratio in a SSB signal **varies greatly with the voice characteristics.**
  - Compressed signals contain more average power and therefore may be more readable by the receiving station.

Wattmeter/SWR Meter

FYI

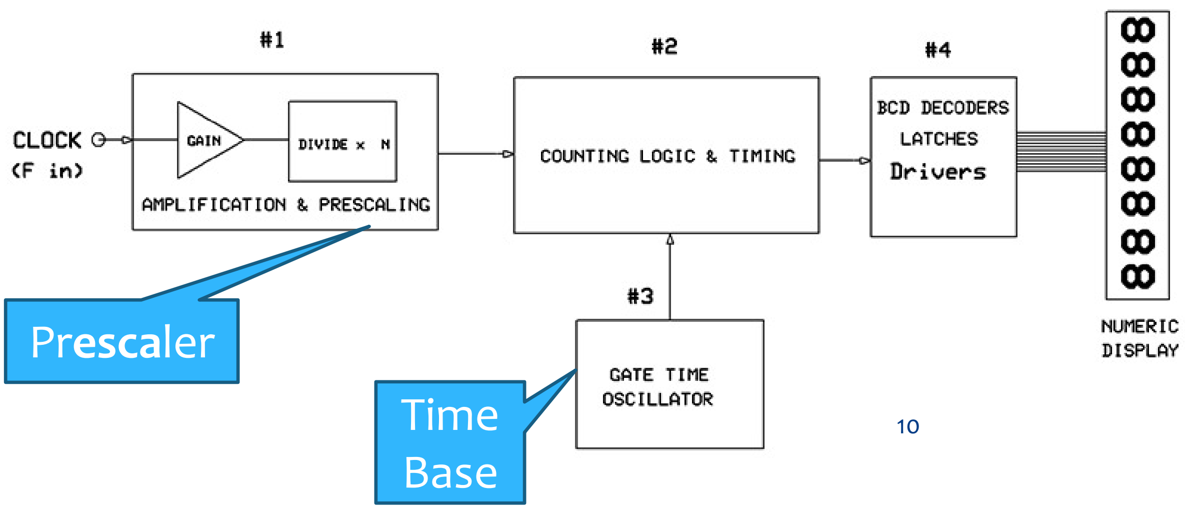


- Most low-cost wattmeter's only read average power.
- More expensive wattmeters may provide for a peak-reading function.

Frequency Counter

Pg. 7-4

- The more accurate the **time base**, the more accurate the readings will be.
- Time base error is specified in PPM (parts per million)
- A prescaler may be used to divide down the input to a lower frequency



Understanding Frequency Counter Error

Pg. 7-4

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

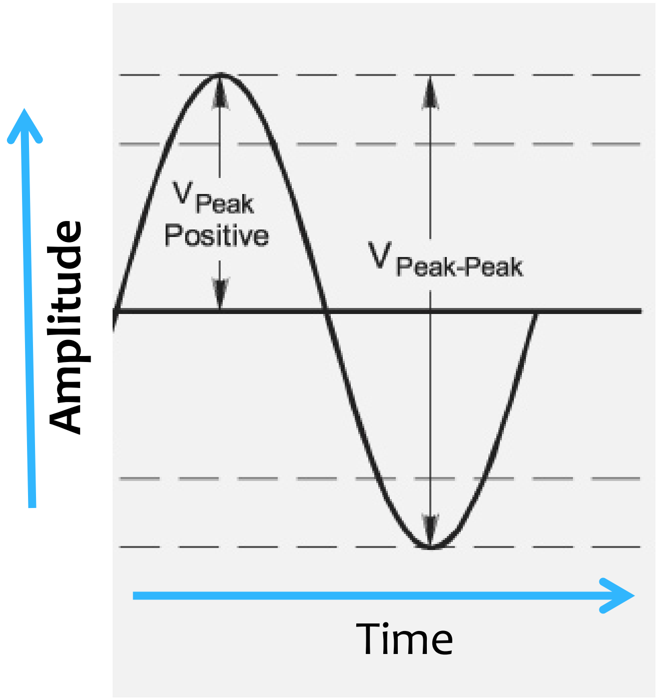
Equation 7.1

* 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

Oscilloscopes

Pg. 7-

* The oscilloscope allows us to evaluate signals in the **time domain**
* All oscilloscopes have a **bandwidth** limit

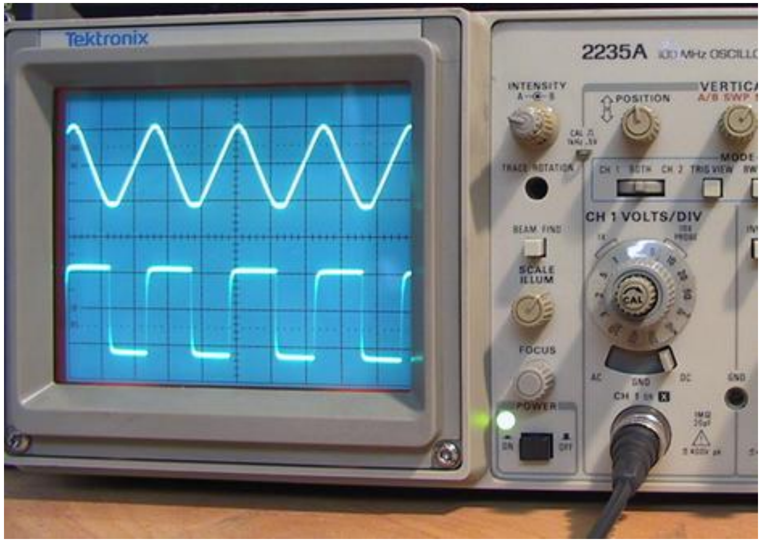


Time domain:
Amplitude at different times

Oscilloscope

Pg. 7-6

* We can also measure the period of an AC signal



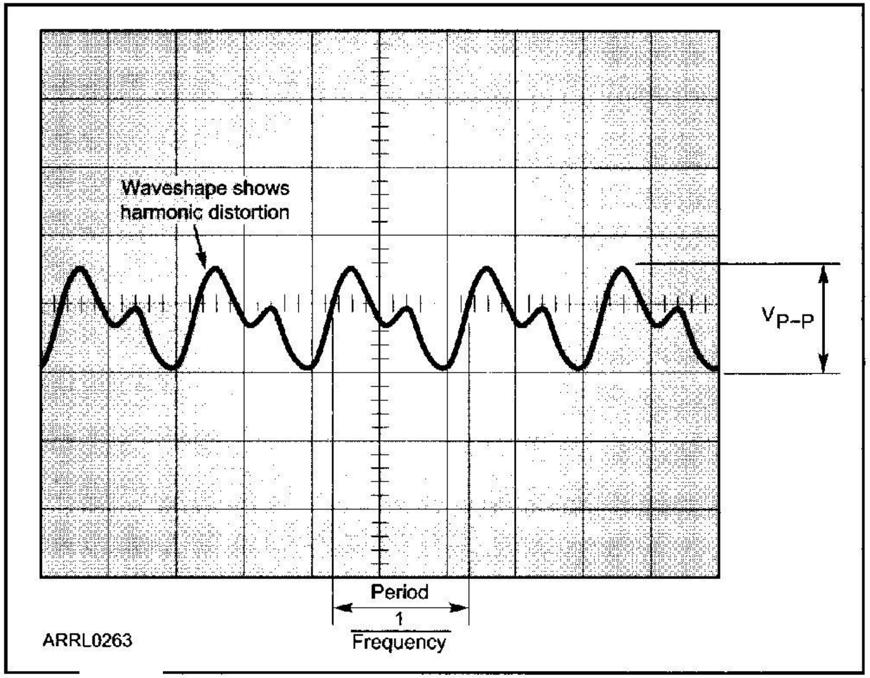
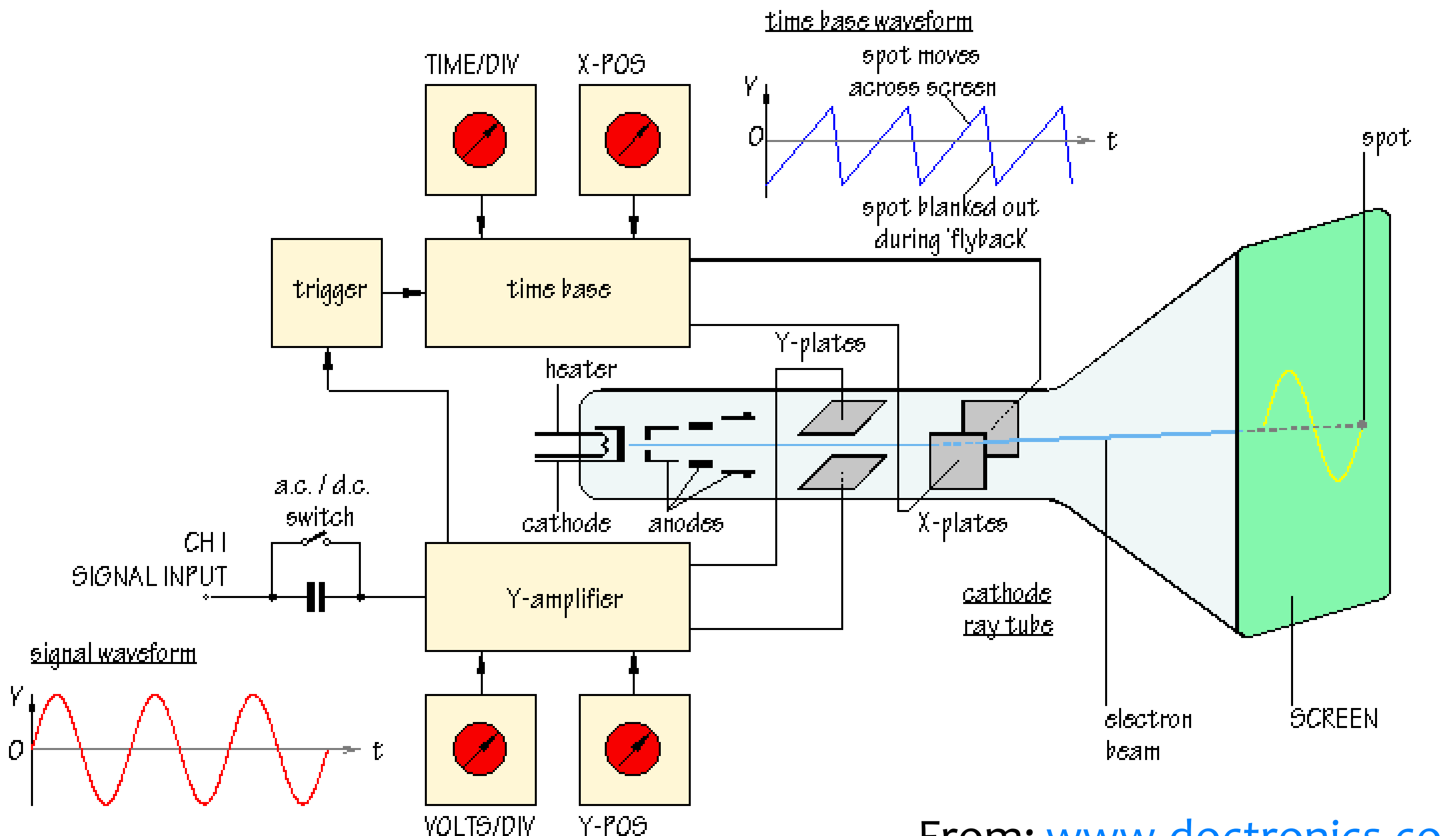


Figure 7-5 - This display shows how the peak-to-peak voltage and period of a complex waveform are measured using an oscilloscope. It can also be seen that the waveform contains enough harmonic energy to cause significant distortion.

Inside the Oscilloscope

FYI

- Simplified analog o'scope



From: www.doctronics.co.uk

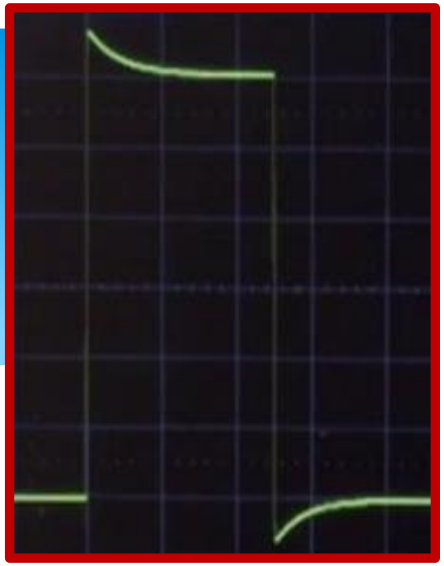
Oscilloscope Probes

Pg. 7-6

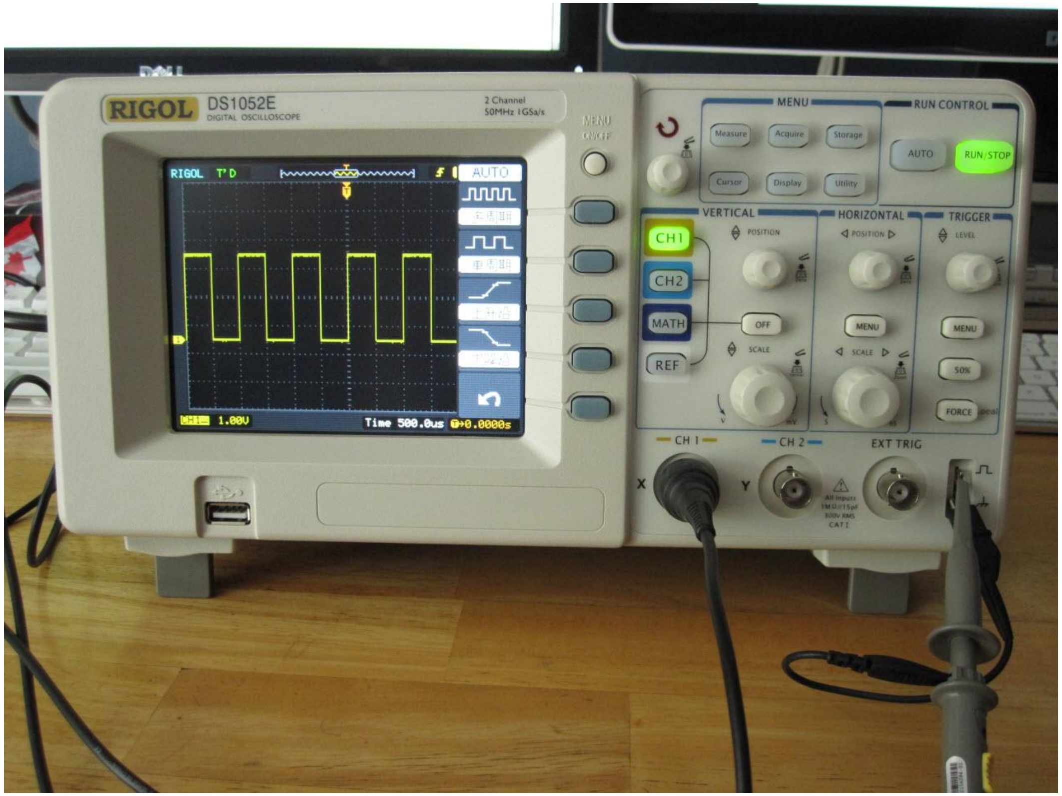
* O'scopes use one or more probes
  * 10:1 divider probe is the most common
* For the most accurate measurements at high frequencies, it is important to **keep the ground connection as short as possible.**

Oscilloscope Probes

Pg. 7-6 & 7



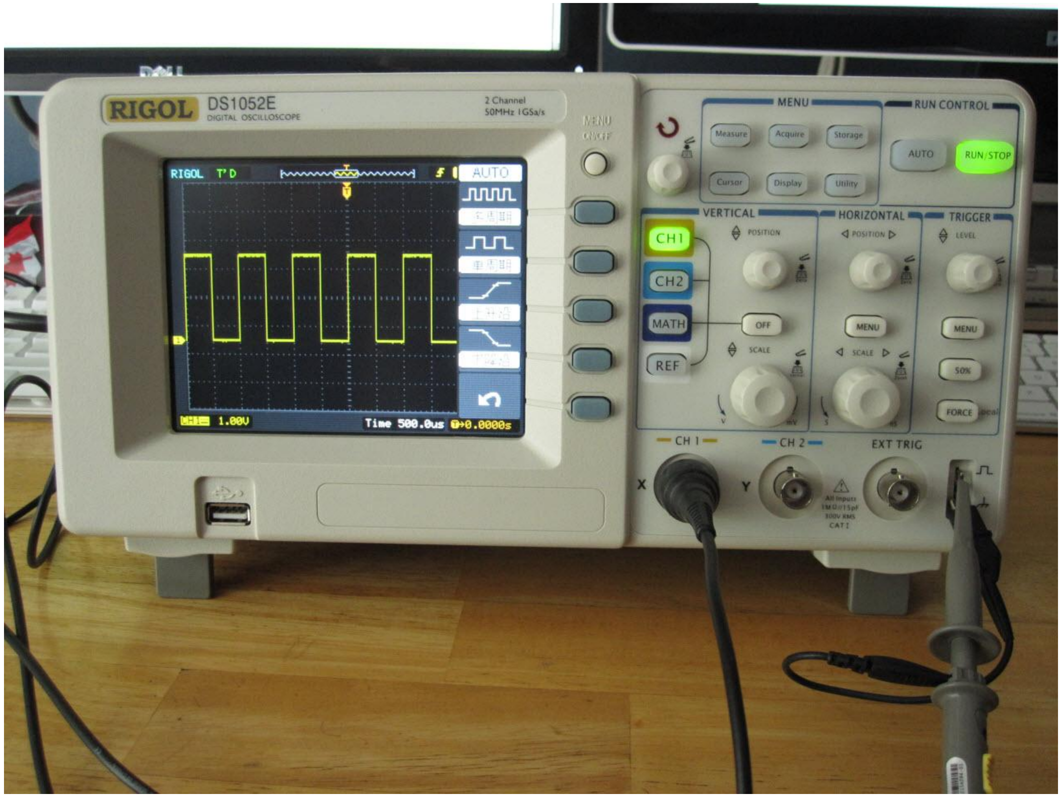
- The probes have to be frequency “compensated”.
- Most scopes provide a square wave calibration signal.
- The probe is connected to this signal and **adjusted until the square wave’s horizontal portions are flat and the corners are sharp.**



Digital Oscilloscopes

Pg. 7-7

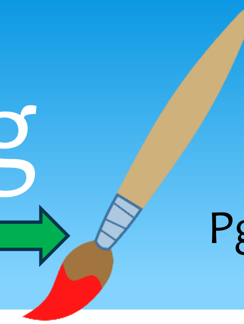
* **Upper Bandwidth is determined by the sampling rate** or analog to digital converter.
* Highest frequency that can be digitized is ½ the sampling rate or there can be a false "aliasing" signals shown that are jittery at a lower frequency than the actual signal.



With digital scopes, you can freeze the waveform and zoom in and out

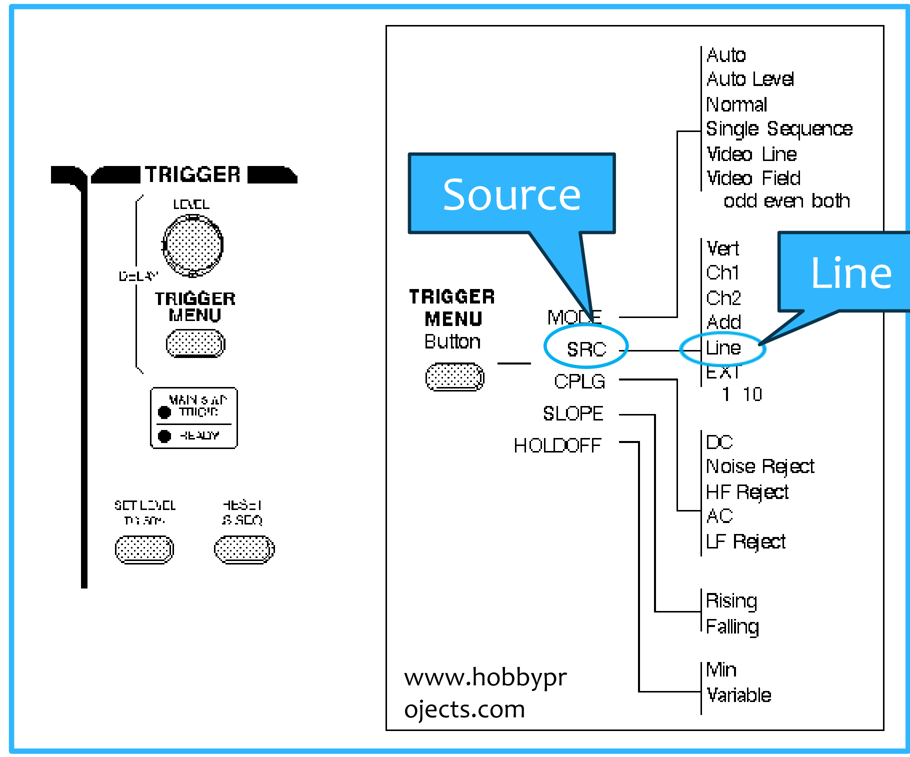
Oscilloscopes - Triggering

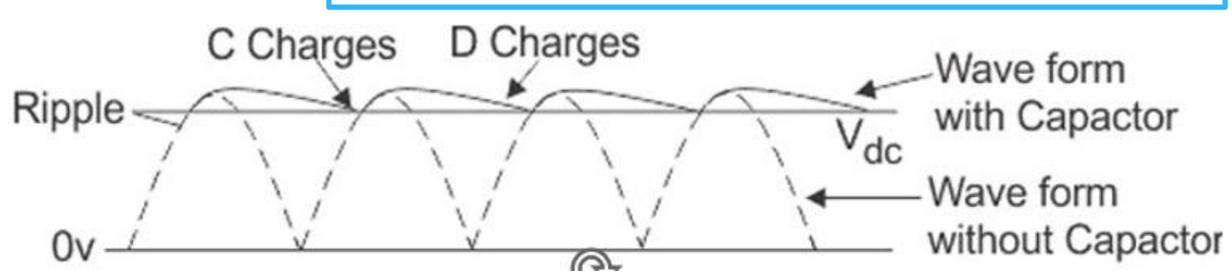
Trigger



Pg. 7-7

- The horizontal trace can be set to trigger on specific criteria.
- If working on a liner power supply, the ripple can be best measured using the “**Line**” trigger option.

