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Frequency Modulation Fundamentals

User's Guide

Computer-Based Training Course

H5267A

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Purpose of this Course

This course is designed for those who have a basic knowledge of electronic theory and circuits and wish to learn about frequency modulation. When you have completed this course, you will have a basic knowledge of the measurement techniques as well as the theory, technology and terminology of frequency modulation.

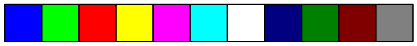
Conventions

The following conventions are used throughout this manual:

- **Bold** is used to emphasize important information in the text or to highlight text to be entered from your computer's keyboard.
- *Italics* are used for titles that refer to the course and its modules, to indicate selections to be made, or for emphasis.
- **<Keystroke>** indicates a key or combination of keys to be pressed.

Table of Contents





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1

Frequency Modulation Fundamentals Computer-Based Training

- **Course Objectives**
- **The Frequency Modulation Fundamentals Program**
- **Hardware/Software Requirements**

Course Objectives

When you have completed this course, you will be able to:

- Describe basic modulation concepts.
- Describe narrowband frequency modulation.
- Compare and contrast frequency modulation and phase modulation.
- Describe basic frequency modulation parameters.
- Describe FM and ϕM modulation and demodulation techniques.

The Frequency Modulation Fundamentals Program

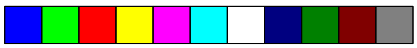
The program needs to be downloaded from www.educatorscorner.com.

Hardware/Software Requirements

To use *Frequency Modulation Fundamentals,* you will need a Vectra computer or an IBM PC/AT compatible computer equipped with the following:

- DOS 3.1 or higher
- Windows 3.0 or higher
- 4 MB of RAM
- A hard disk with 5.5 MB of available space
- One 1.44 MB diskette drive
- A Microsoft-compatible mouse
- VGA or higher resolution monitor. When using SVGA, the program may occupy only a portion of the screen.
- A processor running at 60 MHz is recommended for optimum performance. The program will run satisfactorily on slower processors, but will take more time to complete.





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2

Getting Started

- **Setup and Installation**
- **Starting the Program**

Setup and Installation

Follow these steps to setup and installing Frequency Modulation Fundamentals.

1. Save the file FMF.exe to your computer.
2. Double-click on FMF.exe to unpack.
3. Choose the current file destination or change the folder name to another temporary directory. Note: these files will not be deleted during installation.
4. Click the unzip button.
5. Go to the destination folder you selected and open up the Set Up folder.
6. Then open up the Disk 1 folder.
7. Look for the setup.exe file and click on it to begin installation.
8. The set up and installation will start up.
9. Follow the step by step instructions for installation.

Starting the Program

Click on the Start button; go to Programs and look for FM Fundamentals *and open your new program*.

You can go back and delete the setup files unpacked in the temporary folder.

3

Troubleshooting

- **Installing**
- **Uninstalling**
- **During the Program**

Installing

Below are error messages or conditions which could appear while you install, uninstall, or use *Frequency Modulation Fundamentals,* along with their causes and solutions.

The target location must be different from the source
Try another disk as the target.

The disk drive is an invalid disk
The disk can't hold the program.
Try a different disk drive.

There is not enough space
There is not enough room on the hard drive for the program.
You will need to clear enough room for the program.

Unable to create specified path
You may have typed in the wrong path. Retype the path.

Unable to copy, compress, or delete file
The file is missing or corrupted on the disk.
You may need a new copy if installing.
You may need to use Windows File Manager if uninstalling.

Uninstalling

Unable to find *Frequency Modulation Fundamentals* subdirectory?

You may have typed in the wrong path. Retype the path.

Unable to copy, decompress, or delete file?

You may not be uninstalling from the correct subdirectory or the file may already have been deleted.

During the Program

There is not enough memory...

You may not have enough RAM. Remember that you need at least 4 MB.

Text or graphics appear misaligned or overlapping?

Some SVGA video drivers distort the graphics display. Switch your monitor to normal VGA (640 x 480) resolution.

