



Chapter 8

Modulation, Protocols and Modes

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Thanks to:

- * **Information from:**

- **The ARRL Library**
- **ARRL Extra Class License Manual**

- * **Additional References:**

- **TAPR – Wireless Digital Communications Design and Theory,
Tom McDermott N5EG**

Section 8-1

Modulation Systems

Modulation

Review

- * A radio wave can be thought of as having two parts:
 - The *Carrier*
 - The *Modulation* (the content)
- * Each type of Modulation has it's advantages and disadvantages and a typical bandwidth

• CW (Continuous Wave or Morse code)		100Hz
• SSB (Single SideBand)*		2.8 kHz
• AM (Amplitude Modulation)*		6 kHz
• FM (Frequency Modulation)*		10 kHz
• TV		6 MHz

* **Voice** modulation is also called **Phone** modulation

Emission Designators

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Table 8-1

Partial List of Emissions Designators

(1) First Symbol — Modulation Type

Unmodulated carrier	N
Double sideband full carrier	A
Single sideband reduced carrier	R
Single sideband suppressed carrier	J
Vestigial sidebands	C
Frequency modulation	F
Phase modulation	G
Various forms of pulse modulation	P, K, L, M, Q, V, W, X

(2) Second Symbol — Nature of Modulating Signals

No modulating signal	0
A single channel containing quantized or digital information without the use of a modulating subcarrier	1
A single channel containing quantized or digital information with the use of a modulating subcarrier	2
A single channel containing analog information	3
Two or more channels containing quantized or digital information	7
Two or more channels containing analog information	8

(3) Third Symbol — Type of Transmitted Information

No information transmitted	N
Telegraphy — for aural reception	A
Telegraphy — for automatic reception	B
Facsimile	C
Data transmission, telemetry, telecommand	D
Telephony	E
Television	F



Common Designators

- Voice SSB :
J3E (J3E2K80)
- HF SSB Data:
J2D



Common Emission Designators

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From the International Telecommunications Union - ITU

- N0N — Unmodulated carrier
- A1A — Morse code telegraphy using amplitude modulation
- A3E — Double-sideband, full-carrier, amplitude-modulated telephony
- J3E — Amplitude-modulated, single-sideband, suppressed-carrier telephony
- J3F — Amplitude-modulated, single-sideband, suppressed-carrier television
- F3E — Frequency-modulated telephony
- G3E — Phase-modulated telephony
- F1B — Telegraphy using frequency-shift keying without a modulating audio tone (FSK RTTY). F1B is designed for automatic reception.
- F2B — Telegraphy produced by modulating an FM transmitter with audio tones



Emission Types

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- * The Amateur Radio regulations part 97 refers to emission types rather than emission designators
- * Emission types (Modes) are:
 - CW
 - Phone
 - RTTY
 - Data
 - Image
 - MCW (Modulated CW)
 - SS (Spread Spectrum)
 - Pulse
 - Test

Frequency Modulation

- * FM is the most common VHF mode
 - Voice
 - Data

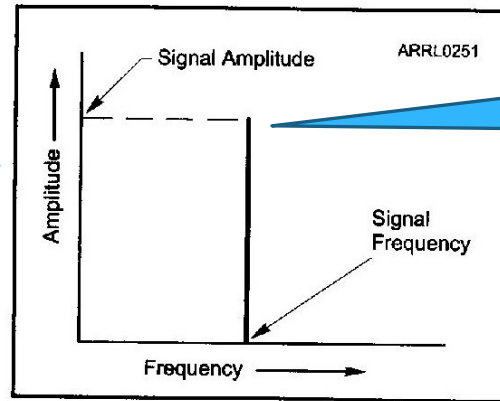


Frequency Modulation

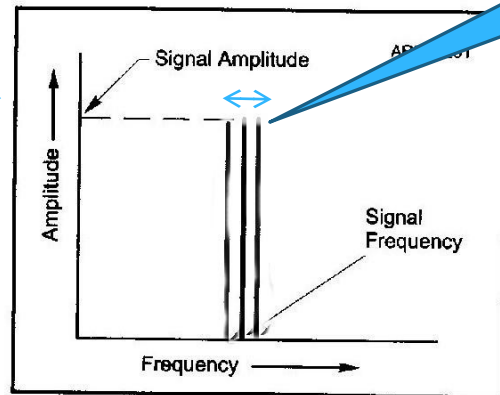
Viewed on a Spectrum Analyzer

Page 8-3

- * A un-modulated carrier is stable in frequency
- * With Frequency Modulation, the carrier shifts back and forth at the rate of the modulating frequency