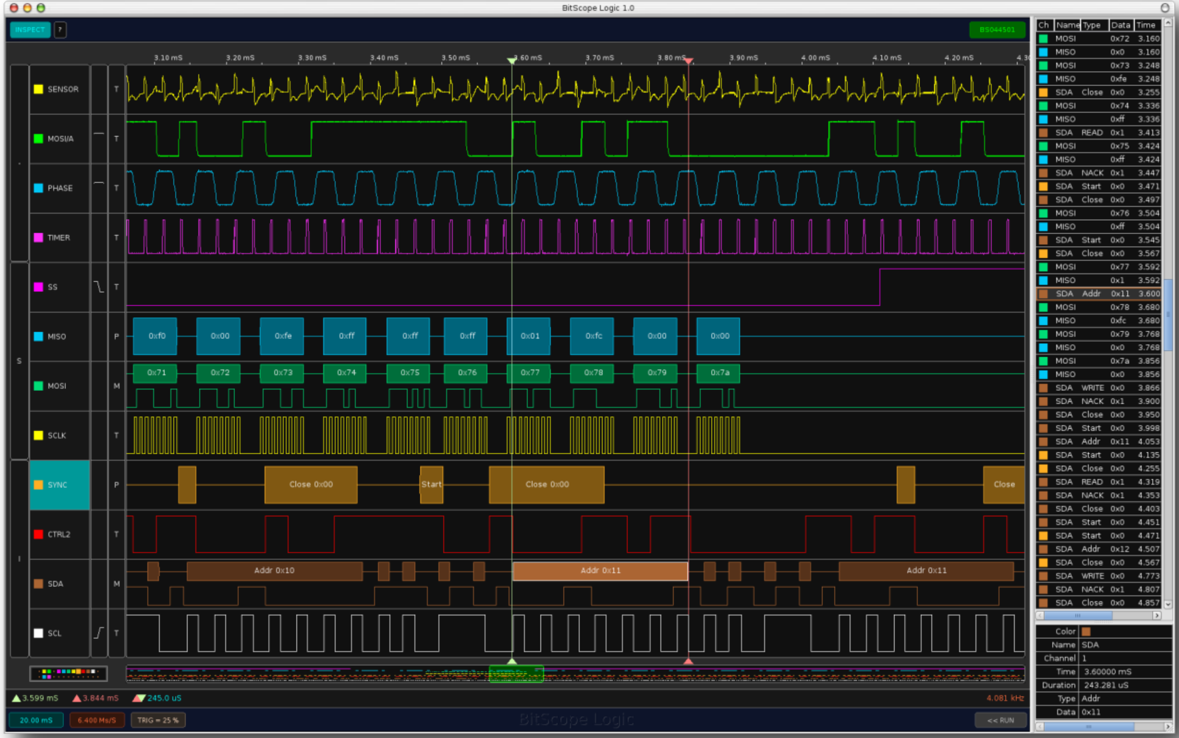




FYI: Logic Analyzers

FYI

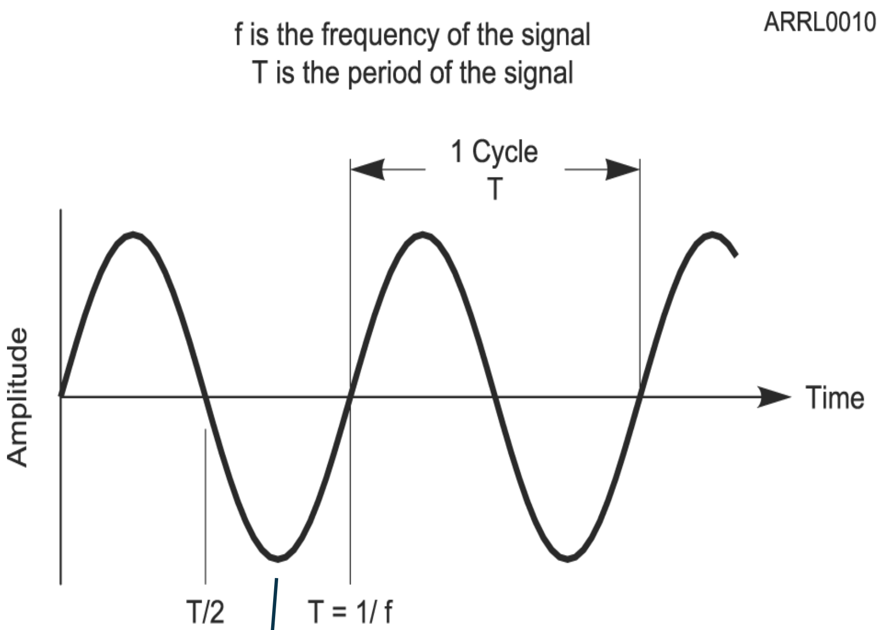
- A Logic Analyzer is a special type of oscilloscope for observing multiple digital signals simultaneously.
- It may have 16 or more input channels.



Remember the Sine Wave?

Technician Review

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



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

Frequency & Period

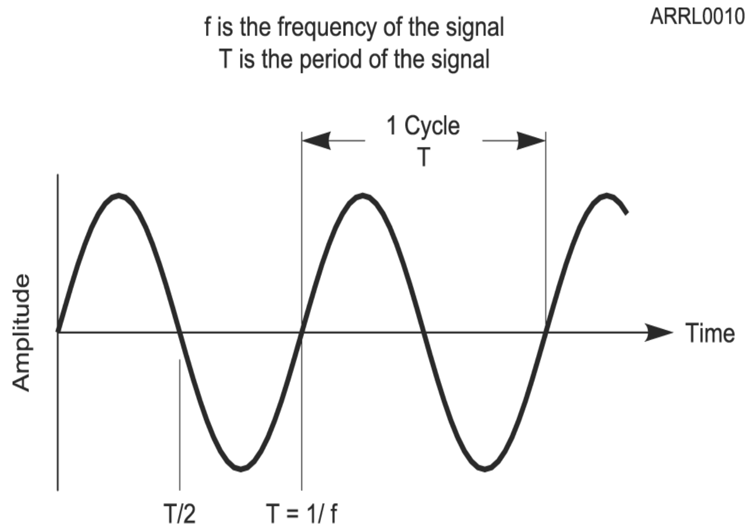
Technician Review

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.

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

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

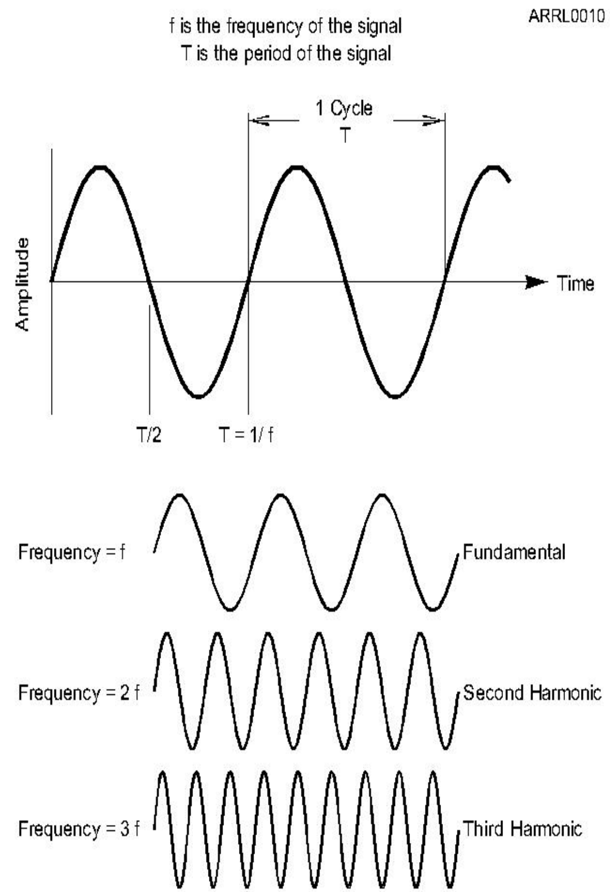


Harmonics

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

dB (Decibels)

Technician – General Review

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

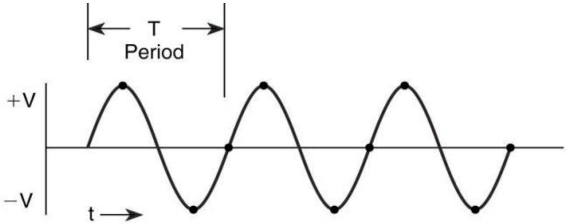
Decibel	Change in Power	Observed Effect
1 dB	Only 20%	Hardly perceivable
3 dB	Factor of 2	Just noticeable
6 dB	Factor of 4	Readily noticeable
10 dB	Factor of 10	Quite significant
15 dB	Factor of 32	A bit more significant
20 dB	Factor of 100	Very significant
30 dB	Factor of 1,000	Very-very significant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

Waveforms

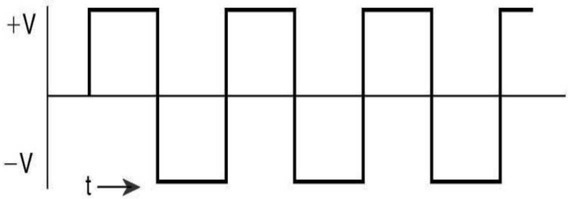
Pg. 7-8

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

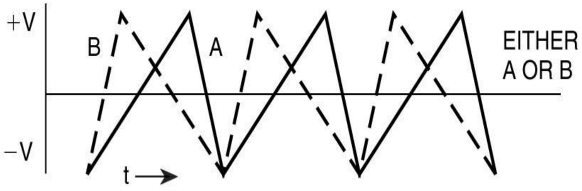
Sine Wave



Square Wave



Sawtooth



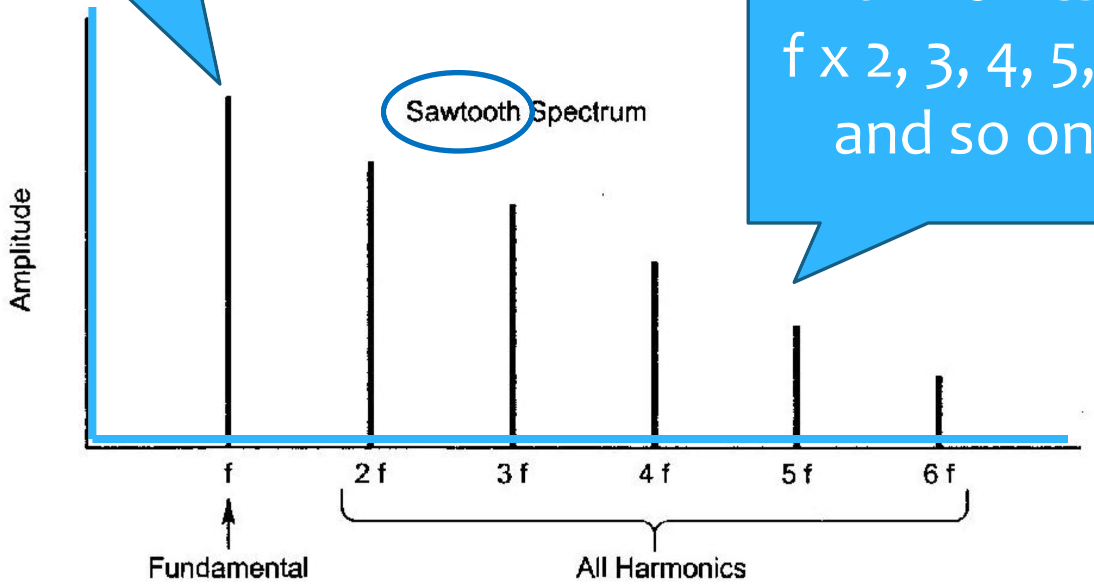
Let’s Take a Spectral Look
(Fourier Analysis)

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



Square Wave (Odd Harmonics)

Pg. 7-4

A **Fourier Analysis** of a **square** wave shows that it is made up of the fundamental and the **odd** harmonics.

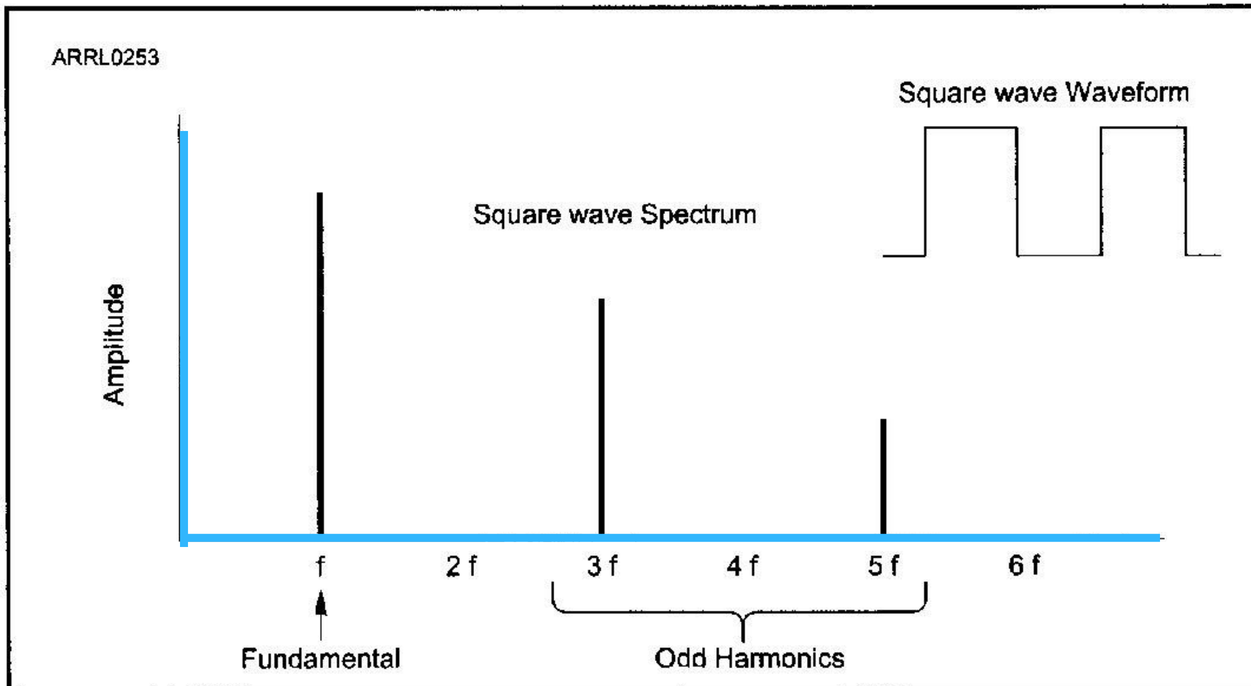


Figure 7-4 — The square wave is made up of sine waves at the fundamental frequency and only the odd harmonics. The amplitude of the harmonics decreases as their frequency increases.

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

Spectrum Analyzers

Pg. 7-8

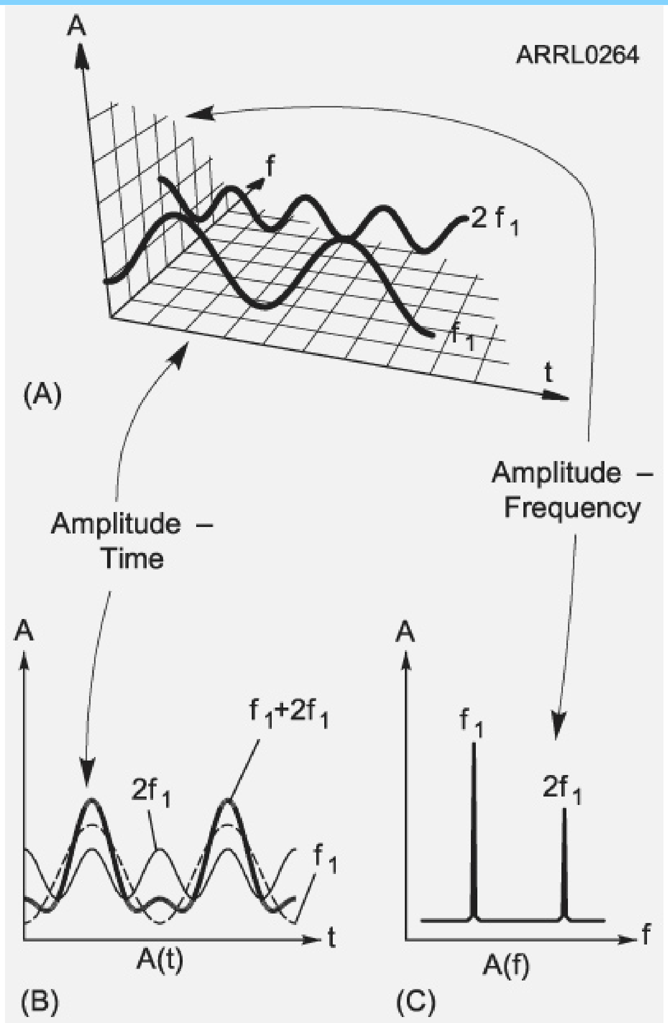


Fig 7-6

- 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. 7-9/10/11

- The spectrum analyzer displays the amplitude vs the frequency.
  - Vertical – Signal Amplitude
  - Horizontal -- Frequency
- We say that the spectrum analyzer allows us to evaluate signals in the <u>frequency domain</u>
- A spectrum Analyzer let's us measure spurious signals and intermodulation distortion products.

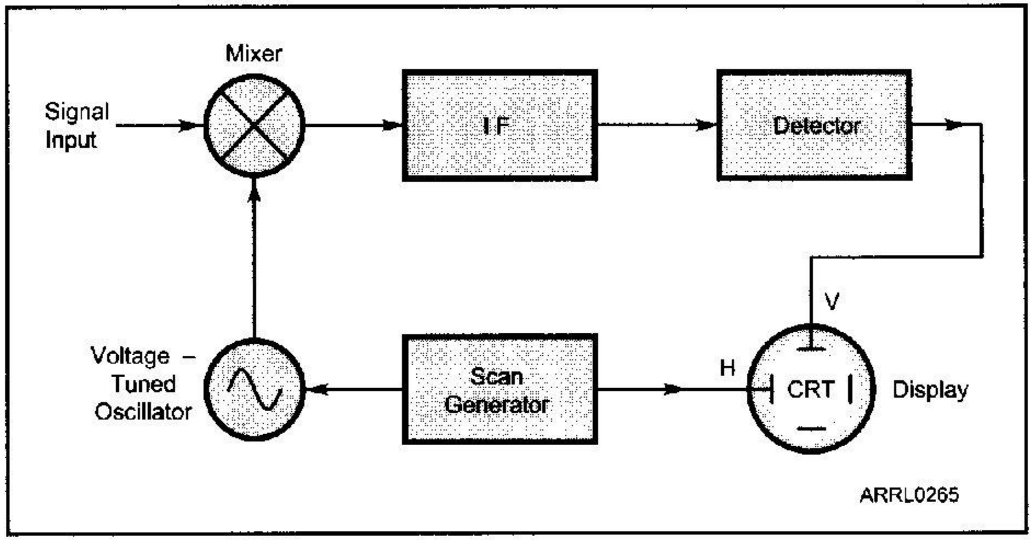
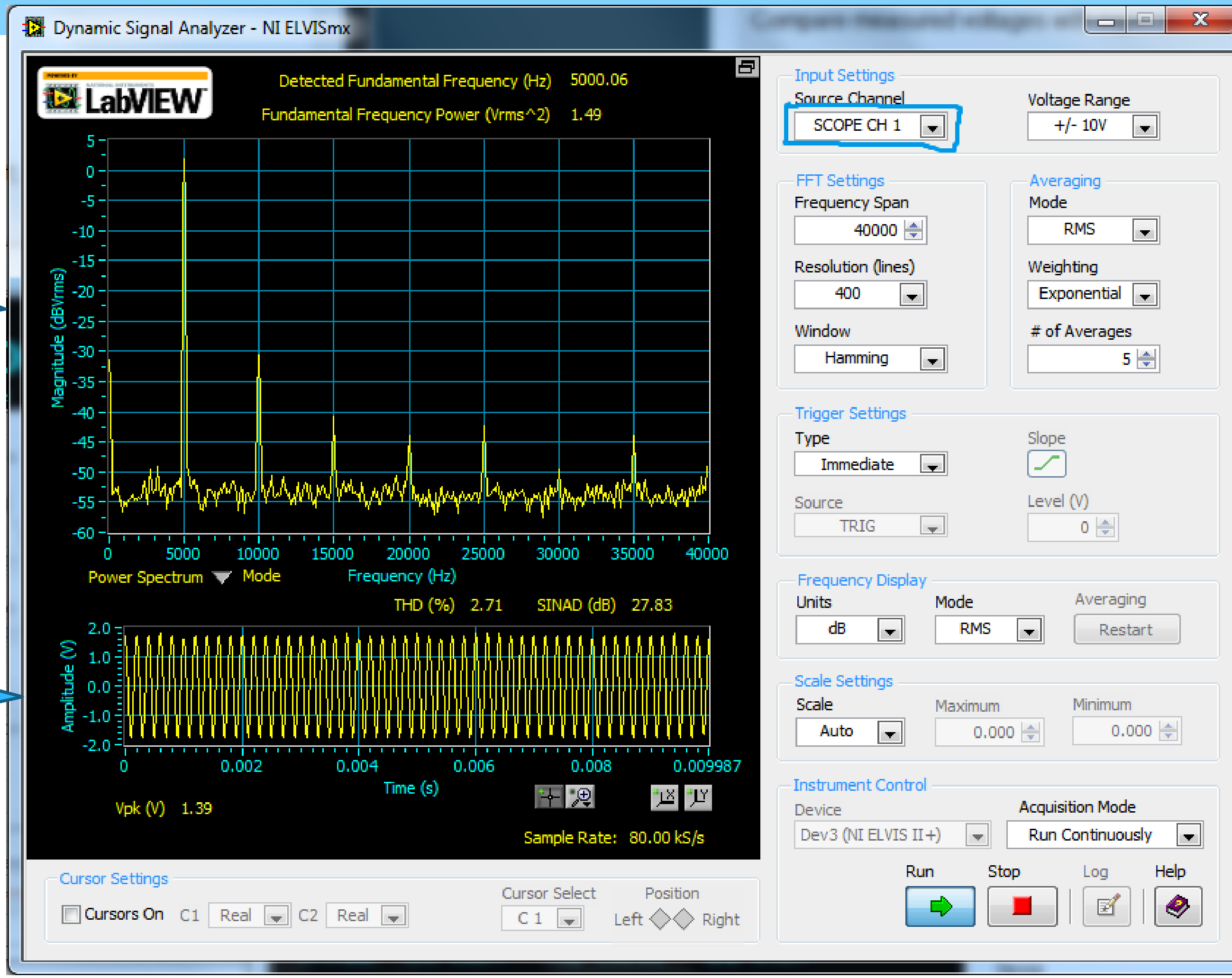


Figure 7-9 – This simplified block diagram illustrates the operation of swept-superheterodyne spectrum analyzer. It is basically an electronically tuned, narrow-band receiver with a CRT display of signal amplitude and frequency.