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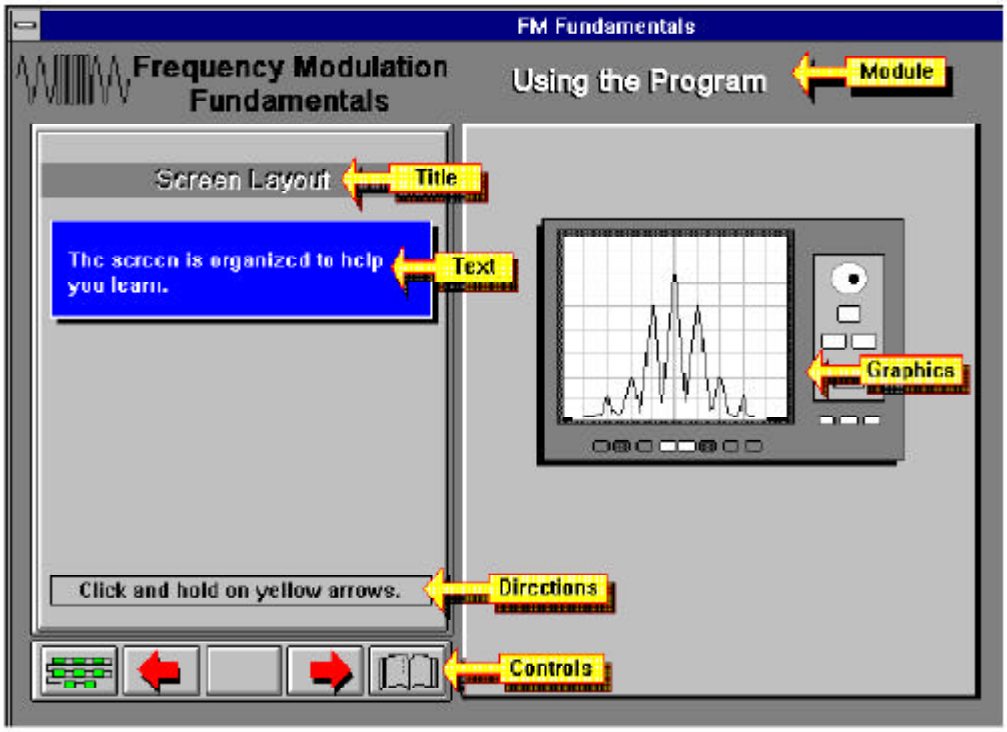
4

Using the Program

- **Screen Layout**
- **Navigating**
- **Math Reference Tool**
- **Glossary**
- **Hotwords**
- **Printing**
- **Exiting**

Screen Layout

A typical screen is organized like this:



Module
Tells you which module you're currently working on.

Title
A short description of each page

Text
Provides instruction, description, or questions.

Directions
Tells you where to click.

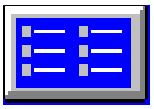
Graphics
Illustrates the meaning of the text.

Controls
Provides navigation through the course.

Navigating

These four controls are used to navigate through *Frequency Modulation Fundamentals.* They are grouped in a row on the lower left part of the screens.

Control your course by pressing these buttons:

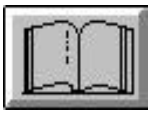


Returns you to the main menu.

Returns you to the previous screen.

Takes you to math reference tool.

Advances you to the next screen.



Takes you to the glossary.

There is also a page box in the lower left corner which you can use to go to any page of the course. To use the page box, click on it, type the page number you want and press <**Enter**>.

Returning

The glossary and math reference tool buttons will take you to those parts of the course for review or reference. You can return to the exact location you left at any time by clicking on the **Return** button.

Math Reference Tool

The math reference tool provides additional information about the mathematical descriptions presented in the material. The math reference tool is not always active. When it is active, click on the math button for more information.

Glossary

The glossary alphabetically lists and defines the technical terms presented in this course. Each tab in the glossary covers listings under two letters of the alphabet (the first covers A-B, the second C-D, and so on) except the last, which covers W-Z.

To use the glossary, clock on a tab and scroll up and down to view all the listings.

Clicking on the **Return** button will return you to exactly where you were in the course before you entered the glossary.

See the Appendix for a complete listing of the terms in the glossary.