An un-modulated carrier



An FM modulated carrier

How far the frequency deviates from the carrier frequency is called the **Deviation**

Deviation Ratio

Pg. 8-3

- * The *Deviation Ratio* is the ratio of the maximum deviation to the highest modulating frequency [E8B09].

$$\text{Deviation Ratio} = \frac{D_{\text{MAX}}}{M}$$

Equation 8.1

where:

D_{MAX} = peak deviation in hertz

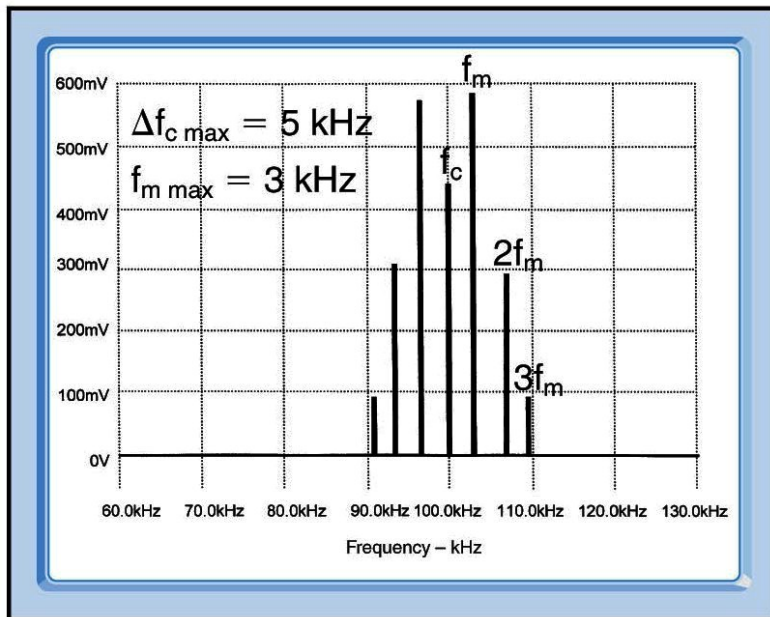
M = maximum modulating frequency in hertz.

To Calculate the Deviation Ratio

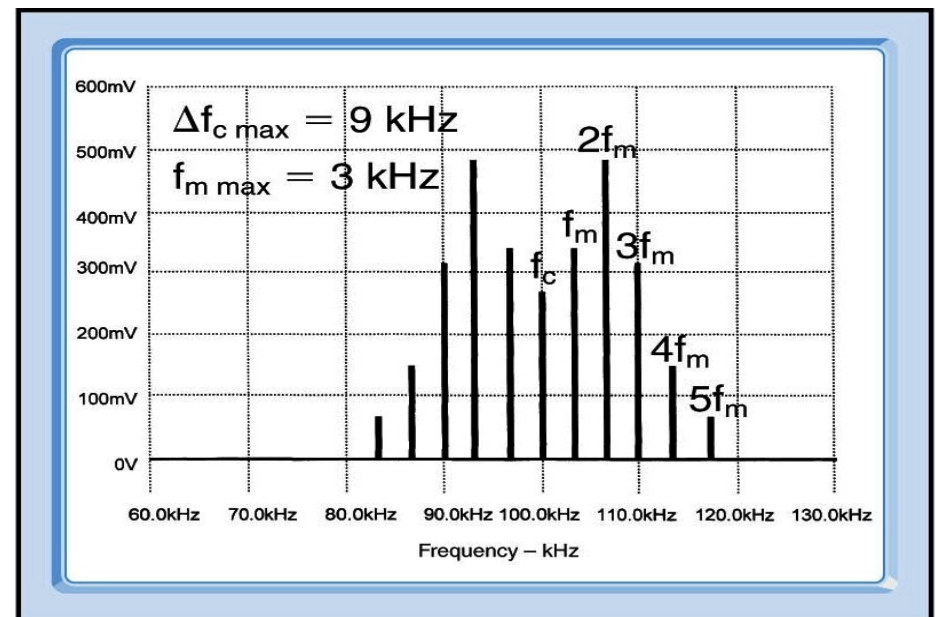
Pg. 8-3 & 4

- * If the **peak deviation** of a FM signal is 5 kHz and the maximum modulating frequency is 3 kHz, what is the deviation ratios?
 - **Deviation Ratio = 5 kHz / 3 kHz = 1.67** (Example 8-1) [E8B05]
- * Or if the peak deviation is 7.5 kHz and the maximum modulating frequency is 3.5 kHz, then:
 - **Deviation ratio = 7.5 kHz / 3 kHz = 2.14** (Example 8-2) [E8B06]

Let's take a look at the FM Spectrum



Deviation Ratio of 1.67



Deviation Ratio of 3

Frequency spectrum of FM signals.