Looking at a Signal with Harmonics

Frequency Domain Display (Spectrum Anlz)

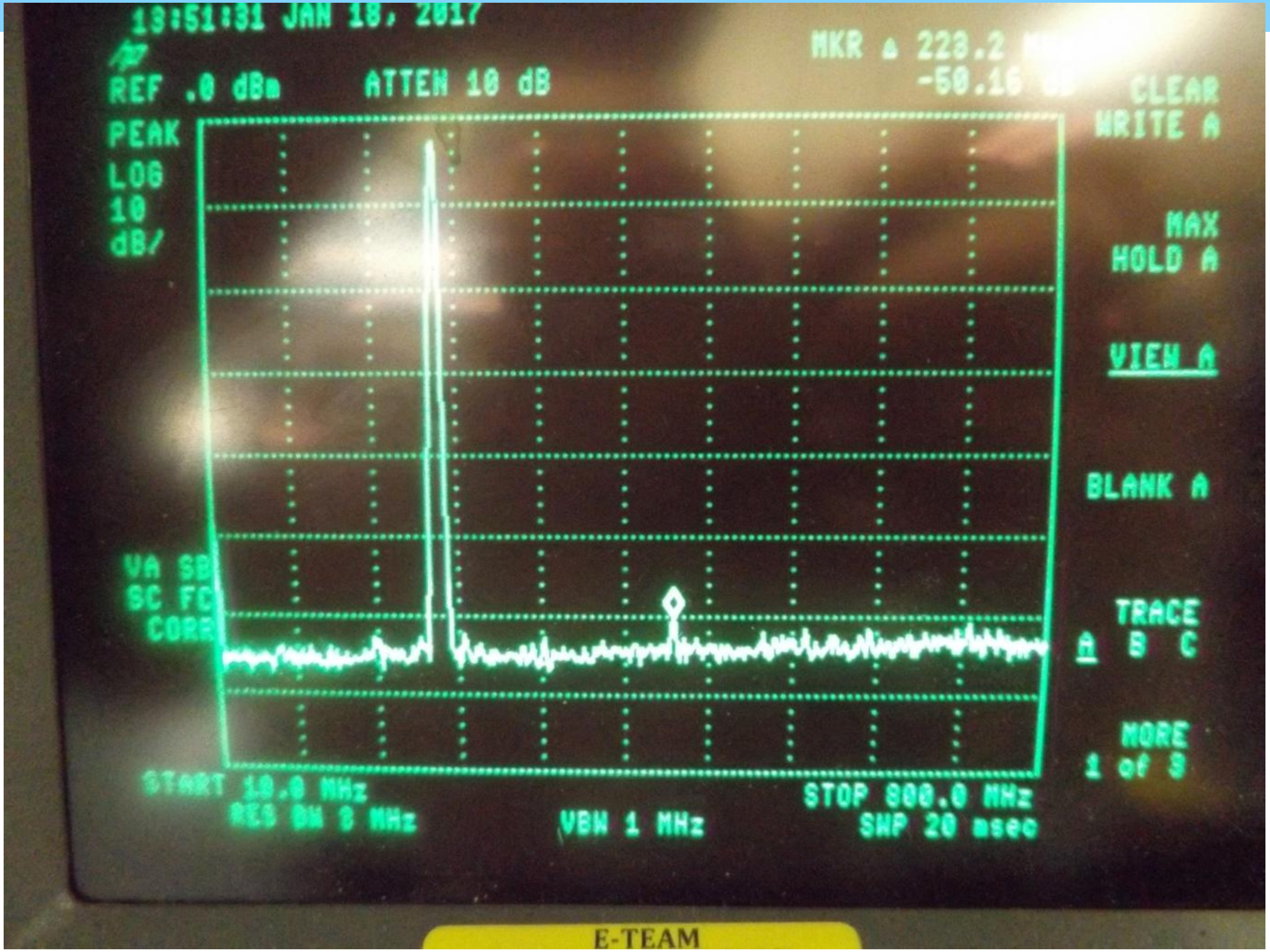
Time Domain Display (Oscilloscope)



http://www.eng.auburn.edu

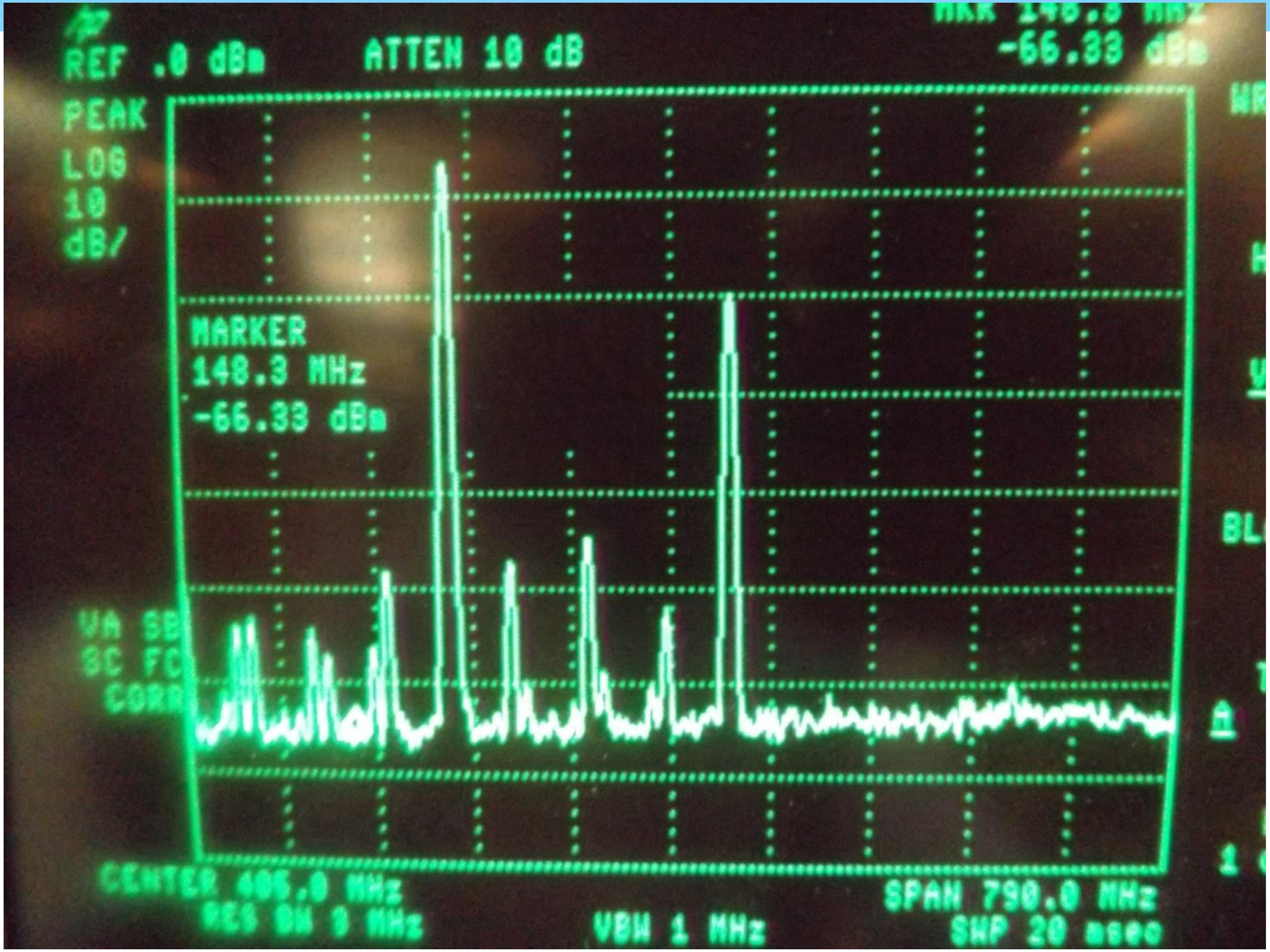
Kenwood TH-F6A

* 224.78 MHz



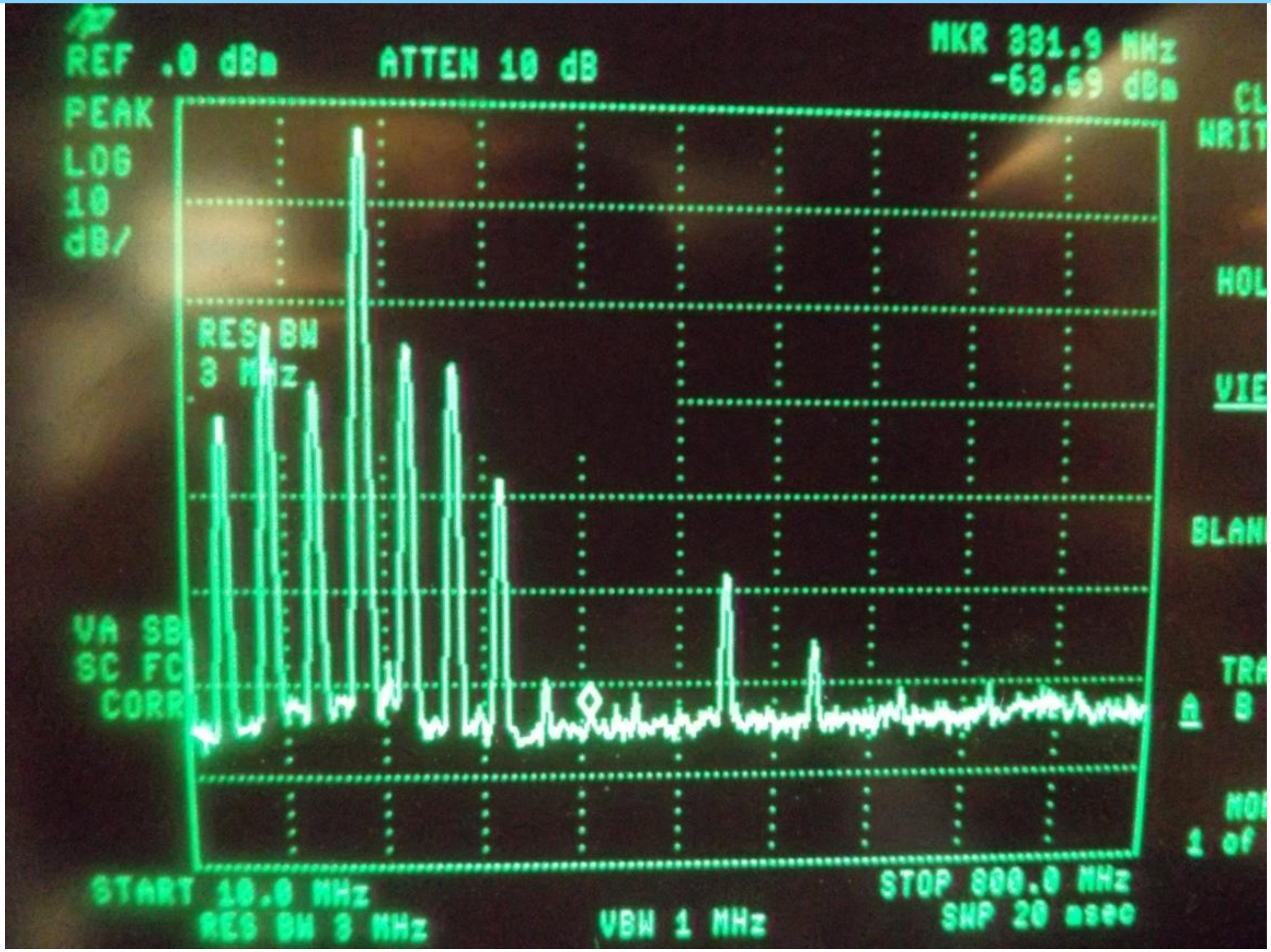
Baofeng UV-82X

* 224.78 MHz



Baofeng UV-82X

* 146 MHz



Using a Spectrum Analyzer

Pg. 7-11

* 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

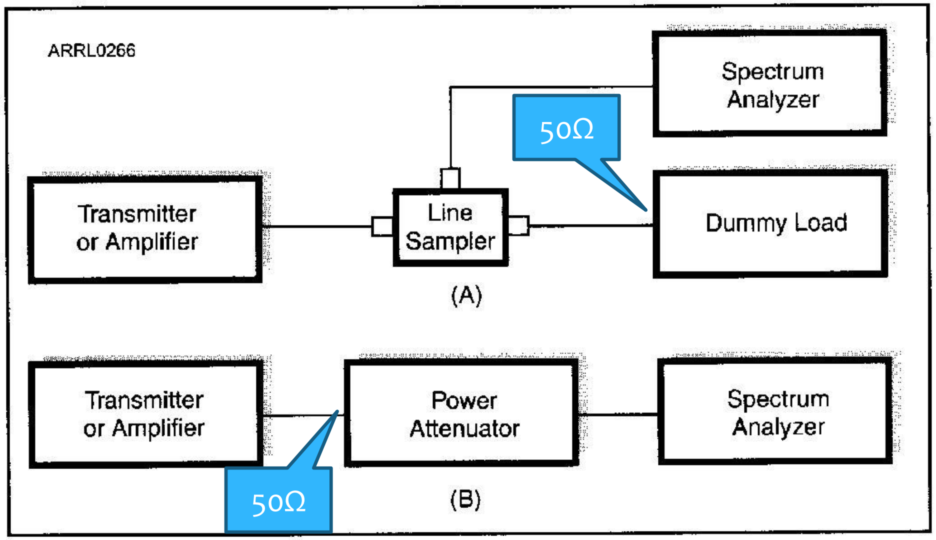


Figure 7-10 These diagrams show two commonly used test set-ups to observe the output of a transmitter or amplifier on a spectrum analyzer. The system at A uses a transmission line power sampler to obtain a small amount of the transmitter or amplifier output power. At B, the majority of the transmitter output power is dissipated by the power attenuator, leaving a small amount to be measured by the spectrum analyzer.

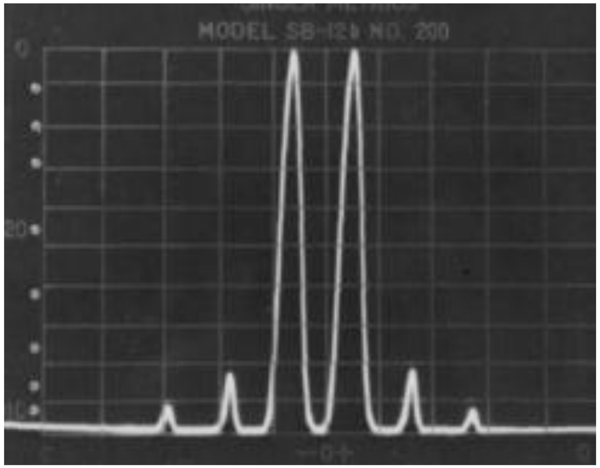
HF Transceivers
with Built-in Spectrum Analyzer and Oscilloscope

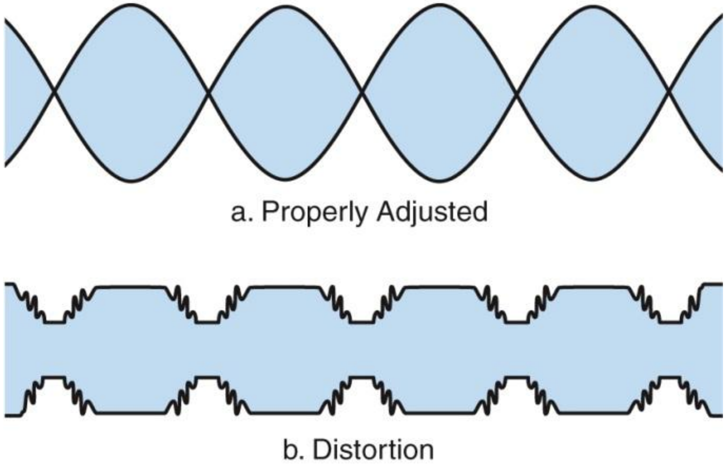
Icom IC-756 Pro

Two Tone Tests

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.
- **The transmitter is modulated with two non-harmonically related audio signals** and the RF output is observed on a spectrum analyzer.

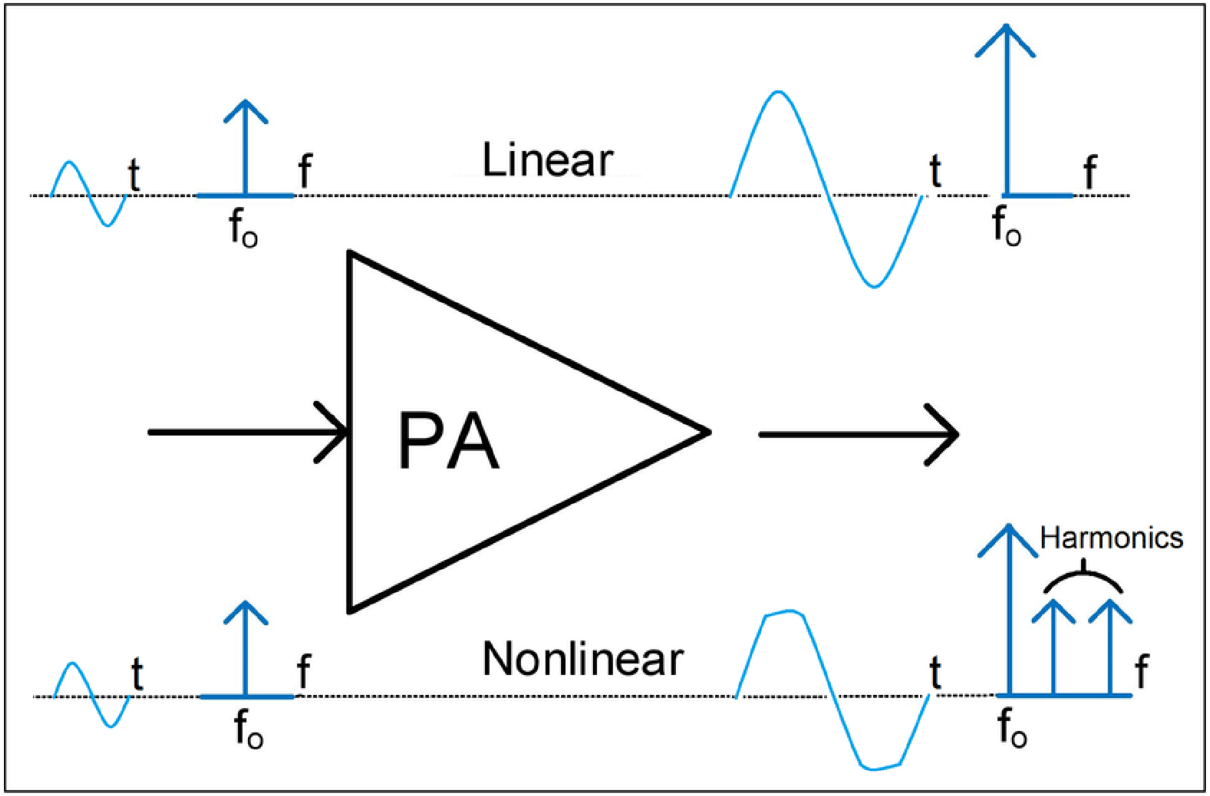




Understanding Linearity vs. Non-linearity

* With a **Linear Amplifier,** the output waveform perfectly matches the input wave form—just amplified

* If the amplifier is **Non-Linear,** there will be distortion



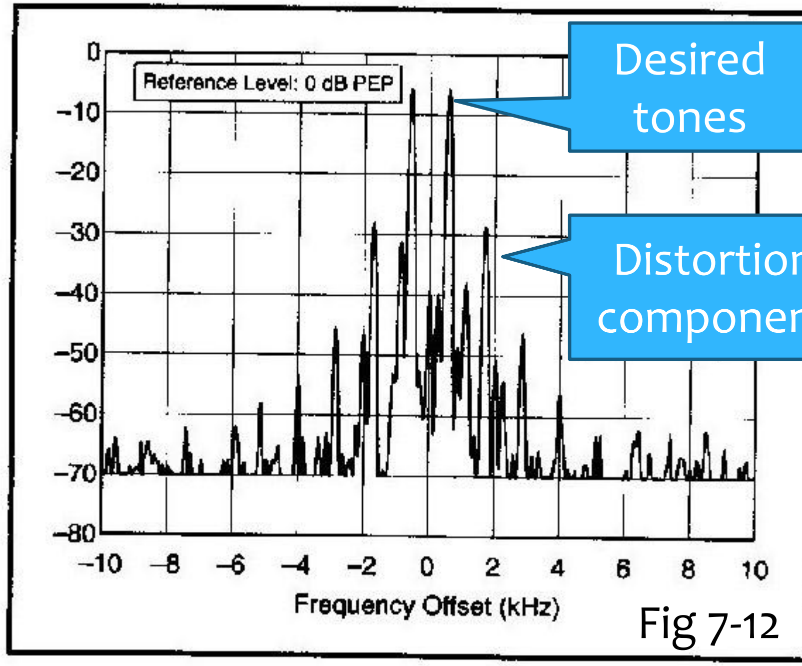
PA = Power Amplifier

www.researchgate.net

Two-Tone Test

Pg. 7-11

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



Desired tones

Distortion component

Fig 7-12

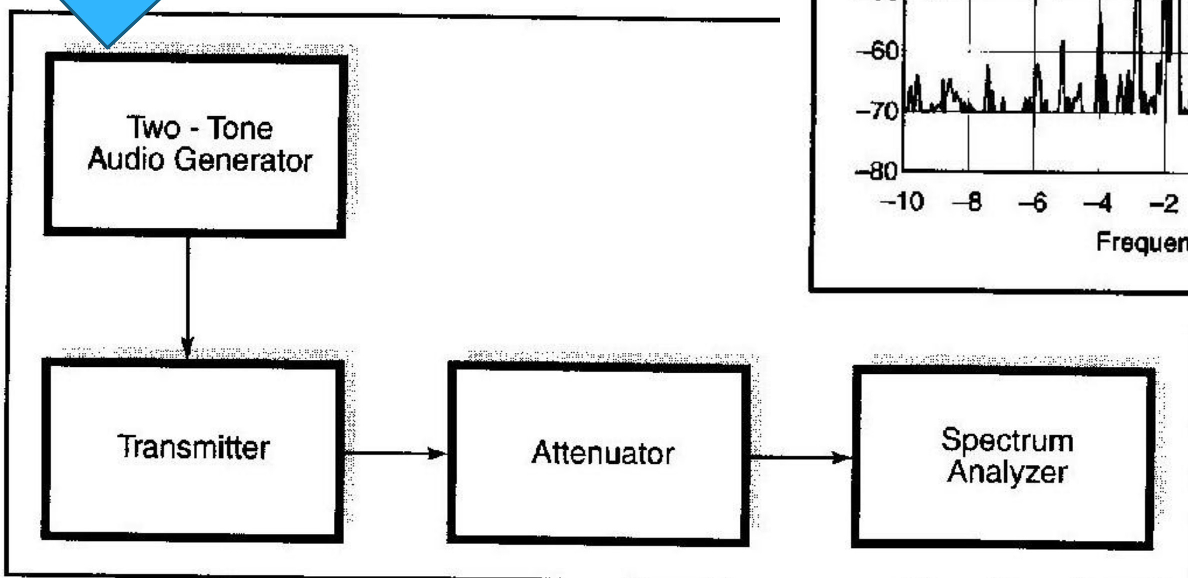


Figure 7-11 - This diagram illustrates the test setup used in the ARRL Laboratory for measuring the IMD performance of SSB transmitters and amplifiers.

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

Affordable Spectrum Analyzers

Spectrum Analyzers are becoming increasingly affordable and common in ham shacks. They can also be used as RF Signal Generators.