Hotwords

Technical terms concerning frequency modulation may be hotwords. Clicking on a hotword will display a short definition of the term.

Hotwords are underlined in the text. When positioned over a hotword, the cursor will change from an arrow to a window. Clicking on a hotword will display a short definition. For a more detailed definition consult the glossary.

Printing

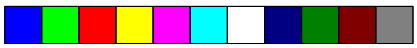
To print a screen, press **Ctrl-P** and select **Print**.

Exiting

You can exit the program from any screen by clicking the system menu box from the upper left corner and selecting **Close** from the menu.

You can also exit by using the **<ALT>** + **<F4>** combination.





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5

Course Contents

- **Module Description**

Module Descriptions

Frequency Modulation Fundamentals consists of seven modules covering the following topics:

Module 1 **Modulation Basics**
reviews basic modulation concepts and introduces frequency modulation.

Module 2 **Narrowband FM**
explains narrowband FM (NBFM) as an introduction to frequency modulation.

Module 3 **Frequency Modulation**
explores frequency modulation concepts in depth.

Module 4 **Phase Modulation**
examines phase modulation concepts in depth.

Module 5 **Modulation Measurements**
explores methods of measuring modulation parameters.

Module 6 **Modulation and Demodulation**
investigates FM and ϕM modulation and demodulation techniques.

Module 7 **Review Questions**
Checks mastery of the material.

6

Appendix

- **Glossary of Frequency Modulation Terms**

Glossary of Frequency Modulation Terms

AM
See Amplitude Modulation.

AM Broadcast Band
The broadcast radio frequency band in the MF region from 550 kHz to 1650 kHz. The AM broadcast band is divided into 10 kHz channels which use full-carrier DSB modulation with a maximum allowed modulation frequency of 5 kHz.

Amplitude Modulation (AM)
A modulation process in which the instantaneous amplitude of a sinewave carrier is caused to vary from the carrier amplitude by an amount proportional to the instantaneous amplitude of the modulating wave.

Amplitude Shift Keying (ASK)
AM technique for transmitting digital data; uses one amplitude level to encode a “1” and another to encode a “0.”

Angle Modulation
Modulation technique in which the angle of the sinusoid carrier is the characteristic varied from its reference value. Frequency modulation and phase modulation are particular forms of angle modulation. See Frequency Modulation and Phase Modulation.

Antenna
The part of a transmitting or receiving system designed to radiate electromagnetic waves. Antenna components must be comparable in size to the wavelengths to be radiated. Many communications applications employ a dipole antenna design consisting of a thin metal conductor a half-wavelength or quarter-wavelength in length.

Glossary of Frequency Modulation Terms

ASK
See Amplitude Shift Keying.

Audio
Any electromagnetic wave frequency corresponding to a normally audible sound wave; ranges roughly from 15 Hz to 20,000 Hz. Indicates a device or system intended to operate at audio frequencies.

Audio Frequency
See Audio.

Band-Pass Filter
An electronic device that transmits one group of frequencies while rejecting both lower and higher frequencies.

Bandwidth
The range of frequencies contained in or occupied by a signal; the range of frequencies that a device can process.

Baseband
The band of frequencies occupied by a signal before it modulates a carrier signal. The baseband signal usually ranges over distinctly lower frequencies than the carrier and may include direct current (zero frequency).

Bessel Functions
Functions resembling damped sinusoids that have certain relationships with trigonometric functions which are very important to modulation theory. Bessel functions take the form Jn(x) which denotes a Bessel function of the first kind (i.e., J), of the nth order, and of argument x. Bessel functions can be expanded to power series which are useful in analyzing angle modulated waves as sinusoid functions.

Glossary of Frequency Modulation Terms

Bessel Null
A term used for a Bessel function zero, in particular for the Jo Bessel function. The value of the argument x (i.e. the root value) for which Jo(x) equals zero. The Jo function has several roots, e.g. 2.4048, 5.5201, 8.6537, 11.7915, 14.0309, etc.

Beta (β)
See Modulation Index.

Broadcast
A signal transmission made to or over a large area, usually to many receivers; generally refers to radio or television broadcast applications. See AM Broadcast Band and FM Broadcast Band.