Modulation Index

Pg. 8-4

- * The *Modulation Index* is the ratio of the maximum deviation to the modulating frequency at any given instant **[E8B01]**.

$$\text{Modulation Index} = \frac{D_{\text{MAX}}}{m} \qquad \text{Equation 8.2}$$

where:

D_{MAX} = peak deviation in hertz.

m = modulating frequency in hertz at any given instant.

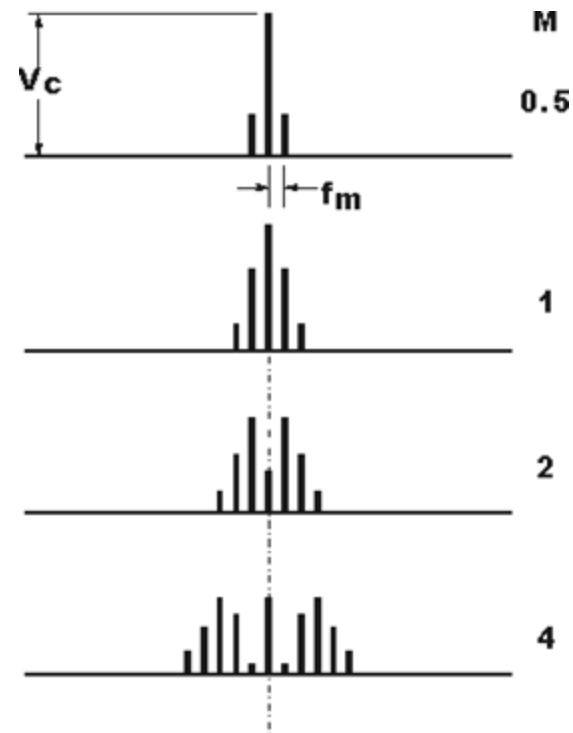
Calculate the Modulation Index

Pg. 8-4

- * If the peak deviation of a FM signal is 3 kHz and the modulating frequency is 1 kHz, what is the modulation index?
 - **Modulation index = 3000 Hz / 1000 Hz = 3** (Example 8-3)
[E8B03]
- * Or if the peak deviation is 6 kHz and the maximum modulating frequency is 2 kHz, then:
 - **Modulation index = 6 kHz / 2 kHz = 3** (Example 8-4)[E8B04]

Modulation Index vs Bandwidth

- * As the modulation index increases, so does the width of the signal as viewed on a spectrum analyzer
- * Modulation index is a way to describe a modulated signal's bandwidth



What About the Operating Frequency?

Pg. 8-4

- * Notice that with either FM or PM, the deviation ratio and modulation index **are independent of the RF carrier frequency (operating frequency) [E8B02]**.
- * It doesn't matter if the transmitter is a 10m rig, a 2m rig or a 23 cm rig.
 - Deviation Ratio = D_{MAX} / M
 - Modulation Index = D_{MAX} / m
- * The maximum modulation index allowed by the FCC rules is 1.0 on frequencies below 29.5 MHz [E1C09].