* **TinySA**
  * 100 kHz – 960 MHz
  * $66 at amazon.com

Cables and Adapters

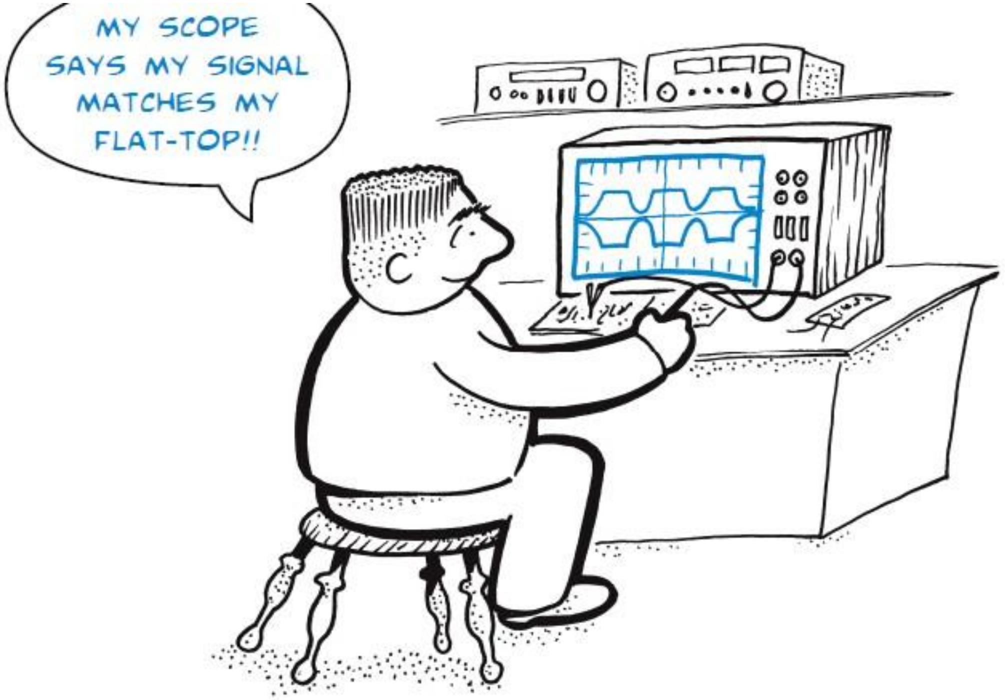
- For VHF/UHF applications, look for connectors with Teflon (PTFE) dielectrics
  - Amphenol (DigiKey, Newark, …)
  - Mookeerf (Amazon)

Test Equipment

More test equipment to follow:

* *Half-time presentation*
* *Receiver Performance Section*

Let’s Look at Some Questions



E4A01 Which of the following limits the highest frequency signal that can be accurately displayed on a digital oscilloscope?

A. Sampling rate of the analog-to-digital converter
B. Amount of memory
C. Q of the circuit
D. All these choices are correct

E4A01 What is the purpose of the prescaler function on a frequency counter?

A. It amplifies low-level signals for more accurate counting

B. It multiplies a higher frequency signal so a low-frequency counter can display the operating frequency

C. It prevents oscillation in a low-frequency counter circuit

D. It divides a higher frequency signal so a low-frequency counter can display the input frequency

E4B10 Which of the following methods measures intermodulation distortion in an SSB transmitter?

A. Modulate the transmitter using two RF signals having non-harmonically related frequencies and observe the RF output with a spectrum analyzer

B. Modulate the transmitter using two AF signals having non-harmonically related frequencies and observe the RF output with a spectrum analyzer

C. Modulate the transmitter using two AF signals having harmonically related frequencies and observe the RF output with a peak reading wattmeter

D. Modulate the transmitter using two RF signals having harmonically related frequencies and observe

Receiver Performance

7-2

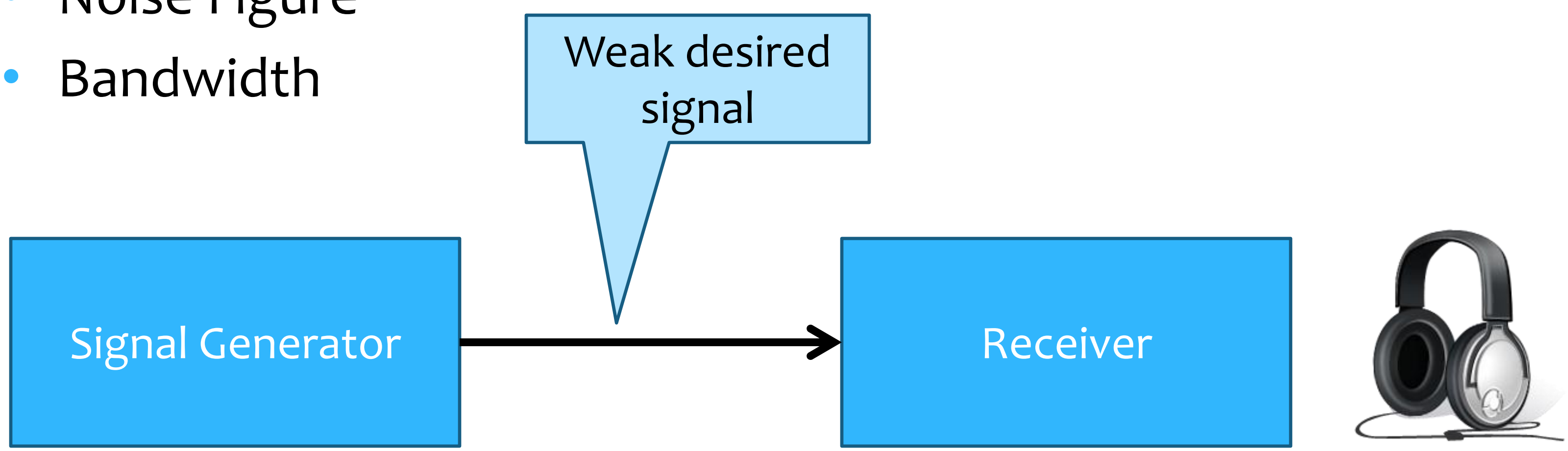
Bang for Your Buck

* 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)

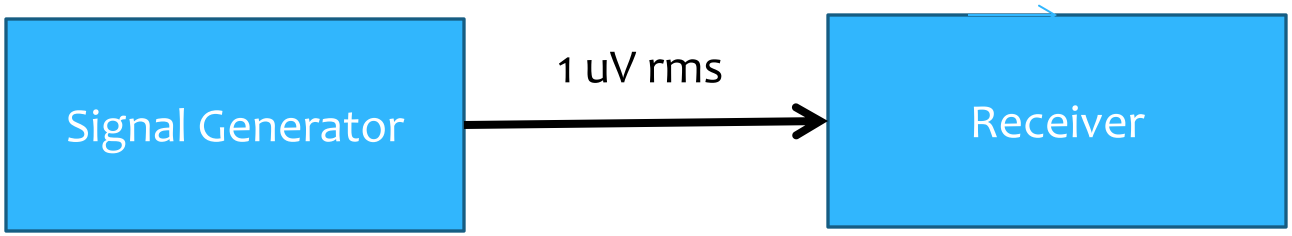
Pg. 7-12

* 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).



RF Signal Generator

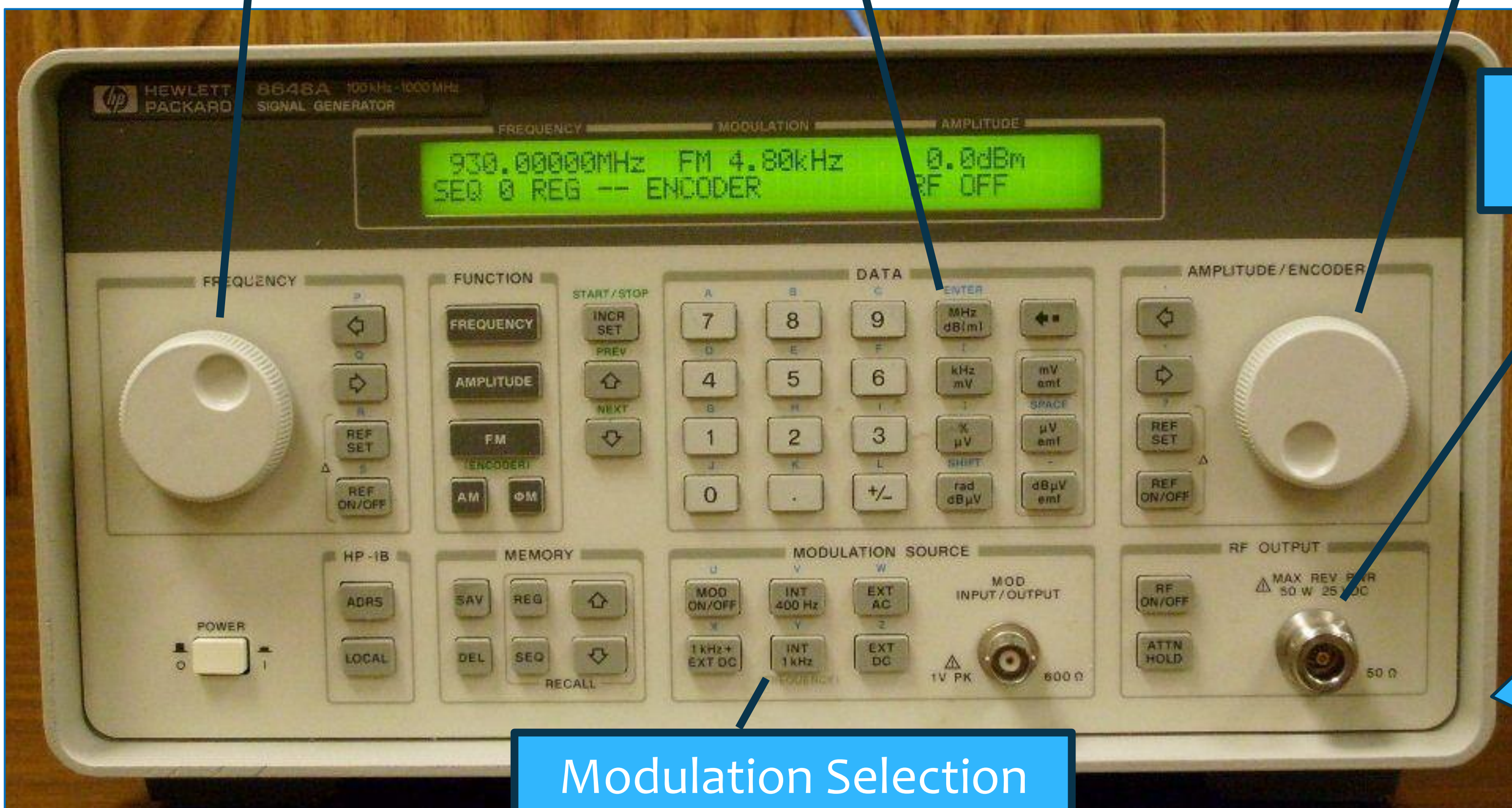
HP 8648A

Frequency Selection

Units Selection
kHz, MHz; dBm, uV …

Amplitude Selection

RF Output Port



Modulation Selection

~$600 - $900

>$3000 with high stability time base

More RF Signal Generators

HP8640B
~ $300 - $400

Switches prone to wear

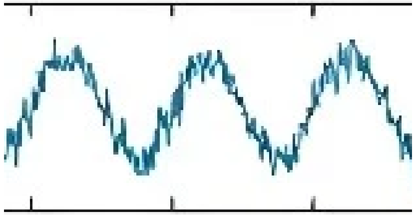
Poor Freq stability, Limited Frequency Range, Uncalibrated Output, Vacuum Tubes

Precision E-200-C
<< $150

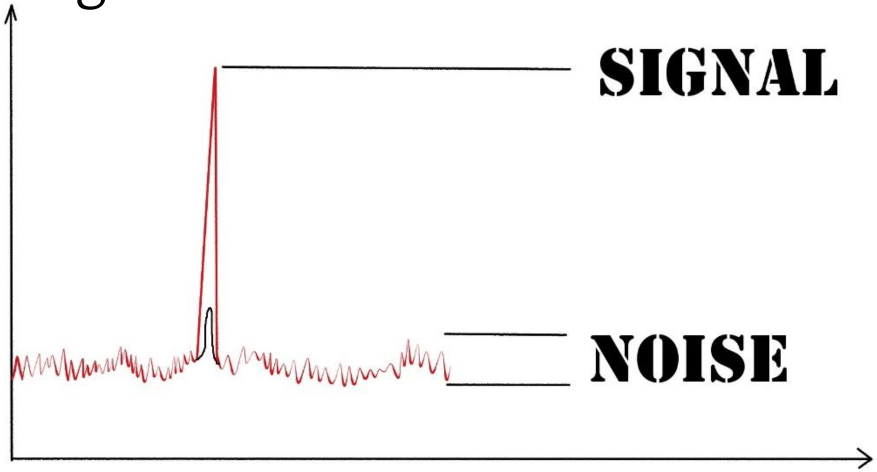
Signal to Noise

Pg. 7-12

* **SNR** or **S/N** = Signal to Noise Ratio
  * The desired signal power compared to the noise power
  * Expressed in dB
  * The higher, the better



* **SINAD** = Signal Including Noise and Distortion
  * This also taken in any ***distortion*** generated in the receiver.
  * Expressed in dB
  * The higher, the better



Audio VM/Distortion Analyzer

Calibrated in V and dB

Audio Notch

HP331A
< $200

Heath IM 5258
< $150

Voltage Selection

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. 7-12/13

- 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

Pg. 7-12

* dBm = 20 log (V / 0.224 V)
  * A **positive** value if V is > 0.224V
  * A **negative** value if V is < 0.224V

0.224 V across a 50 ohm resistor dissipates 1 mW of power, i.e.:

0 dBm

* V = 0.224 (antilog (dBm /20))

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. 7-12

* The **Minimum Discernable Signal** (**MDS**) represents the strength of the weakest discernable signal.
  * This is similar to the sensitivity of the receiver
* **- 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

Think of BW as being like a sliding glass door; how far open is it?

Rx Bandwidth and Noise Floor

Pg. 7-13

* How much does increasing a receiver's BW from 50 Hz to 1000 Hz increase the receiver's noise floor?

Calculate the BW ratio in dB:

$BW_{\text{RATIO dB}} = 10 \log (BW2 / BW1)$

$= 10 \log (1000 \text{ Hz} / 50 \text{ Hz})$

$= 10 \log (20)$

$= 10 \times 1.3$

$= 13\text{dB}$

A 13 dB increase in the noise floor will be realized

E4C06

Remember:
dB = 10 log (P2 / P1)

Rx Bandwidth -- A Practical Application

FYI

* How much reduction in noise will be realized if we switch in a 500Hz CW filter, rather than using the 2400 Hz SSB filter?

Calculate the BW ratio in dB:

$$\begin{aligned} BW_{\text{RATIO dB}} &= 10 \log (BW2/ BW1) \\ &= 10 \log (2400\text{ Hz} / 500\text{ Hz}) \\ &= 10 \log (4.8) \\ &= 10 \times 0.68 = 6.8\text{ dB} \sim 7\text{ dB} \end{aligned}$$

In a typical HF receiver:
SSB Voice BW = 2400 Hz
CW BW = 500 Hz
CW Narrow = 250 Hz

A ~7 dB reduction will be realized with a <u>500</u> Hz BW filter
If we use a <u>250</u> Hz filter, we get a ~10 dB noise reduction

Converting dBm to Power

* What power level does a receiver minimum discernible signal of -100 dBm represent? E4D14
* (Convert -100 dBm to power in watts.)
* The -100 dBm signal is 100 dB below 1 mw of power (0 dBm in a 50 ohm system)

1 mW = 0.001 Watt = 0000000000000.001 W

A 100 dB change moves the decimal point 10 places

After moving the decimal point left 10 places

= 0.0000000000001 W

mw uw nw pw

= 0.1 picowatts

For every 10 dB of **power** change, we move the decimal point over 1 place.
100 dB = 10 places

A. 100 microwatts
B. B. 0.1 microwatt
C. 0.001 microwatts
D. 0.1 picowatts

Converting dBm to Power

- What power level does a receiver minimum discernible signal of -100 dBm represent? E4D14
- (Convert -100 dBm to power in watts.)

$$dB = 10 \log (P2/P1)$$

$$dBm = 10 \log (P2/0.001W)$$

Use algebra to solve for P2:

$$P2 = \frac{antilog\,(\frac{dBm}{10})}{1000}$$

10^x

$$P2 = \frac{antilog\,(\frac{-100}{10})}{1000} = \frac{antilog\,(-10)}{1000}$$

$$P2 = \frac{100\ x\ 10-12}{1000} = 100 \text{ x } 10^{-15}$$

$$= 0.0000000000001 \text{ W}$$

A. 100 microwatts
B. B. 0.1 microwatt
C. 0.001 microwatts
D. 0.1 picowatts

As a practical matter …

- Atmospheric noise is the limiting factor for sensitivity on the lower HF bands.
- So is power line noise

160m, 80m, 40m

On a receiver, RF-input attenuators can be switched in to help reduce receiver overload. Interestingly, on the lower frequencies, the addition of the attenuation has little or no impact on the signal-to-noise ratio because atmospheric noise is generally greater than the internally generated noise, even after attenuation. E4C11

Noise Figure

Pg. 7-14

* 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.