BW
See Bandwidth.

BWeff
See Effective Bandwidth.

C/N; CNR
See Carrier-To-Noise Ratio.

Cable; Coaxial Cable
A two-conductor (center conductor, shield system), concentric, constant-impedance transmission line.

Carrier, RF Carrier
An electrical signal that is modified in frequency, amplitude, and/or phase in order to transmit an information signal from one point to another.

Carrier Signal; Carrier Wave
See Carrier.

Glossary of Frequency Modulation Terms

Carrier-To-Noise Ratio
The ratio of the carrier power to the noise power. Can be defined in many ways but generally the ratio mean power of the unmodulated carrier to mean noise power after specified band limiting and before any nonlinear process such as amplitude limiting and detecting.

Carrier-Tracking-Loop
A phaselock loop demodulator design in which the modulation spectrum falls outside the loop bandwidth. As a result the PLL control loop maintains lock (follows or "tracks") with the carrier but not its frequency variations due to modulation.

Channel
A connection between two points for the transmission of information, as in a communications channel.

Common-Channel Interference
Undesirable frequencies affecting transmission which originate from another signal transmission with the same or nearly the same carrier frequency, i.e. the situation arising when two signals occupy the same frequency spectrum.

Demodulation
The process of recovering (separating) an information signal from a modulated carrier signal.

Demodulator
A circuit that recovers the modulating (information) signal from a modulated carrier.

Depth of Modulation
See Modulation Index.

Glossary of Frequency Modulation Terms

Detected Signal
The recovered information signal in the receiver after demodulation.

Differentiating Network
See Differentiator.

Differentiator; Differentiating Network
A device producing an output proportional to the derivative of one variable with respect to another.

Direct Modulation
Modulation system in which the baseband or information signal is applied directly to phase modulate or frequency modulate to the carrier.

Digital Radio
Radio systems which employ digital modulation techniques to transmit digital data. Generally used for terrestrial, line-of-sight digital links in communications applications which operate at UHF and MW frequencies.

Discriminator
A circuit in which the output is dependent upon how an input signal differs in some aspect from a standard or from another signal. See Frequency Discriminator.

Distortion
Undesired alterations to the shape of a waveform. Can be caused by the addition of atmospheric noise (atmospheric distortion) or system noise (noise distortion) or the addition of undesirable frequencies (harmonic and/or intermodulation distortion) generated by non-linear system components. Can be caused by addition of undesirable frequencies from signal transmissions occupying the same frequency band (interference distortion).

Glossary of Frequency Modulation Terms

Double Sideband or Double Sideband Full Carrier (DSB)
An frequency modulation technique which transmits the carrier and both sidebands. Used for broadcast AM and some applications of mobile and marine short wave, and amateur radio in the MF and HF regions.

DSB
See Double Sideband.

Effective Bandwidth
In modulation systems, a measure of signal bandwidth that neglects insignificant frequency components; the range of significant frequencies occupied by a signal. In FM and ϕM systems, significant frequency components have amplitudes equal to or greater than 1% of the unmodulated carrier.

Electromagnetic Waves
Waves characterized by variations of electric and magnetic fields and classified as radio waves, heat rays, light rays, etc., depending on frequency. Radio waves range from 0 Hz to 1 THz. See Radio Spectrum.

Envelope Detection
Simplest method for the recovery of the information signal from a frequency-modulated carrier. Uses a diode to rectify the modulated signal and a RC network that follows the signal waveform but not the high-frequency fluctuations of the RF carrier. The recovered information has the shape of the “envelope” of either the positive or negative portion of the frequency-modulated carrier wave.

Glossary of Frequency Modulation Terms

Error Signal
In a control system, the error signal is the difference between a sensing signal and a constant reference signal.

Filter
A transducer for separating electromagnetic waves on the basis of their frequency.

Filter Cutoff Frequency
A frequency which defines a limit or boundary for the intended transmission band for a particular filter.

FM
See Frequency Modulation.

FM Broadcast Band
The broadcast radio frequency band in the VHF region from 88 MHz to 108 MHz. The FM broadcast band is divided into 200 kHz channels which use two-sideband, wideband FM modulation with a maximum allowed modulation frequency of 15 kHz and a maximum allowed frequency deviation of 75 kHz.