Multiplexing

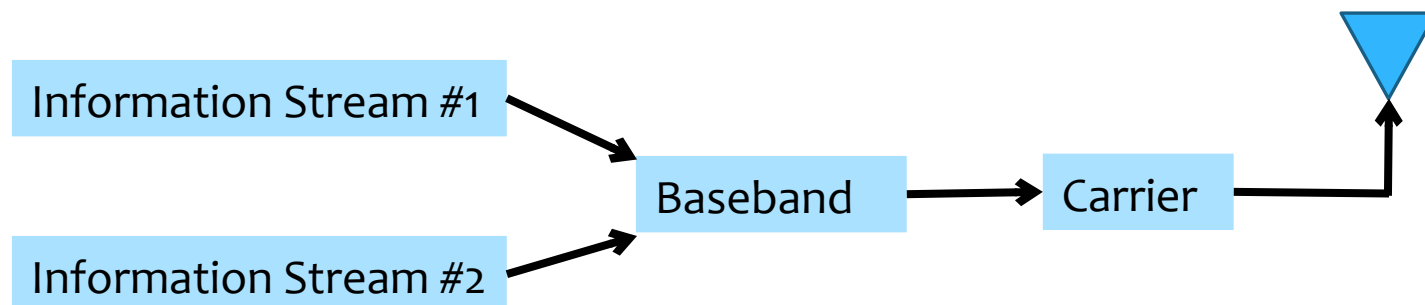
Pg 8-5

- * Multiplexing means combining more than one stream of information (baseband) into one modulated signal.
- * The two common multiplexing methods are:
 - Frequency division multiplexing (**FDM**) i.e. FT8 **[E8B10]**
 - Time division multiplexing (**TDM**) i.e. DMR **[E8B11]**

Frequency Division Multiplexing

Pg. 8-5

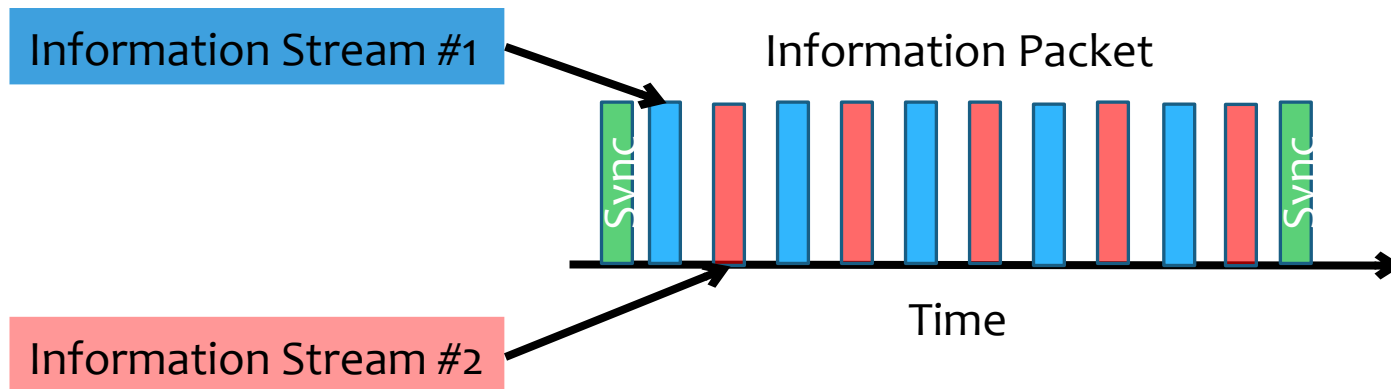
- * With **FDM**, two or more information streams are merged together in a “*baseband*” signal that is used to modulate the carrier **[E8B10]**.



Time Division Multiplexing

Pg. 8-5

- * With **TDM**, two or more information streams are carried over a single channels by so that they occur in separate discreet **time slots** [E8B11].
- * In amateur radio, TDM is used mostly in telemetry, such as from satellites and digital voice modes such as D-Star, DV and DMR.



Section 8-1

Questions

How does the modulation index of a phase-modulated emission vary with RF carrier frequency (the operating frequency)?
[E8B02]

- A. It increases as the RF carrier frequency increases
- B. It decreases as the RF carrier frequency increases
- C. It varies with the square root of the RF carrier frequency
- D. It does not depend on the RF carrier frequency

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What is the modulation index of an FM-phone signal having a maximum frequency deviation of 3000 Hz either side of the carrier frequency, when the modulating frequency is 1000 Hz?
[E8B03]

- A. 3
- B. 0.3
- C. 6
- D. 0.6

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- B. 0.3
- C. 6
- D. 0.6

What is deviation ratio? [E8B09]

- A. The ratio of the audio modulating frequency to the center carrier frequency
- B. The ratio of the maximum carrier frequency deviation to the highest audio modulating frequency
- C. The ratio of the carrier center frequency to the audio modulation frequency
- D. The ratio of the highest audio modulating frequency to the average audio modulating frequency

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What is frequency division multiplexing (FDM)?

[E8B10]

- A. The transmitted signal jumps from band to band at a predetermined rate
- B. Dividing the transmitted signal into separate frequency bands that each carry a different data stream
- C. The transmitted signal is divided into packets of information
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