Selectivity

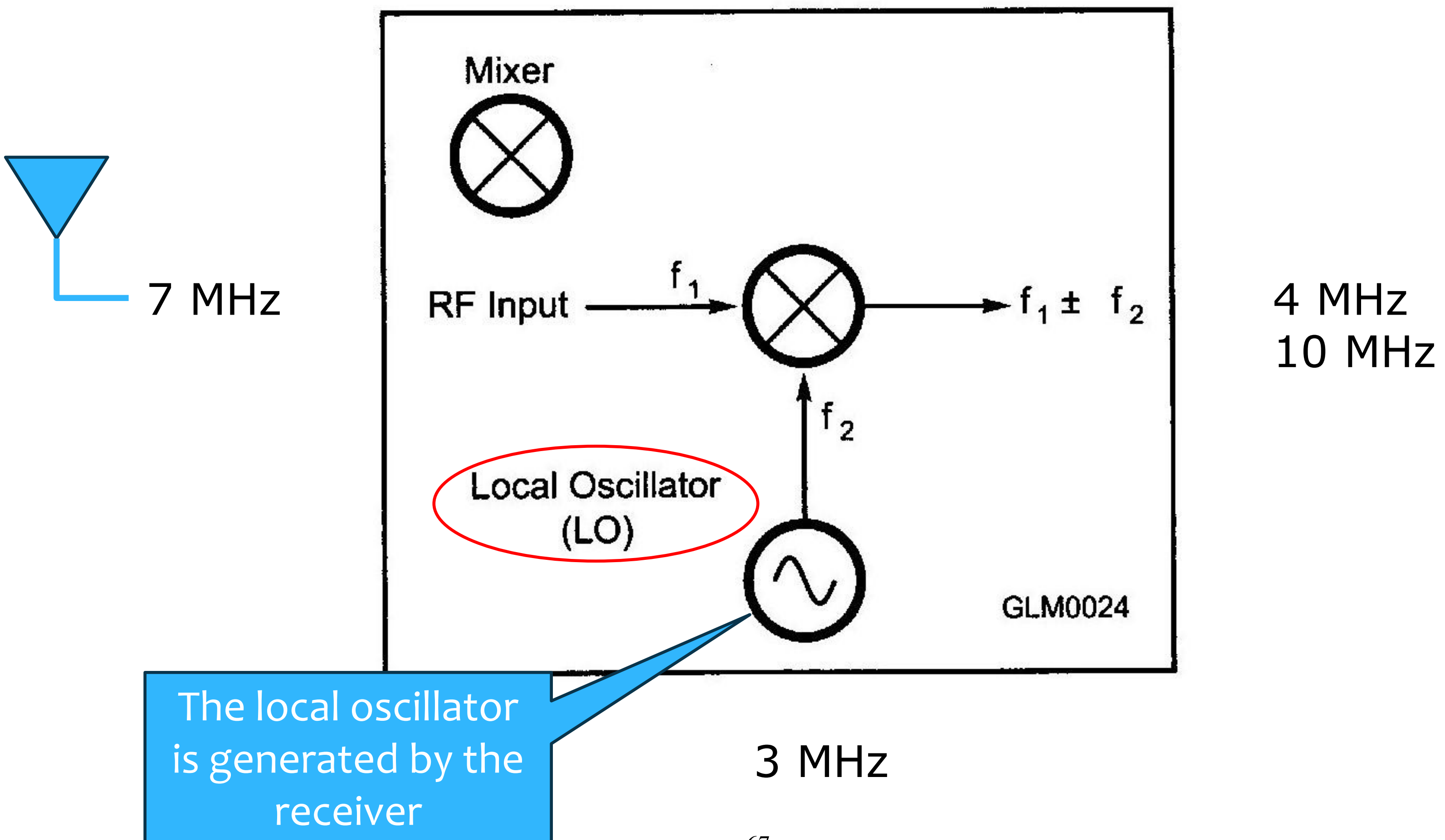
Pg. 7-14

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

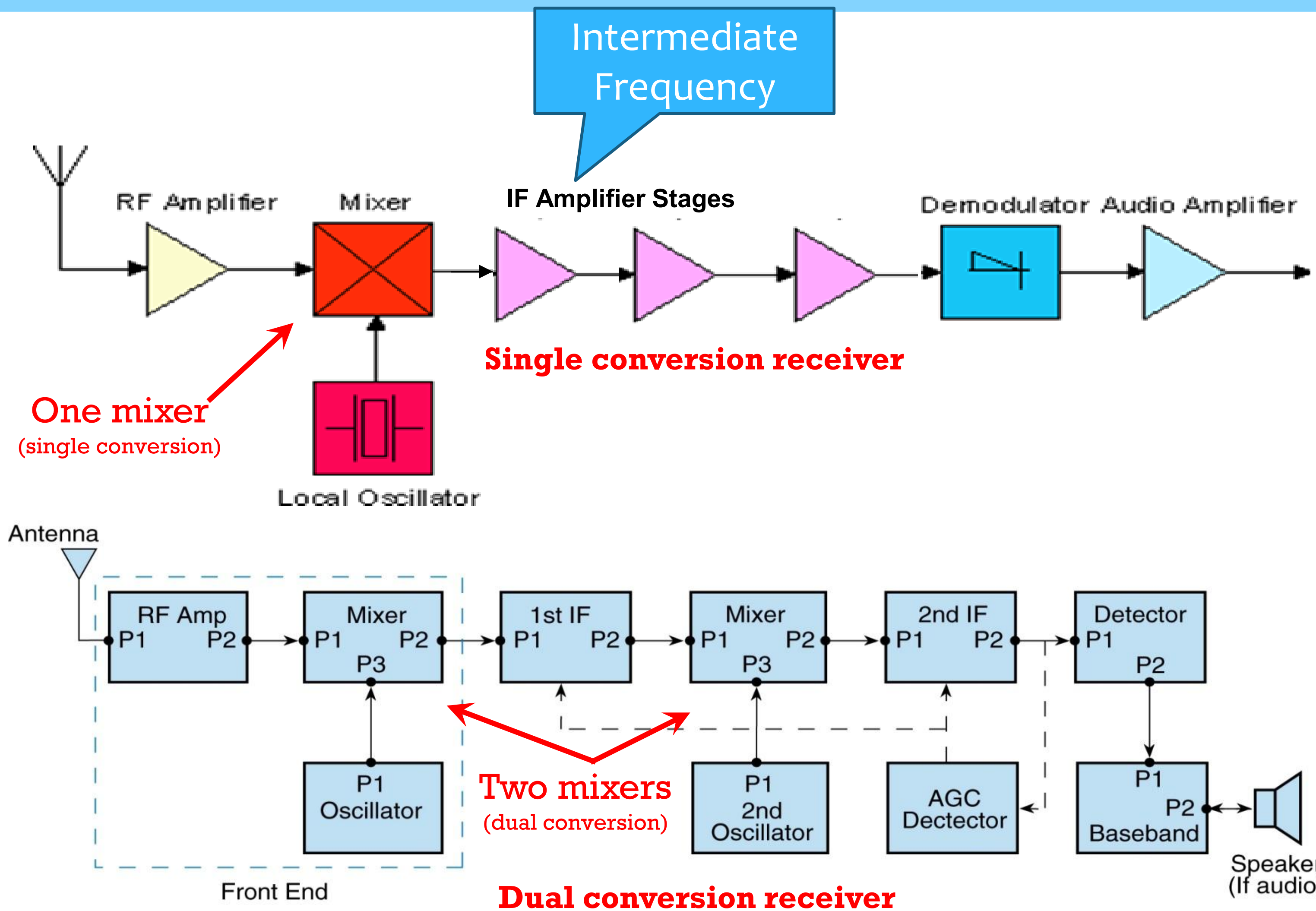
Mixer

General Review



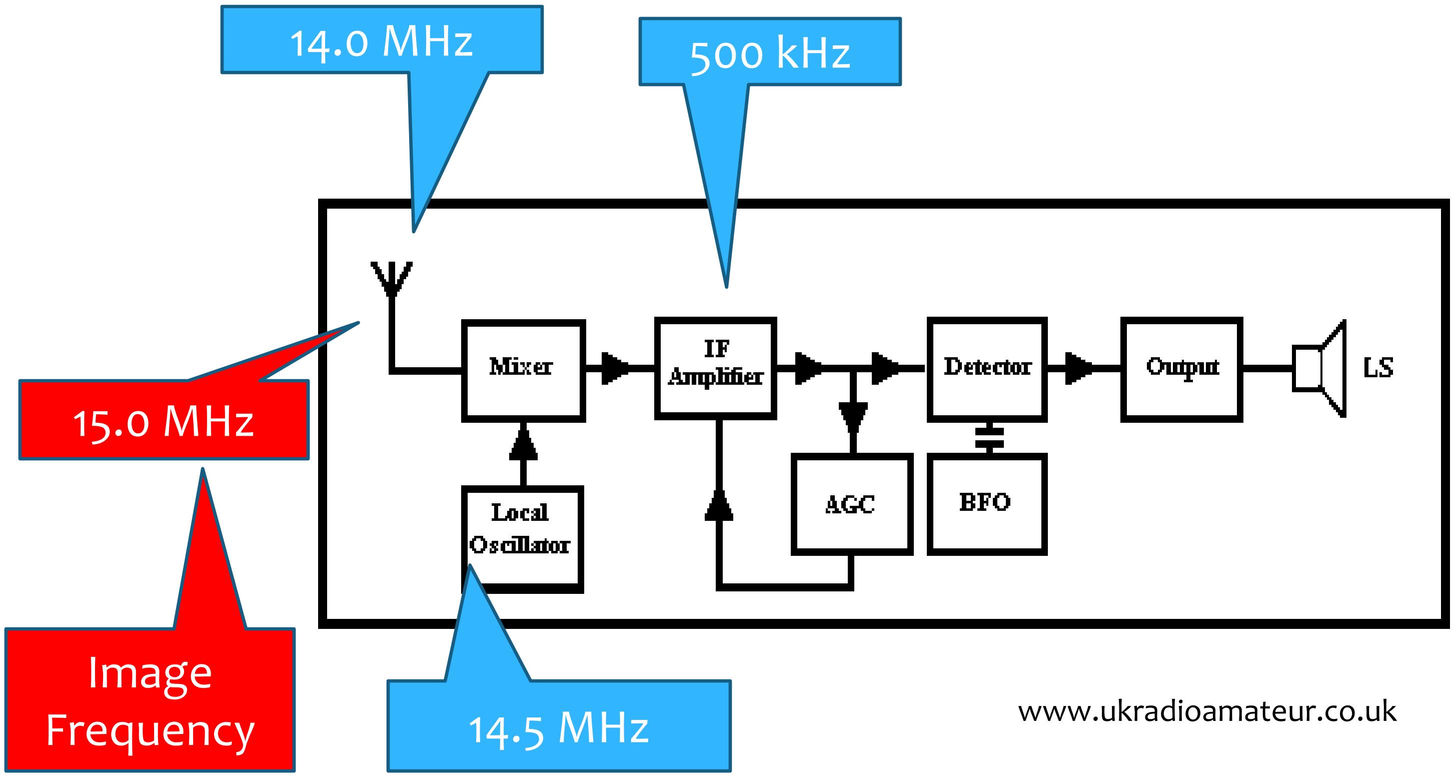
Receivers

General Review



Superheterodyne Receiver

500 kHz IF



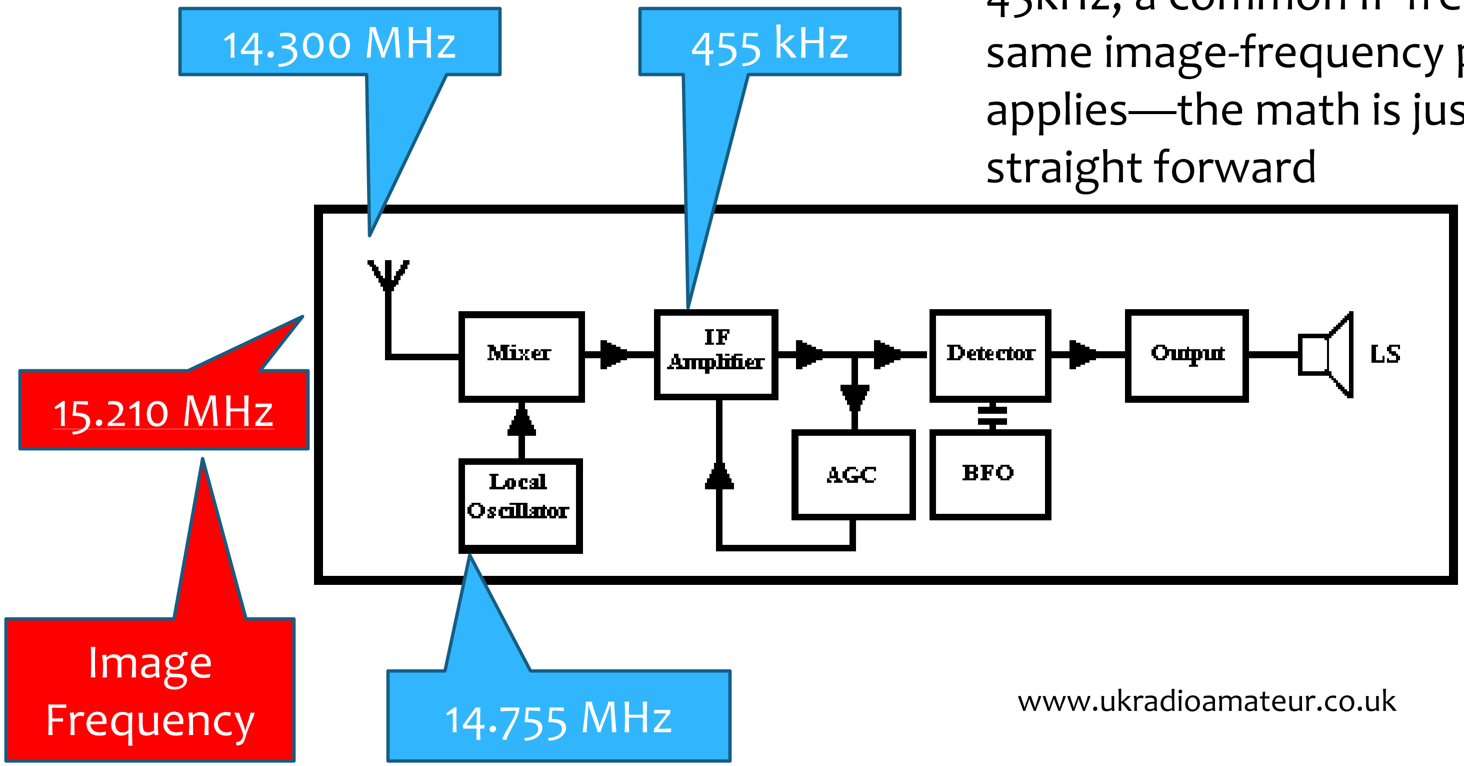
www.ukradioamateur.co.uk

Superheterodyne Receiver

455 kHz IF

Pg. 7-14 & 15

The example in the ARRL manual uses 14.3 MHz and an IF frequency of 45kHz, a common IF frequency. The same image-frequency principal applies—the math is just a bit less straight forward

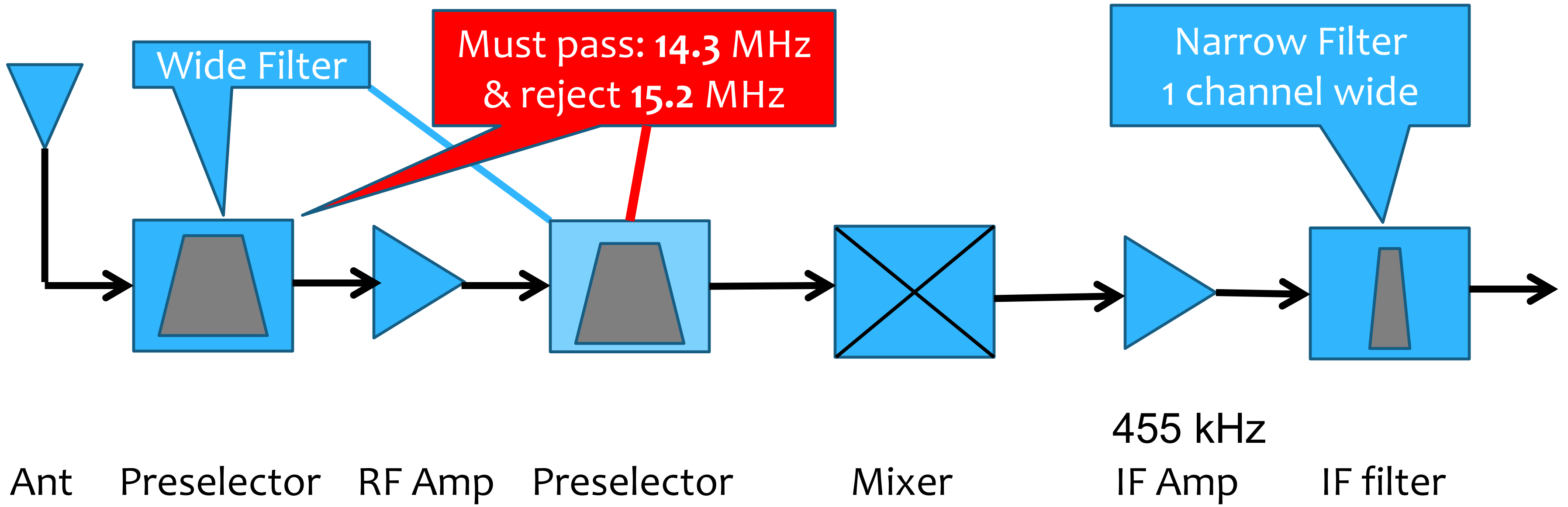


www.ukradioamateur.co.uk

Let's Add Some Filters

Pg. 7-14 & 15

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



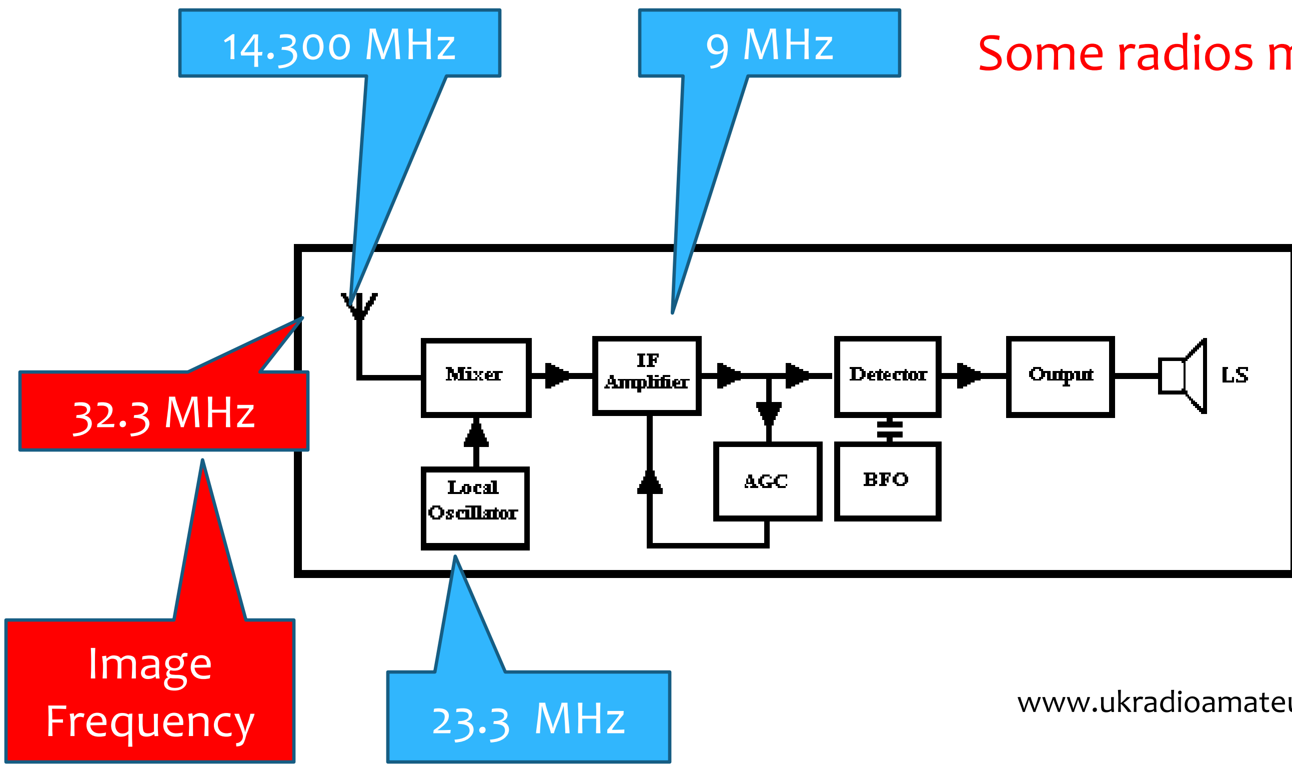
Superheterodyne Receiver

9 MHz IF

Pg. 7-14 & 15

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

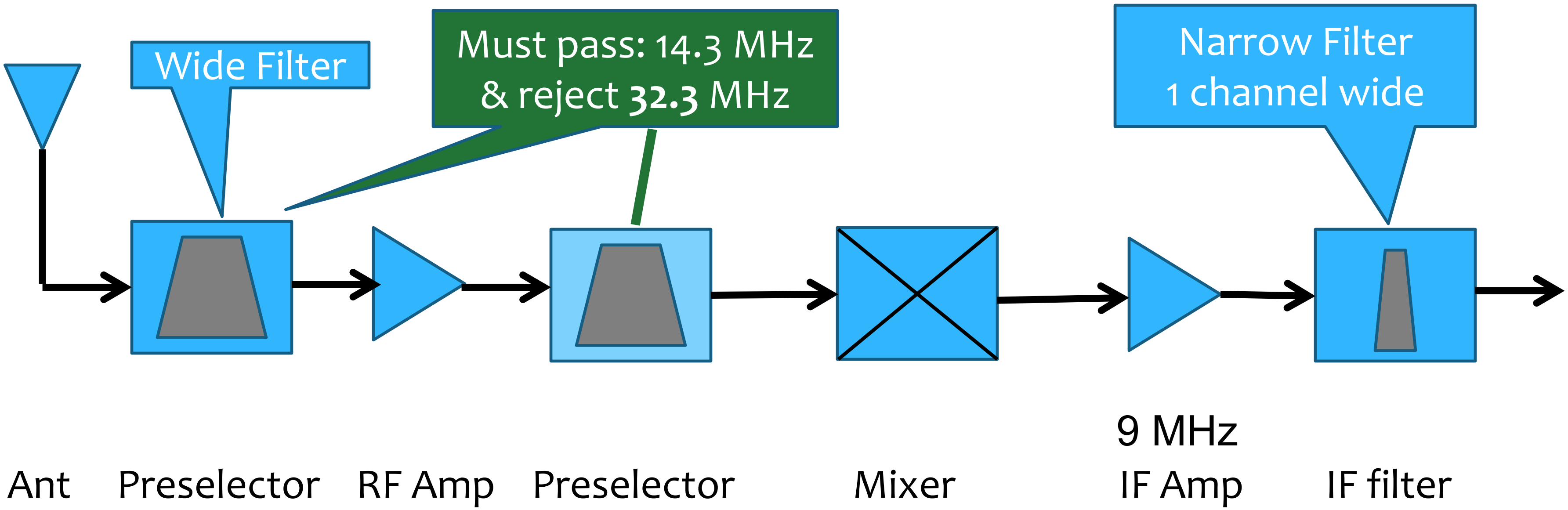


www.ukradioamateur.co.uk

Let's Move that Image far Away

Pg. 7-14 & 15

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

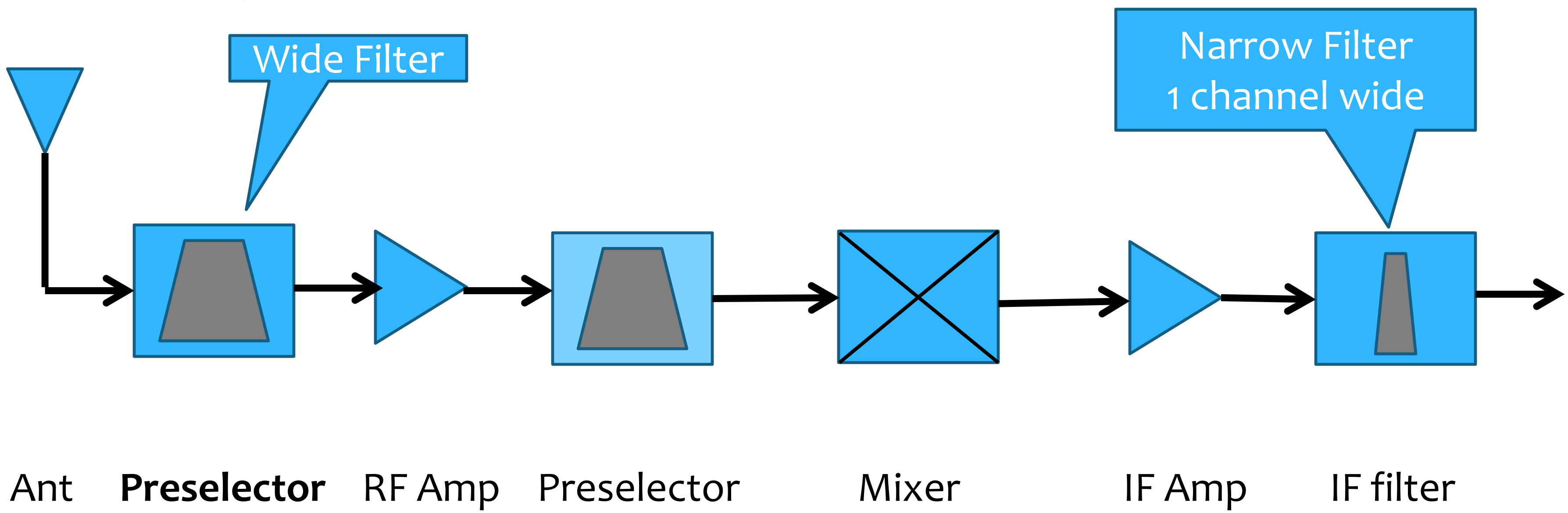


Reject that Image Response

Pg. 7-14 & 15

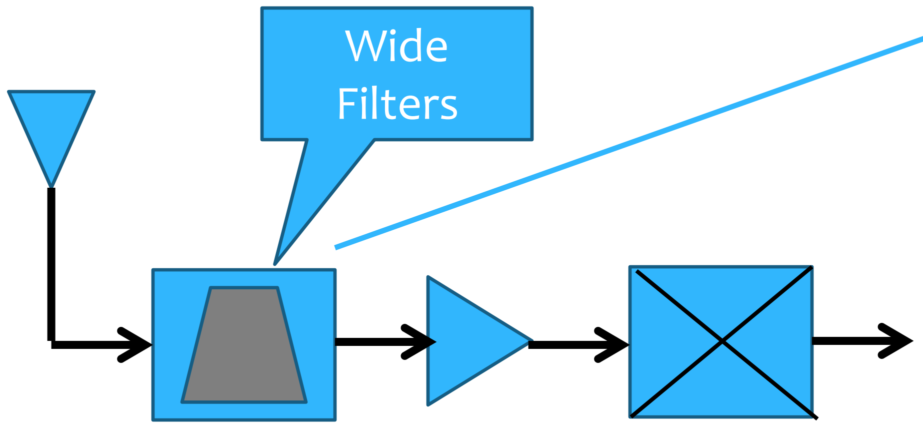
The front-end filter or **Preselector** rejects the image frequency of the receiver and other out-of-band signals.