Frequency Conversion
Process of combining an input signal with an injected frequency and putting them through a nonlinear device which intermodulates them and generates sum and difference frequencies. If the sum frequencies are selected by filtering, the input signal can be converted or raised in frequency by the magnitude of the injected frequency. Also called frequency mixing or frequency multiplication.

Frequency Deviation
See Peak Frequency Deviation.

Glossary of Frequency Modulation Terms

Frequency Discriminator
A circuit in which the signal output is proportional to the frequency of the input.

Frequency Divider
A device for delivering an output wave whose frequency is a submultiple of the input frequency.

Frequency Domain
A mode of signal analysis in which the amplitude versus frequency characteristics of a signal are displayed and analyzed.

Frequency Modulation (FM)
An angle modulation process in which the instantaneous frequency of a sinewave carrier is caused to depart from the carrier frequency by an amount proportional to the instantaneous amplitude of the modulating wave.

Frequency Multiplication
See Frequency Conversion.

Frequency Shift Keying (FSK)
FM technique for transmitting digital data; uses one frequency to encode a “1” and another to encode a “0.”

Frequency Synthesis
System in which the output of one or more stable oscillators operating at fixed frequencies is transformed by synthesizer circuitry to produce a signal of a desired frequency.

FSK
See Frequency Shift Keying.

Glossary of Frequency Modulation Terms

Gaussian Filter
A polynomial filter whose magnitude-frequency response approximates the ideal Gaussian response. Gaussian filters are noted for their good transient characteristics with small overshoot and ringing in response to signal pulses.

Harmonics
Sinusoidal frequencies which are integral multiples of a signal frequency. Each signal frequency associated with a harmonic is called a fundamental frequency. Only a pure sine wave has no harmonics.

Heterodyning
The operation of multiplying a signal with an auxiliary sinusoidal signal; also called mixing. See Frequency Conversion.

Improvement Threshold; Quieting Threshold
For a given FM receiver having a specified noise level, that amount of signal power below which the output is relatively noisy and above which the output is relatively noise free. For most FM systems the improvement threshold is approximately 10 dB above the thermal noise level.

Index
See Modulation Index.

Indirect Modulation
Modulation system in which the baseband or information signal is transformed through integration or differentiation before being applied to phase modulate or frequency modulate the carrier. The transformation enables a ϕM system to produce a FM signal and vice-versa.

Glossary of Frequency Modulation Terms

Information Signal
The electrical signal containing the information to be transmitted; the modulating signal. In test situations, a single sinewave, or test tone, substitutes for the information signal.

Integrator; Integrating Network
See Information Signal.

Intermodulation
Frequency components that result from two tones modulating together. The frequencies present in the output satisfy the criteria

$$wnm = | nw1 \pm mw2 |$$

where w1 and w2 are the frequencies of the original tones.

Ionosphere
The portion of the earth's outer atmosphere where ions and free electrons are normally present in quantities sufficient to affect propagation of radio waves.

IQ Modulation
Modulation technique in which two quadrature carriers (an I or in-phase carrier and a Q or quadrature-phase carrier), are phase modulated by baseband signals and then combined into one carrier.

Limiter
A transducer in which the output is constant for all input above a set value. In radio receivers a limiter removes all incidental amplitude modulation while transmitting angle modulation thereby removing a source of distortion. Limiting is very important in some applications such as mobile radio to mitigate the noise and interference effects from engines and their electrical systems.

Glossary of Frequency Modulation Terms

Loop Bandwidth
The range of frequencies that pass around a closed loop. The loop may be part of a control circuit as in a phaselock loop application. The signal frequencies passed by the loop bandwidth control the phaselock loop characteristics.

Loop Filter
The element in a closed loop that determines the loop bandwidth. See Loop Bandwidth.

Low-Pass Filter
An electronic device that transmits one group of frequencies, including direct current (zero frequency) while rejecting higher frequencies.

Lower Sideband
A sideband having a frequency lower than the carrier signal frequency. See Sidebands.

m
See Modulation Index.