E4C02 E4D09

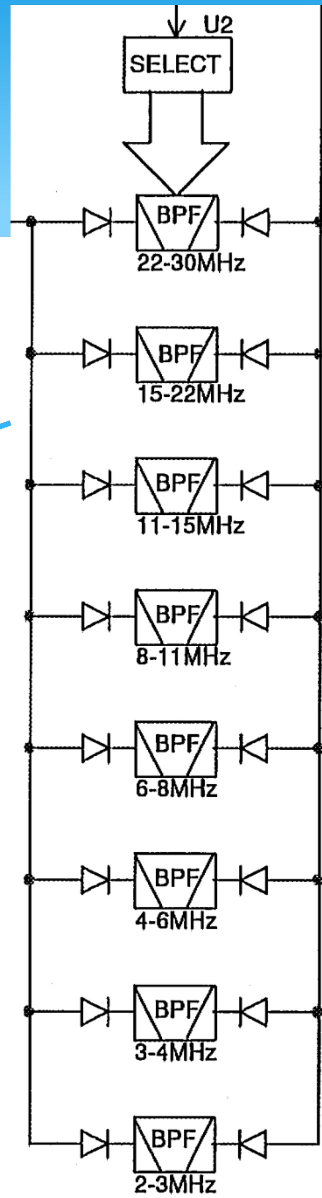


A Bank of BPF Filters

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

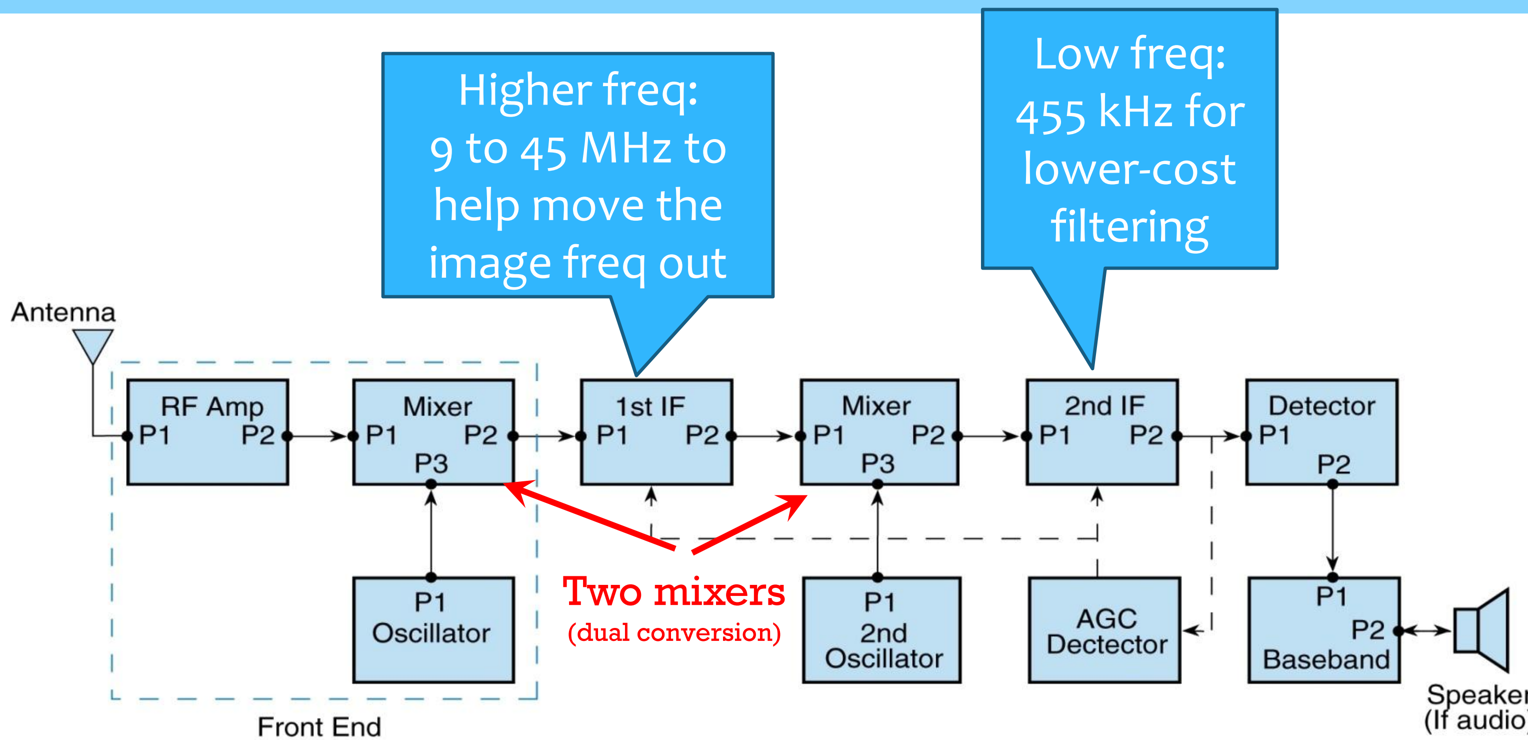


Ant **Preselector** RF Amp Mixer



An advantage of Dual Conversion

Practical Information



Dual conversion receiver

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

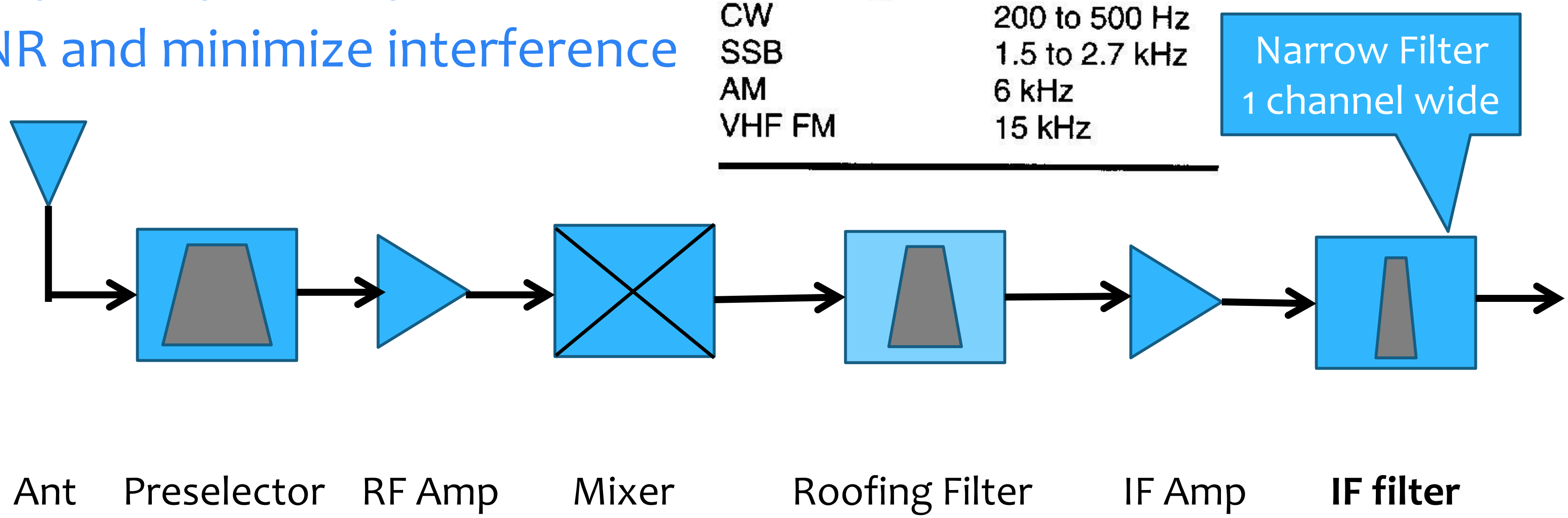
Let’s Look at the Narrow Filter

Pg. 7-15 & 20

It is desirable to have multiple bandwidth filters to match the modulation BW to maximize SNR and minimize interference

Table 7-2
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

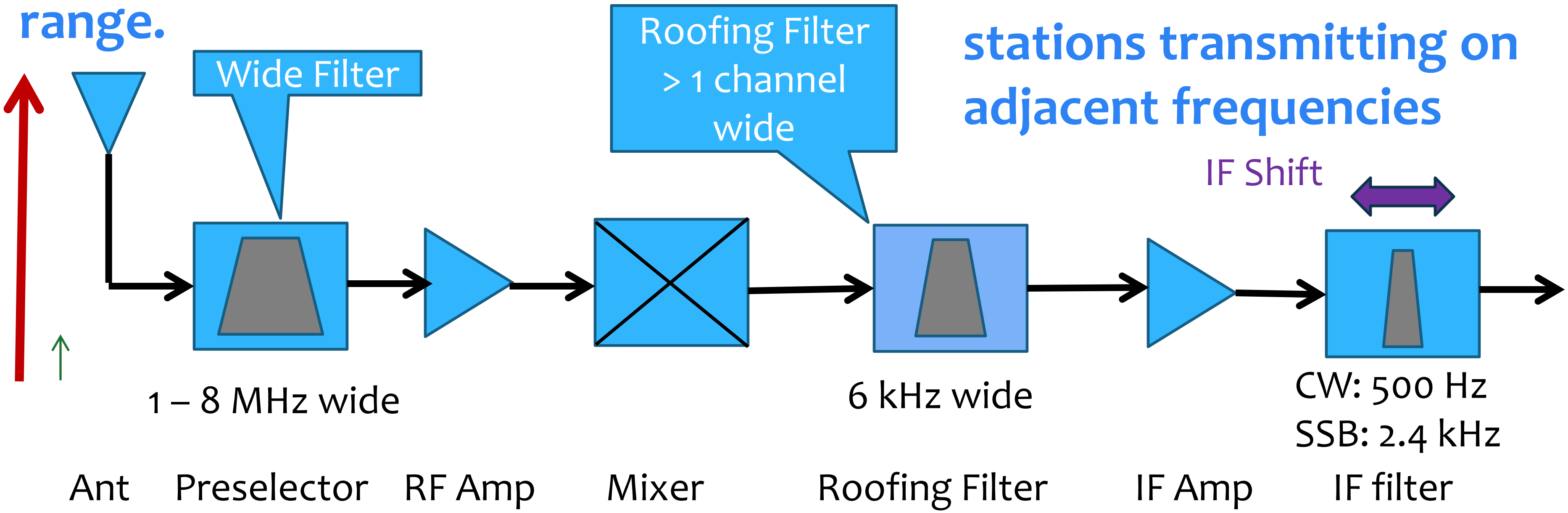


The Roofing Filter & IF Shift

Pg. 7-15

A **roofing filter attenuates strong signals on nearby frequencies, improving the blocking dynamic range.**

An IF-Shift control can help, reducing interference from stations transmitting on adjacent frequencies



Filters, Filters and More Filters

The view looking down the "throat" of a receiver

Pg. 7-15

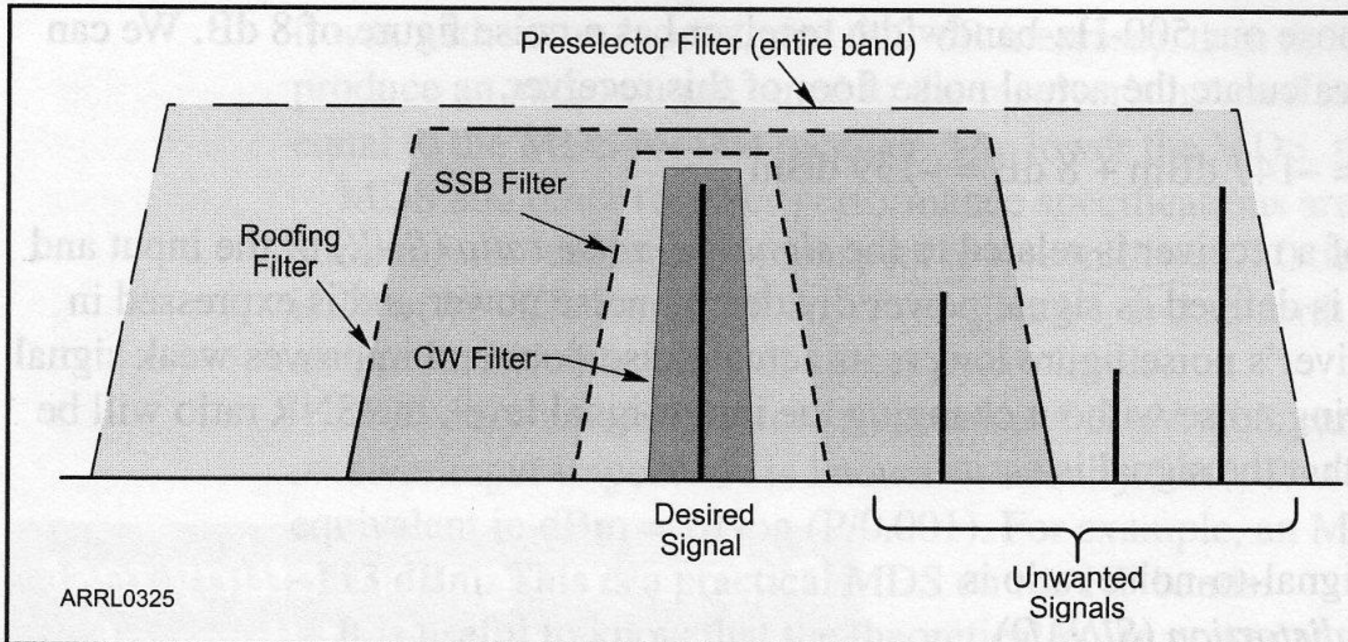
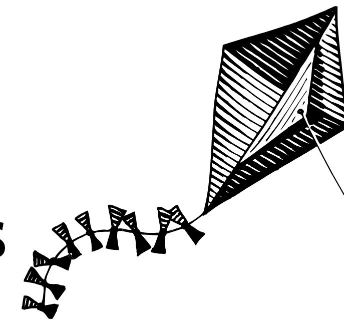


Figure 7-13 A typical multiple-conversion superheterodyne receiver has several stages of filtering. Preselector filters reject out-of-band signals. Roofing filters at the input to each IF further restrict receiver bandwidth, attenuating strong in-band signals that might overload the IF amplifiers. In the final IF stage, single-signal filters are used to select just the desired signal.

Dynamic Range

Pg. 7-15 & 16



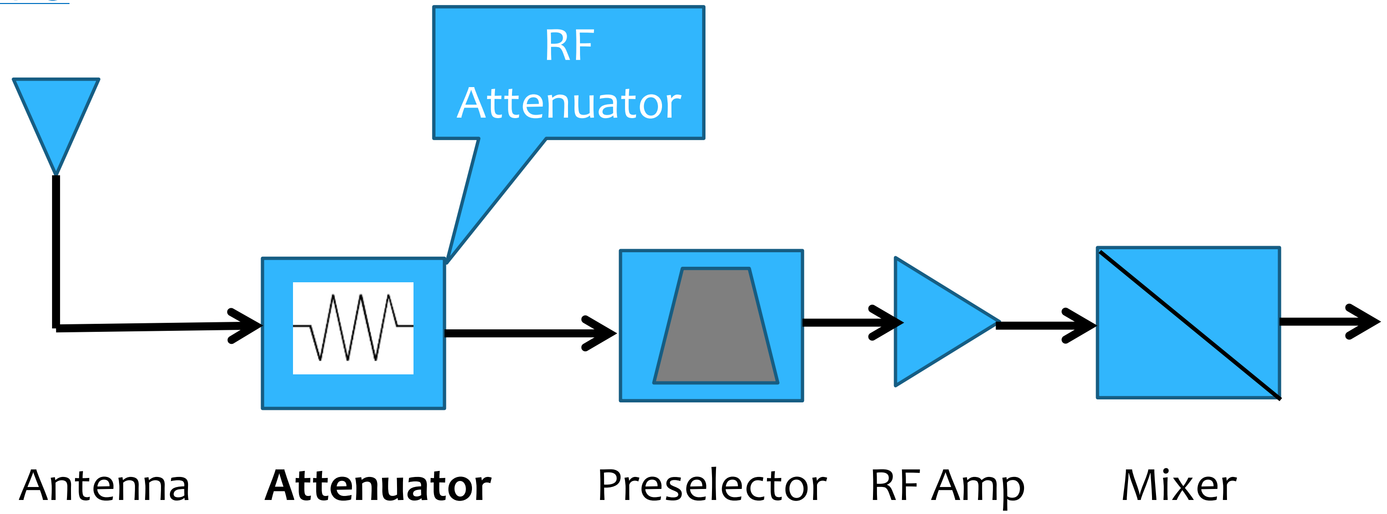
Dynamic Range in Analog Radios

* Dynamic Range is a measure of a radio's ability to receive a weak signal in the presence of a strong nearby interfering signal.
* 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**

RF Attenuator

Pg 7-13

* An RF **attenuator** will reduce the input level to the front-end stages
  * This may be helpful in preventing overload from a strong local station
* **Both the desired and the undesired signals are reduced by the attenuator, therefore it <u>has little to no impact on the signal-to-noise ratio</u>**



BDR & Gain Compression

Pg. 7-16

* Blocking Dynamic Range (BDR) is the difference in dB between the level of the receiver's MDS noise floor and the level the signal level that will cause 1 dB of compression E4D06

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

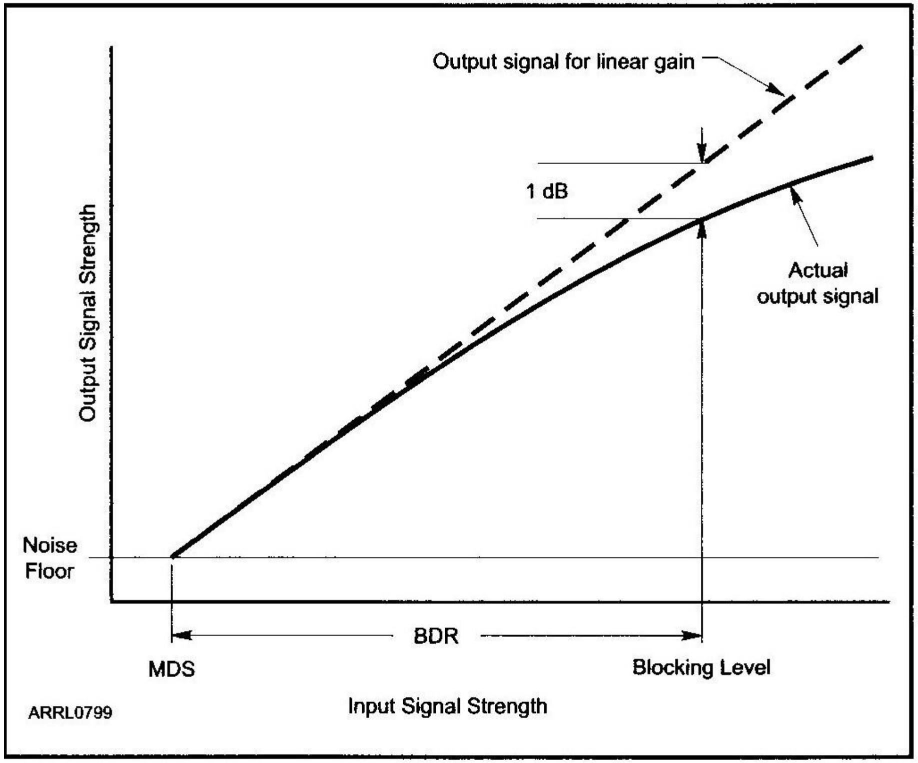


Figure 8-11 — Gain compression occurs when the input signal is too strong for the receiver to develop full gain. Blocking Dynamic Range (BDR) is measured in dB from MDS to a level at which the input signal strength causes a 1 dB drop in receiver gain, called the blocking level.

Blocking Dynamic Range

Pg. 7-16

* 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).

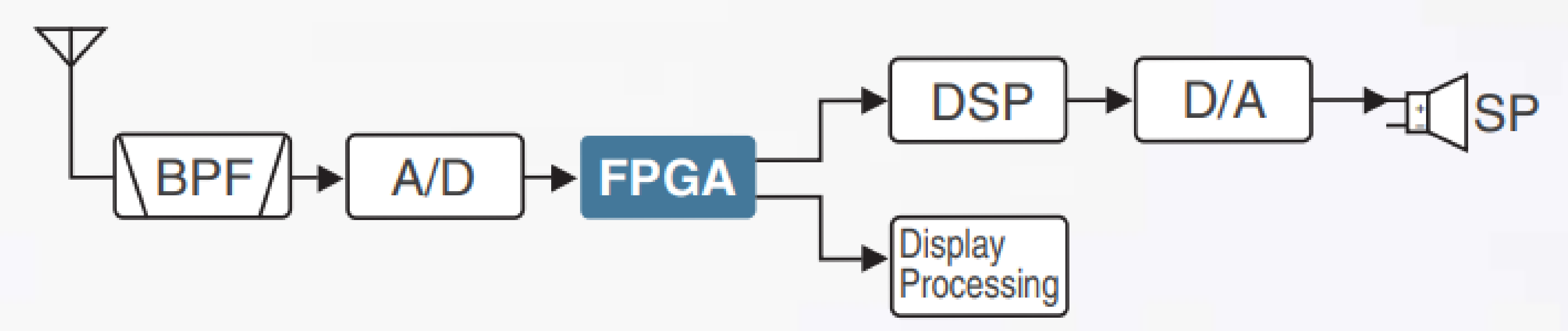
* **Desensitization** is the reduction in receiver sensitivity caused by strong signals near the receive frequency.

* We may be able to reduce the desensitization by switching in Attenuation or reducing the RF Gain.

SDR -- Software Defined Radio

Icom IC-7300

* Signals from the antenna are converted to digital information by an analog-to-digital converter, then to a DSP
* This minimizes the traditional analog radio circuitry

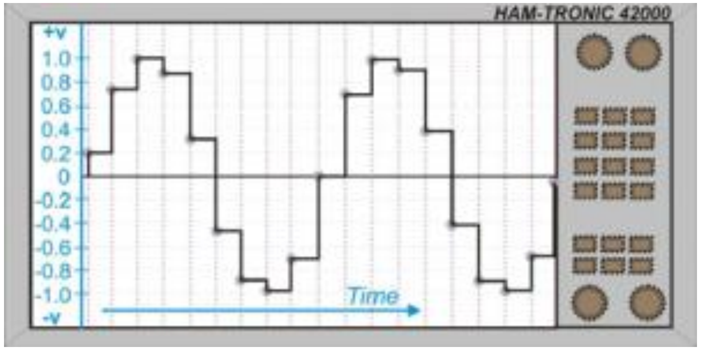


Dynamic Range of a SDR Radio

Pg. 7-16

Strong-signal performance in a Software Defined Radio

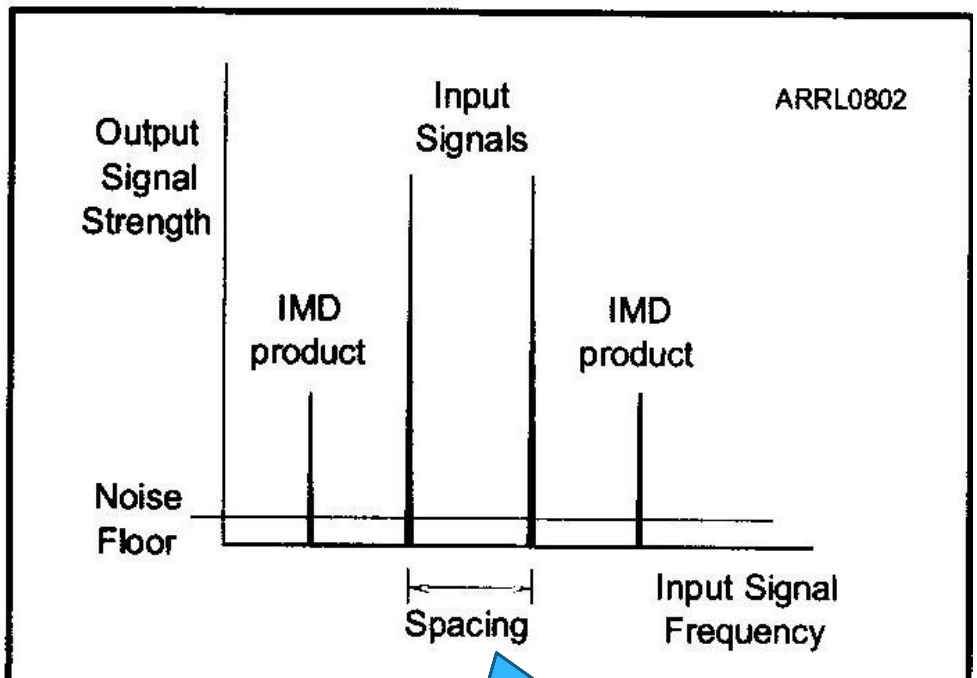
* **Sample Width** is the number of bits in each sample of the input signal to the analog-to-digital converter in the DSP. This is related to a reference voltage
* The **larger the sample width**, the larger the range of signals the DSP can process linearly, thus the better the SDR's dynamic range
* If the input signal **exceeds the analog-to-digital converter's reference voltage**, the DSP chokes and **overload** occurs! E4C08



Receiver Intermodulation (IMD) in Analog Receivers

Pg. 7-18

- 3^{rd} order IMD products can be created within a receiver.
- Two very strong in-band undesired signals can cause odd-order IMD products that are also in band. These are particularly problematic because they are in band. E4D11
- Pg 7-18 gives you the math that explains it.



The tones will be equally spaced in frequency.

Fig 7-15

Intermodulation (IMD)

Pg. 7-18/19

* 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 = **146.34 MHz**
* A similar product can be generated with a strong **146.61** MHz signal

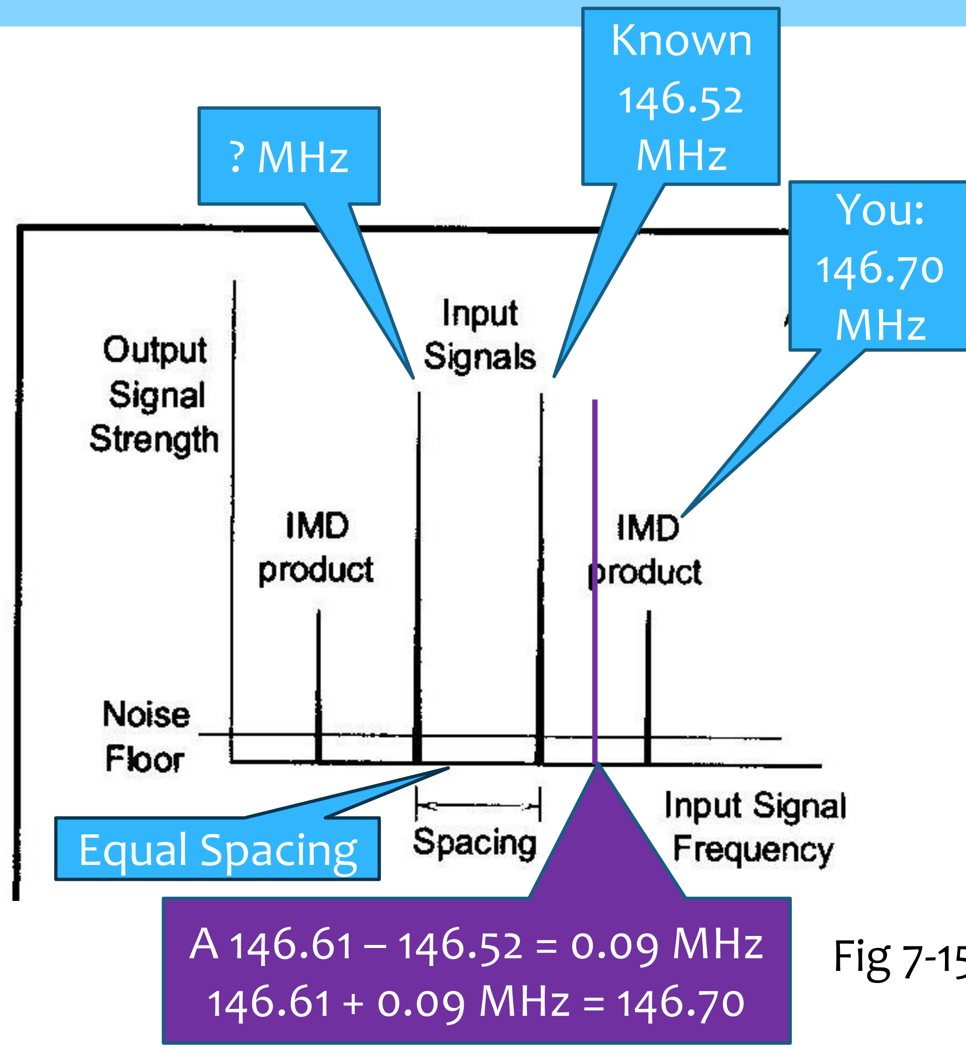


Fig 7-15

Intermodulation (IMD)

Pg. 7-18

Let's take a look at the levels:

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

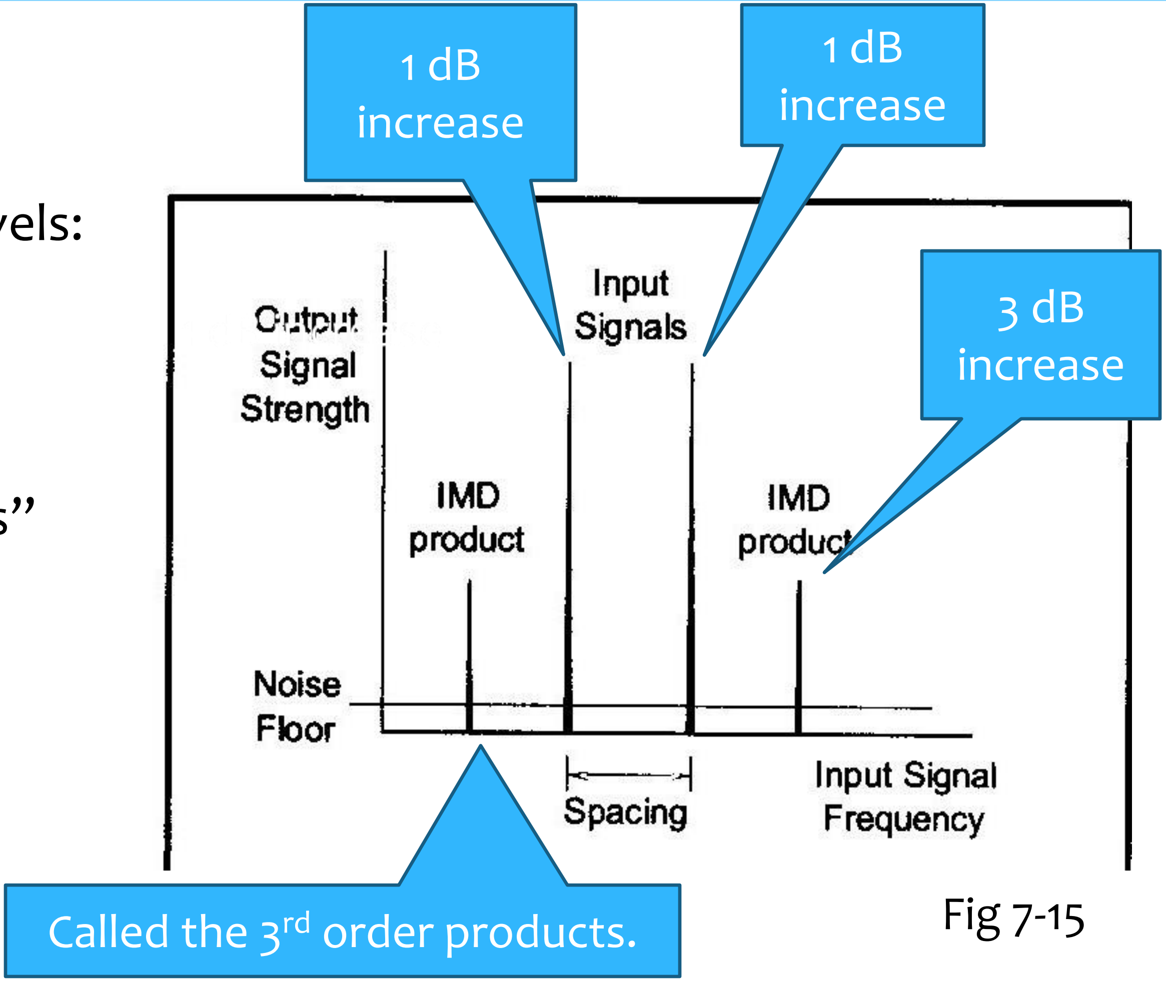
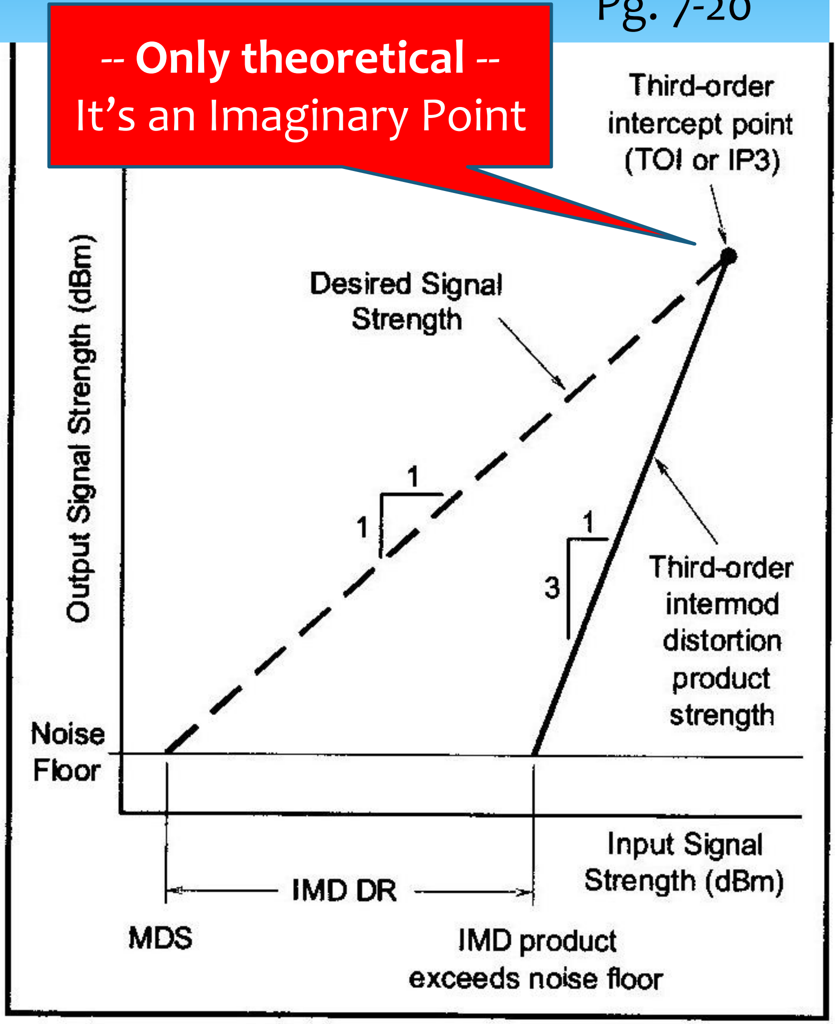


Fig 7-15

3^{rd} Order Intercept Point

Pg. 7-20

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



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. E4D10

* The higher the 3rd order intercept point spec, the better.

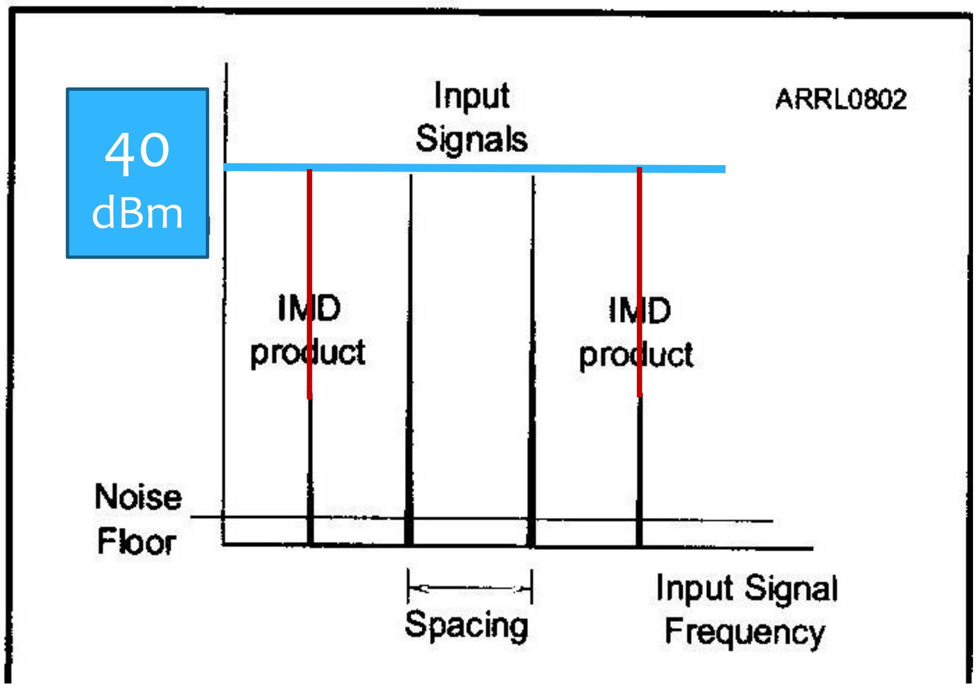


Fig 7-15

Example of a Rx IMD Spec

FYI

* 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)

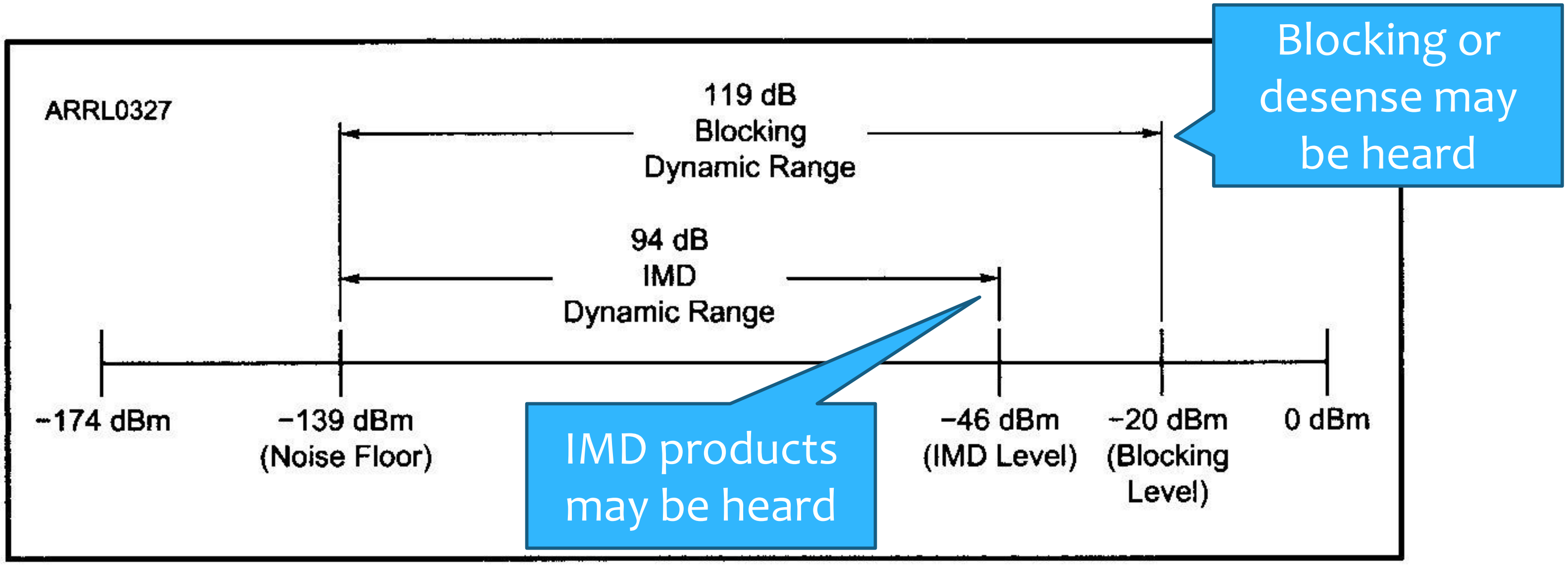
SSB (2.4kHz BW)
10 kHz SEP.:106 dB, IP3 +40 dBm

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. 7-20

* If a receiver has poor dynamic range, cross modulation or IMD products will be generated and desensitization from strong signals can occur. E4D02



Phase Noise

Pg 7-20

- 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.
- **Reciprocal mixing** occurs when the local oscillator phase noise mixes with a strong adjacent-channel signal and interferes with the reception of a desire signal

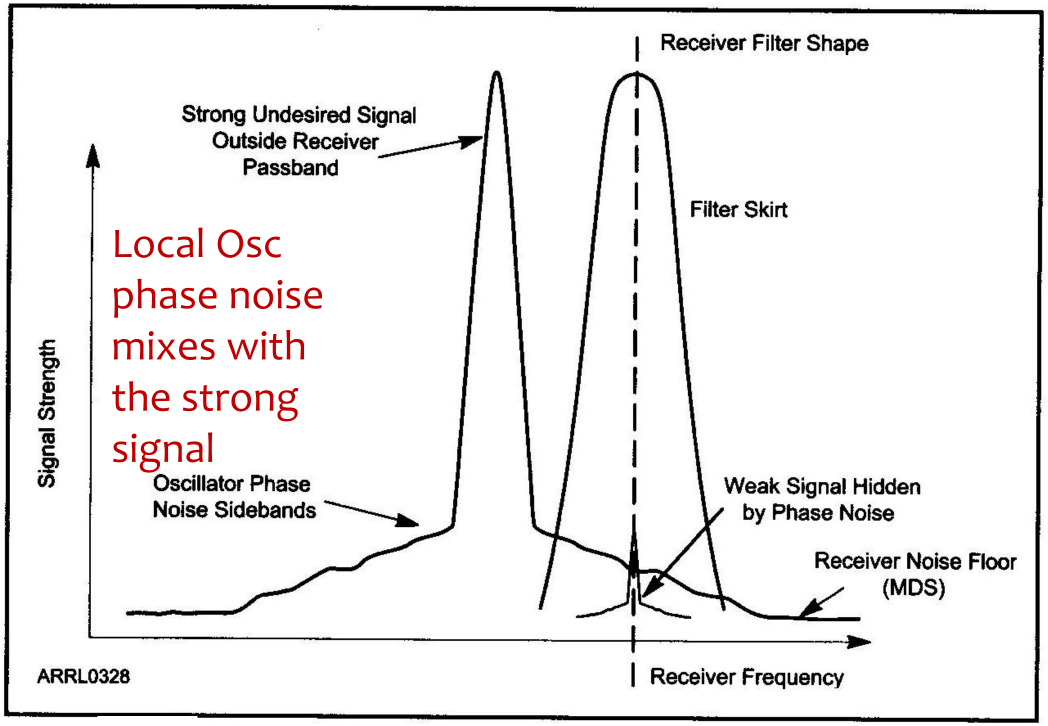


Figure 7-17 - In a receiver with excessive phase noise, a strong signal near the receiver passband can raise the apparent receiver noise floor in the passband. This increased noise can cover a weak signal that you are trying to receive.

FM Capture Effect

Pg 7-22

- *FM voice receivers exhibit a characteristic known as* ***capture effect where a strong signal suppresses 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 top of the desired signal.

E4C04 What is the noise figure of a receiver?

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

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 7-3

Intermodulation from Transmitters

Interfering with a Receiver

Pg. 7-22

* A specific frequency relationship must exist

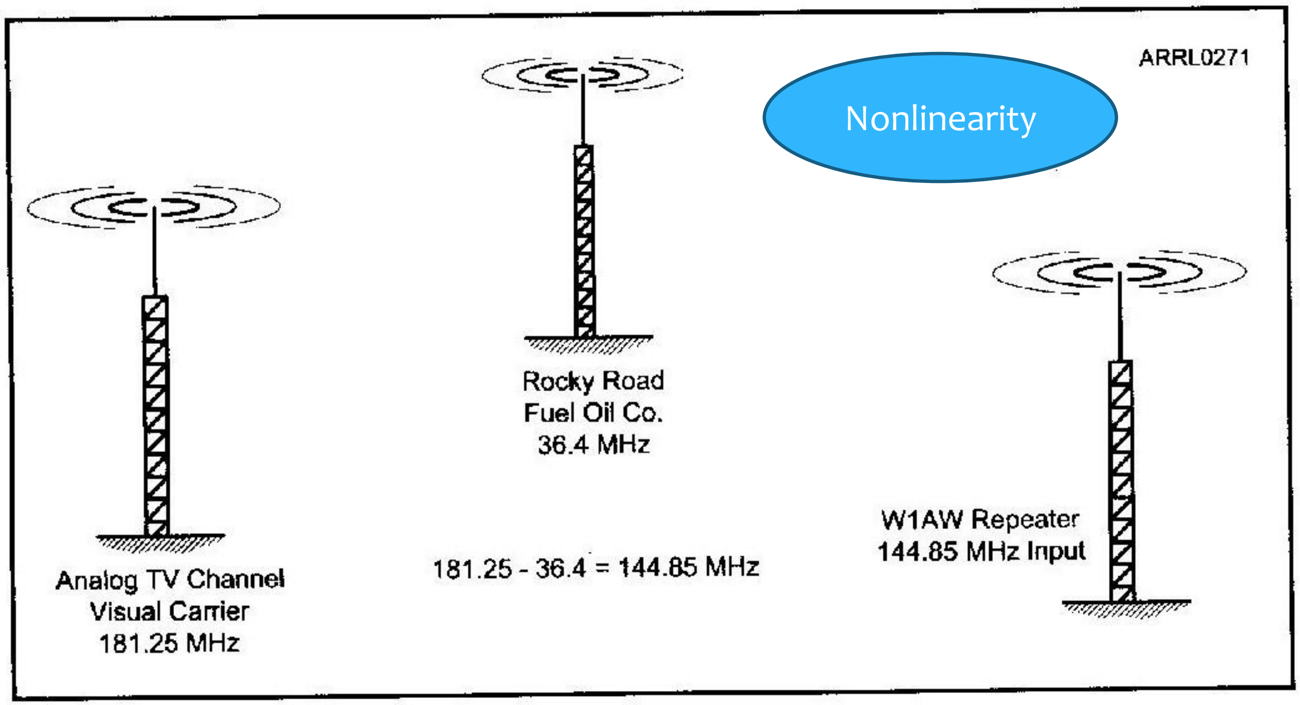


Fig 7-18

Correction in the second paragraph under Transmitter Intermodulation

Pg. 7-23

Nonlinear circuits or devices can cause intermodulation distortion in just about any electronic circuit. IMD (als~~o 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.

Intermodulation Distortion - IMD

Pg. 7-23

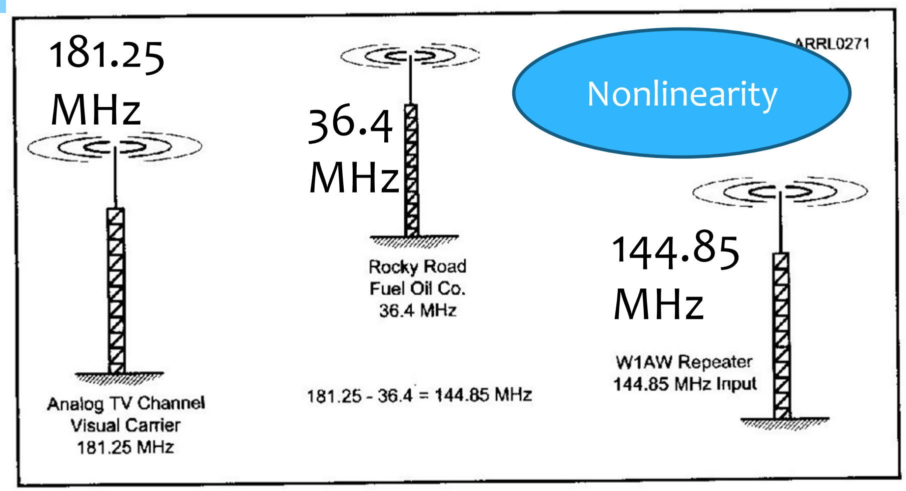


Fig 7-18

If we have:

* A specific frequency relationship
* And we have a **nonlinearity**

We can get Intermodulation which is

* 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.