Microwave
Generally refers to the super high frequency portion of the radio spectrum: 3 GHz to 30 GHz.

Mixer; Mixing
See Frequency Conversion.

Mobile Radio
System for communication between a radio station at a fixed location and one or more mobile stations, or between mobile stations.

Glossary of Frequency Modulation Terms

Modulated Carrier Signal
A carrier to which the information signal has been added by the process of modulation.

Modulating Frequency; Modulating Signal; Modulating Waveform
See Information Signal.

Modulation
The process by which some characteristic (amplitude, frequency, and/or phase) of a carrier wave is varied in accordance with a modulating function or wave. See Amplitude Modulation, Frequency Modulation, and Phase Modulation.

Modulation Depth
See Modulation Index.

Modulation Distortion
Undesired alterations to the shape of the waveform, or undesired frequency components added by the process of modulation. See Distortion.

Modulation Domain
Mode of signal analysis in which the frequency versus time characteristics of a signal are displayed for analysis.

Modulation Index
A measure of the amount, degree or depth of modulation.

In AM: The modulation index **m** ranges from 0 to 1 and relates to the amplitude of the sidebands with respect to that of the carrier, i.e. a modulation index of **m** means that each of the upper and lower sideband amplitudes are m/2 times the amplitude of the

carrier. Multiplying the modulation index by 100 gives the percentage modulation.

In FM: The modulation index β ranges from 0 to a maximum value limited only by the design of the modulation system. β reflects the peak phase shift of the carrier as expressed by the ratio of the carrier frequency deviation to the modulating frequency, and determines the energy distribution of the carrier and sidebands.

In ϕM: The modulation index β ranges from 0 to π in most applications. β reflects the peak phase shift of the carrier and determines the energy distribution of the carrier and sidebands.

Modulation Percentage
See Modulation Index.

Modulation-Tracking Loop
A phaselock loop demodulator design in which the modulation spectrum falls within the control loop bandwidth. As a result, the phaselock loop maintains lock (follows or "tracks") with the carriers's phase and frequency variations due to modulation.

Modulator
A circuit that adds the modulating (information) signal to an unmodulated carrier signal.

Multiplex
To interleave or simultaneously transmit two or more messages on a single channel.

Multipliers
See Frequency Conversion.

Glossary of Frequency Modulation Terms

MW
See Microwave.

Narrowband FM (NBFM)
FM technique characterized by signals which have a carrier and two sidebands as the only significant signal components. NBFM radio systems with 10 kHz bandwidth are widely used in mobile radio applications because of their inherent ability to reject amplitude related noise interference better than AM systems.

NBFM
See Narrowband FM.

Over Modulation
A condition where the modulation index has exceeded its maximum. In AM, results in distortion of the transmitted signal.

Peak Frequency Deviation (Δf_{pk})
In FM, the maximum or peak difference between the instantaneous frequency of the modulated wave and the carrier frequency, i.e. $\Delta fpk = f_{max} - f_c$.

Peak Phase Deviation ($\Delta\phi_{pk}$)
In ϕM, the maximum or peak phase shift experienced by the modulated carrier.

Percentage Modulation
See Modulation Index.

Phase Deviation
See Peak Phase Deviation.

Glossary of Frequency Modulation Terms

Phaselock Loop (PLL)
A circuit for synchronizing a variable local oscillator signal with the phase of a transmitted signal.

Phase Modulation (ϕM or PM)
An angle modulation process in which the phase angle, f, of a sinewave carrier is caused to depart from a reference value by an amount proportional to the instantaneous amplitude of the modulating wave.

Phase Shift Keying (PSK)
fM technique for transmitting digital data; uses one phase state to encode a “1” and another to encode a “0.”

PLL
See Phaselock Loop.

PSK
See Phase Shift Keying.

Quadrature Amplitude Modulation (QAM)
Combination of AM and ϕM techniques for transmitting digital data. In general, the M-QAM modulation techniques use 4*M levels to encode (2 + $\log_2$M) bits for each RF signal change, e.g. 8-QAM uses 32 levels to transmit 5 bits.

Quadrature Modulation
See IQ Modulation.