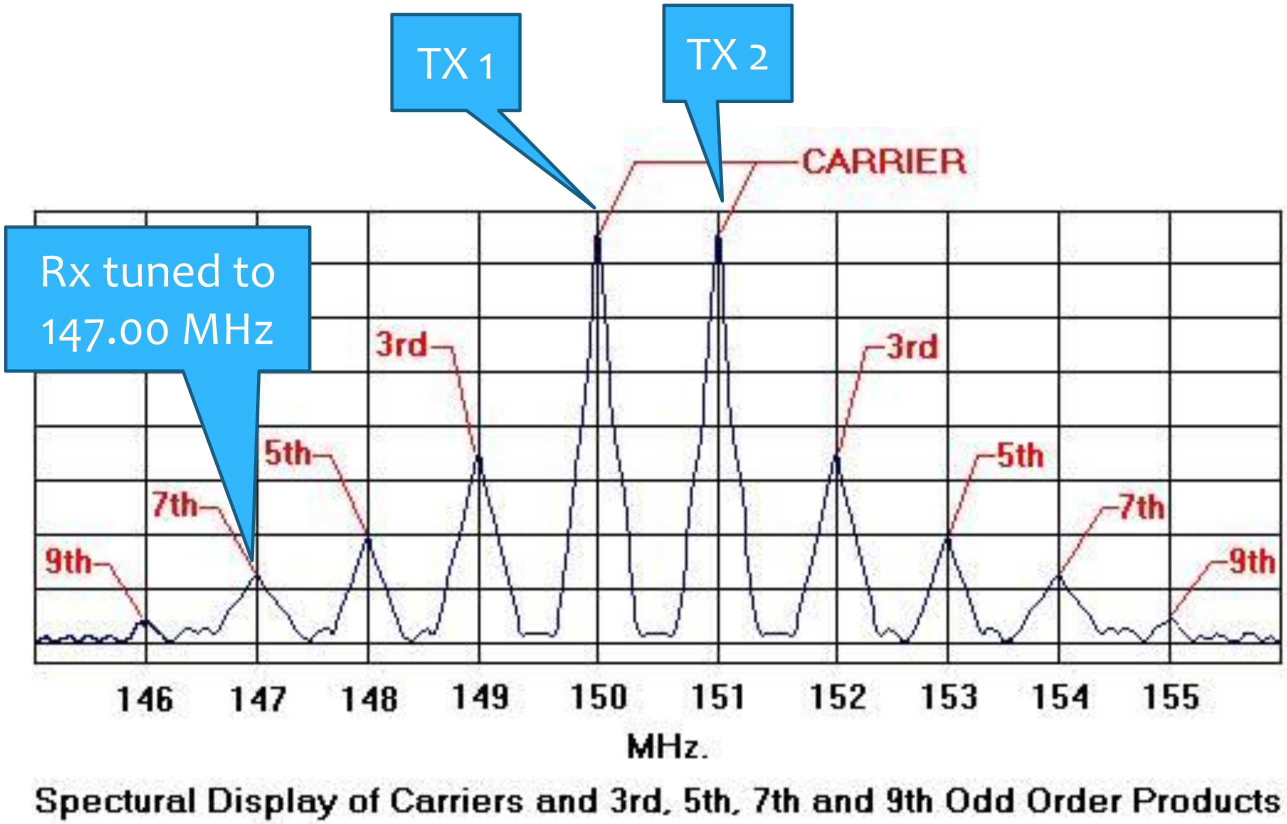
Nonlinearities Cause IMD Products

A mixing action occurs in nonlinear devices

Pg. 7-23

Nonlinearities can occur in:

- Receivers
- Transmitters
- Other non-linear electronic devices and circuits
- Passive connections

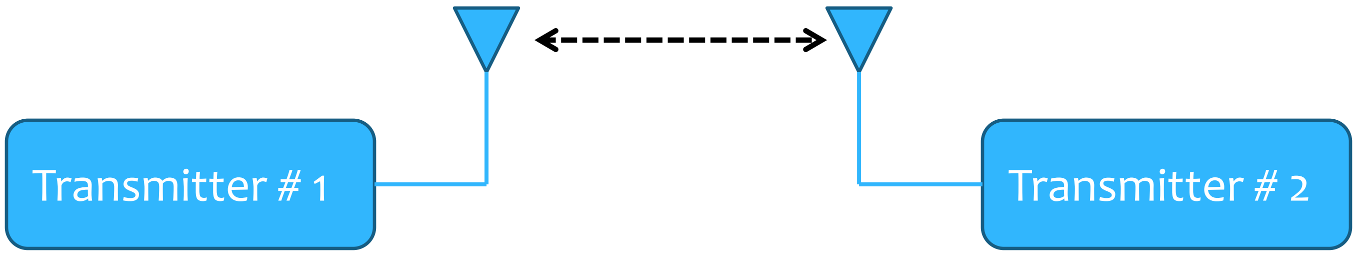


www.midians.com/html/intermod-explained.php

Repeater Sites With Multiple Repeaters are at Risk of IMD

Pg. 7-22

* IMD can be produced when two transmitted signals mix in the final amplifier of one or both of the transmitters. This is especially true if they are located in close proximity to each other.



Circulators and Isolators

Pg. 7-22

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

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

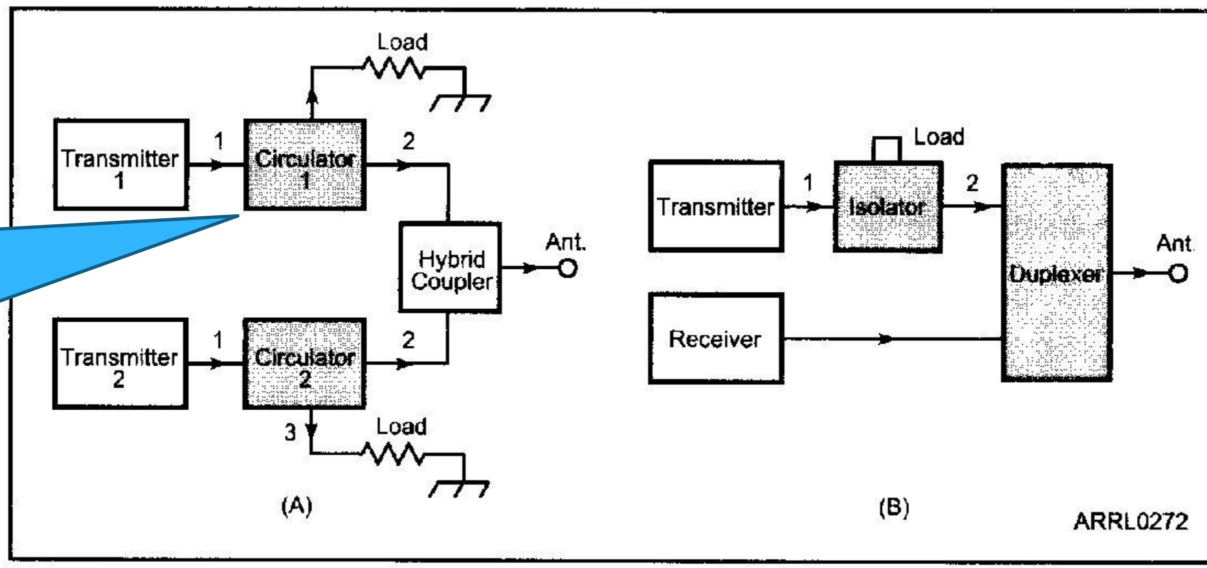


Figure 7-19 - This block diagram shows the use of circulators and an isolator. Circulators may be used to share one antenna with two transmitters, as in A, particularly at multi-transmitter sites. Duplexers are also used along with the circulators. In B, an isolator is placed between the transmitter and duplexer to reduce intermodulation.

Nonlinear Connections

Pg. 7-24

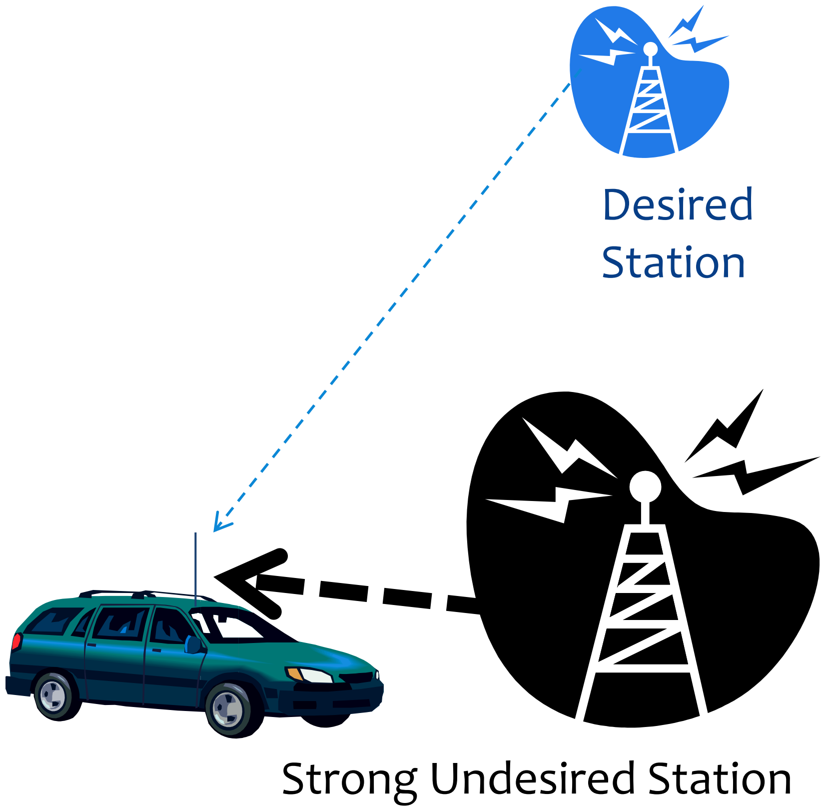
* Corroded metal joint are very nonlinear.

* If two strong AM broadcast stations are nearby, the signals can mix at the joint and generate spurious IMD products across the MF and HF frequencies.

Cross Modulation

Practical Information

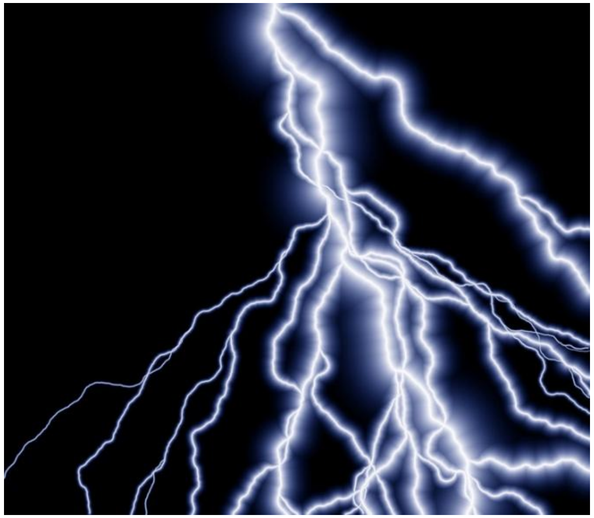
* Unlike IMD, **Crossmod does not require** a specific frequency relationship
* A strong undesired transmitter simply overwhelms the receiver's front end.
* The modulation of the strong undesired signal is combined with that of the desired signal.
* The off-frequency unwanted signal is heard in addition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



Atmospheric Static Noise

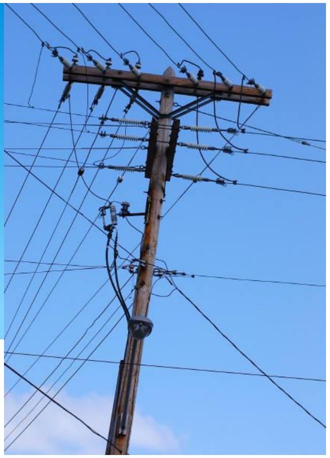
Practical Information

* One of the most common forms 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



AC Line Noise

Pg. 7-24



* 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

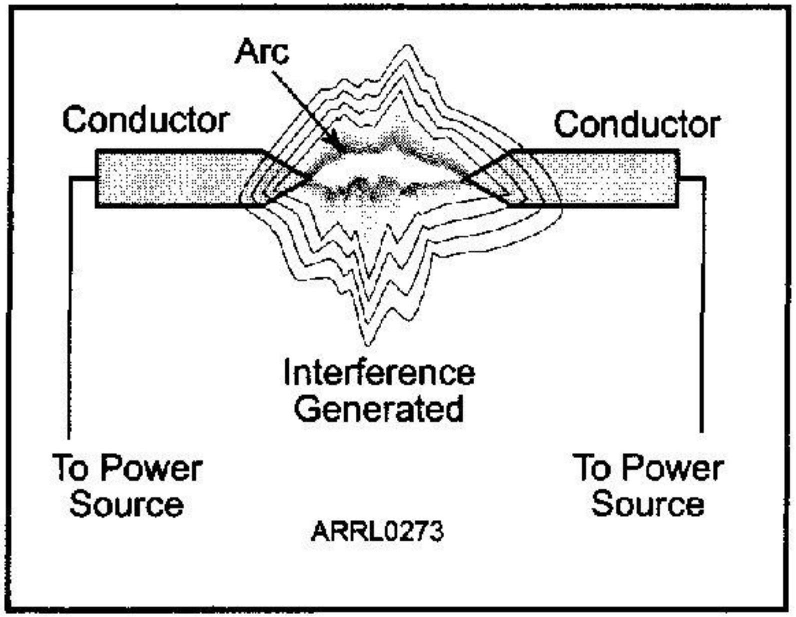


Figure 7-26 — An electrical arc can form through the air gap between conductors. Arcs radiate noise across a wide RF spectrum.

Brute Force

Pg. 7-25

* 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.

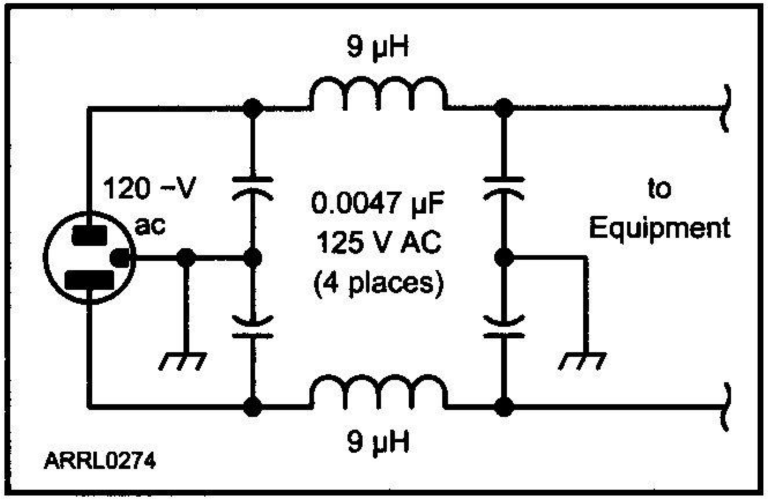
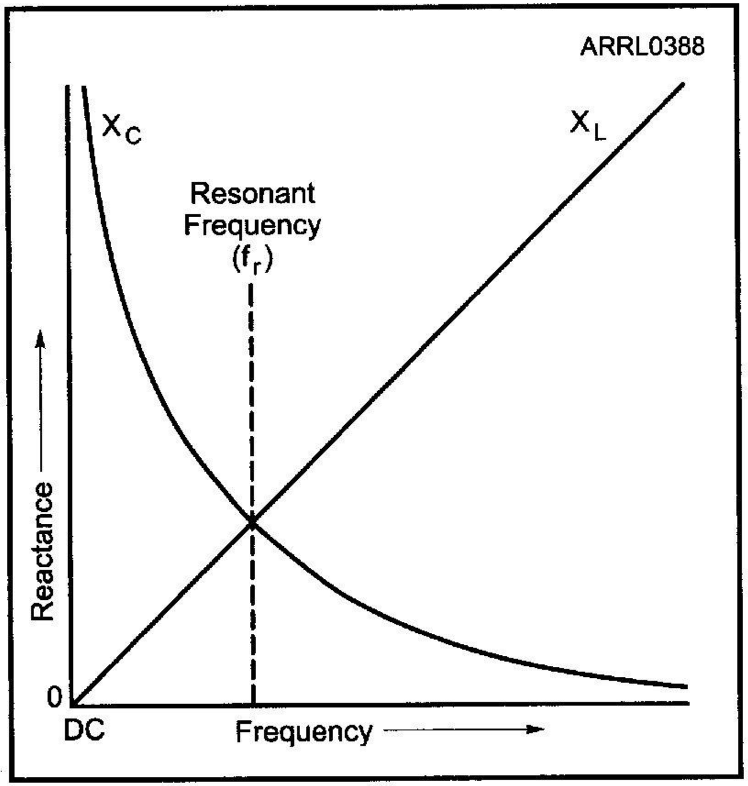


Figure 7-21 — A "brute force" ac line filter may reduce or eliminate line noise when installed in the power leads to an ac brush-type motor.

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



Noise Hunting

Pg. 7-25

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.

K0NK Noise Hunting

- Test with:
  - Full House ON
  - Mains OFF
  - 240 V Restored
- Record:
  - Frequency
  - Mode
  - Antenna
  - Noise Level per S-meter
  - Date/day/time

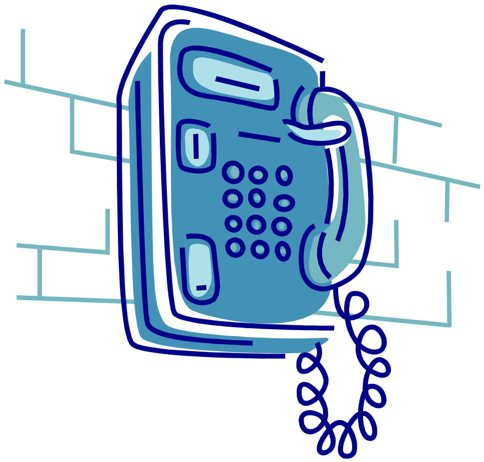
Jan 13 23 Noise Survey
Friday 1pm

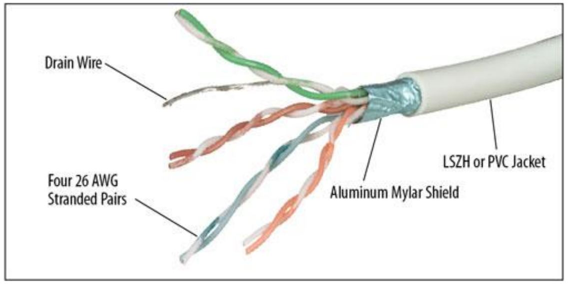
Freq	Mode	Ant	Full House ON	Main OFF	240v Restored
1.820	CW	Shunt	S9	S8-9	S8-9
3.920	LSB	Dipole	S9	S9	S9
7.270	LSB	Dipole	S5-7	S5-7	S7-9
10.115	CW	Loop	S4-6	S7-9	S5-7
14.250	USB	Vert	S7-9	S7-9	S7-9
21.350	USB	Vert	S5-7 S4-6	S3-5	S4-6
28.400	USB	Vert	S1-2	S0-1	S7-9 ↓ S1-2

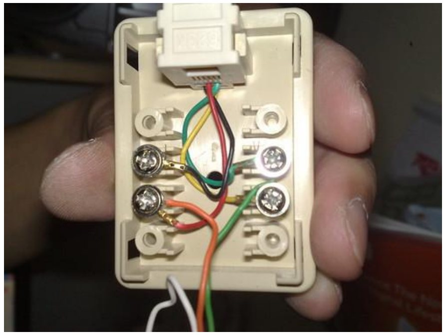
Your Transmitter May Cause Interference to Other Electronics

Pg. 7-25

- Your transmitted signal can cause **common mode** interference to devices such as TV, radio or telephone.
- **Common-mode currents** flow equally on all conductors of an unshielded multi-conductor cable.
- **Even shielded cables can receive or radiate common-mode interference.**







Noise, Noise and More Noise

Pg. 7-25

* **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.**

Automotive Noise

Pg. 7-27

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. 7-27

Charging System Noise

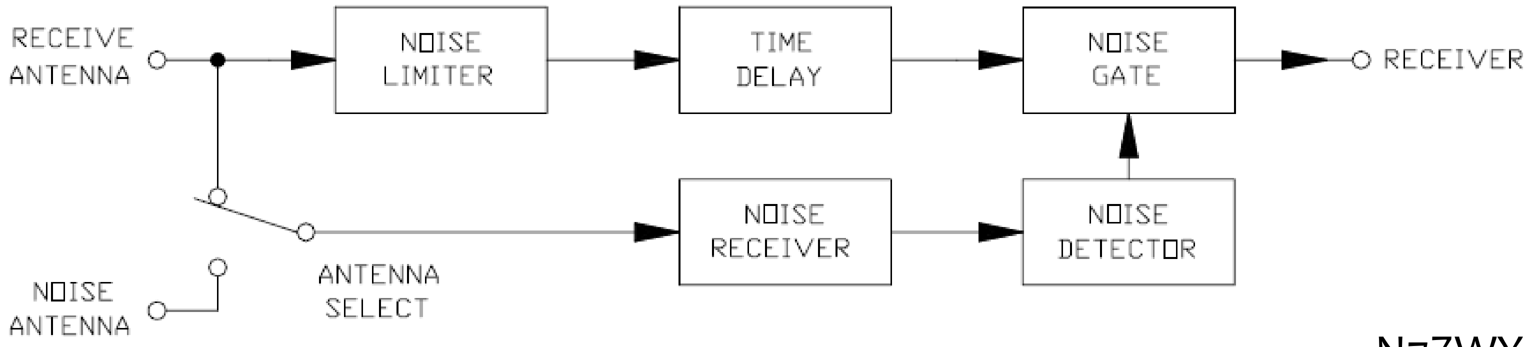
- Alternator whine is a common form of conducted interference and can affect both transmitting and receiving.
- Standard fixes:
  - Connect both positive and negative power leads of the radio directly to the battery. Fuse each lead.
  - **Install ferrite chokes on the charging system leads.**

Note: Ferrite is normally used for the suppression of higher frequency noise.

Noise Blankers

Pg. 7-27

* 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.

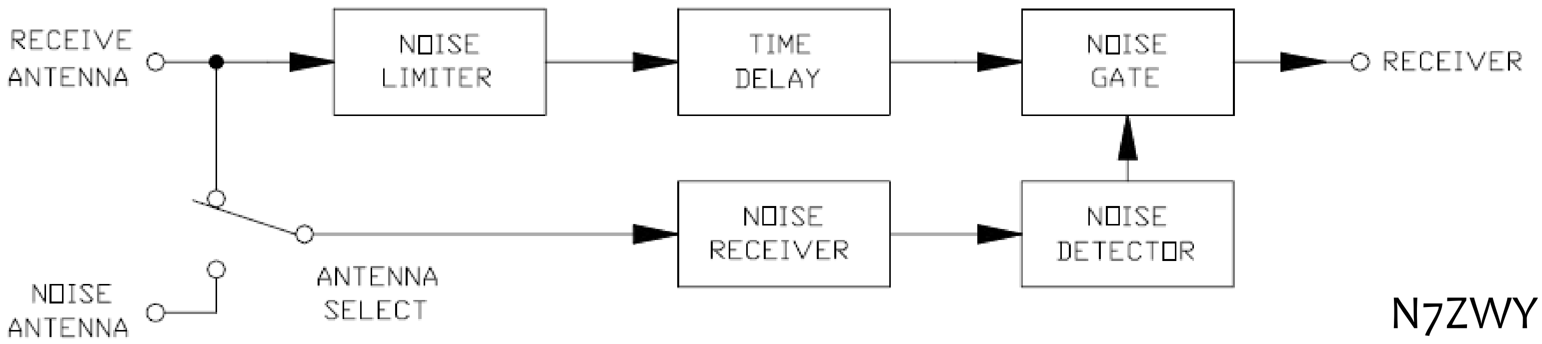


N7ZWY

Noise Blankers

Pg. 7- 28

* The noise blanker must detect signals that appear across a wide bandwidth.
* **A noise blanker can be fooled by strong signals** on the band, shutting down the receiver as if they were noise pulses. **This can cause severe distortion of desired signals, even if no noise is present. Nearby strong signals may falsely appear to be very wide and splattering.**



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DSP Noise Reduction

Pg. 7-28

* DSP noise reduction filters operate by using adaptive filter techniques in the software
* **DSP noise reduction can be effective on "white noise" and it may also work for ignition noise and power line noise.**
* While **automatic notch filters** can track and remove interfering tones, **they may also remove CW** as well as the interfering **signal.**

E4E10 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

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

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