Quieting; FM Quieting; Quieting Threshold
See Improvement Threshold.

Glossary of Frequency Modulation Terms

Radio Spectrum
The radio frequency portion of the electromagnetic spectrum subdivided as follows:

ULF (ultra low frequency) — lower than 3 Hz
ELF (extremely low frequency) — 3 Hz to 3 kHz
VLF (very low frequency) — 3 kHz to 30 kHz
LF (low frequency) — 30 kHz to 300 kHz
MF (medium frequency) — 300 kHz to 3 MHz
HF (high frequency) — 3 MHz to 30 MHz
VHF (very high frequency) — 30 MHz to 300 MHz
UHF (ultra high frequency) — 300 MHz to 3 GHz
SHF (super high frequency) — 3 GHz to 30 GHz
EHF (extremely high frequency) — 30 GHz to 300 GHz
Submillimeter — 300 GHz to 1 THz

Regulatory Agencies
International and national governmental bodies responsible for the allocation and use of the airwaves.

RF
Also called Radio Frequency. See Radio Spectrum.

RF Carrier
See Carrier.

S/N; SNR
See Signal To Noise Ratio.

Satellite
A body revolving around the earth with motion primarily and permanently determined by the gravitational forces of attraction; commonly used in navigation and telecommunications applications as stations for transceivers.

Glossary of Frequency Modulation Terms

Second Harmonic Distortion
In modulation, unwanted signals separated from the carrier at twice the frequency of the information signal. Caused by non-linearity in the modulation process.

Selective Fading
Fading that affects unequally the different spectral components of a radio signal since the propagation characteristics of a wave varies with frequency.

Short Wave
Radio signals having shorter wavelengths than those used by the AM broadcast band, i.e. less than 200 meters.

Sidebands
Frequency bands on both sides of the carrier containing the frequencies of the information signal produced by the process of modulation. See Upper Sideband and Lower Sideband.

Signal-To-Noise Ratio
The ratio of the signal power to noise power. Expressed in dB. S/N (dB) = 10 log10 S/N. Can be defined in many ways but generally calculated as the ration of mean signal power with noise absent to mean noise power in the presence of an unmodulated carrier.

Significant Sidebands
In angle modulation, sidebands that have amplitudes at least 1% of the amplitude of the unmodulated carrier.

Spectrum Analyzer
An instrument for frequency domain measurements. Spectrum analyzers apply narrowband measurement techniques to reduce noise levels to increase sensitivity and remove interfering signals at undesirable frequencies.

Glossary of Frequency Modulation Terms

Synthesizer
See Frequency Synthesis.

Threshold
See Improvement Threshold.

TIA
See Time-Interval Analyzer.

Time Domain
A mode of signal analysis in which the amplitude versus time characteristics of a signal are displayed and analyzed.

Time-Interval Analyzer
An instrument with high speed, time sampling capability to continuously measure and display a signal's changing frequency; a continuous counter.

Time-Varying Phase Angle
Refers to the value of a periodic waveform's phase angle which varies with time with respect to a fixed reference . For a sinusoid waveform the phase angle varies in a predictable fashion with respect to a fixed starting point. For example, in the sinusoid function

$$f(t) = \sin \theta(t) = \sin(2\pi ft),$$

$2\pi ft$ is the value of the time-varying phase angle $\theta(t)$ at time t.

Tuned-Circuit Oscillator
A circuit that uses the resonance characteristics of reactive circuit elements to produce a signal output of a particular frequency.

Two-Way; Two-Way Radio
See Mobile Radio.

Glossary of Frequency Modulation Terms

UHF
Ultra High Frequency. See Radio Spectrum.

Unmodulated Carrier
A carrier signal to which no modulation has been added.

Upper Sideband
A sideband having a frequency higher than the carrier signal frequency. See Sidebands.

VCO
See Voltage-Controlled Oscillator.

Vector Modulation
See IQ Modulation.

VHF
Very High Frequency. See Radio Spectrum.

Voltage-Controlled Oscillator (VCO)
A circuit in which the signal output frequency is determined by an input control voltage.

H

Frequency Modulation Fundamentals

User's Guide

Computer-Based Training Course

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