Jules' Workshop

Standard

Unit 14

TRANSMITTERS

ACMA Syllabus February 2024

Contents

Transmitters 3
Modulation Methods 4
Types of Modulation 4
Amplitude Modulation (AM) Transmitter A3E 5
Overmodulation 6
Single Side Band (SSB) Transmitter J3E 8
Balanced Modulator 9
Frequency Modulation (FM) Transmitter F3E 10
FM Modulation 11
Frequency modulation index 11
FM Signal Bandwidth 11
Phase Modulation (PM) Transmitter P3E 12
Continuous Wave (CW) Transmitter A1A 13
Varying the Transmitter Frequency 15
Transmitter Power 16
Measuring Transmitter Output Power 16
Peak Envelope Power (PEP) or Px 16
Average Power or Py 16
PEP level control 17
Transmitter Field Strength 17
Transmitter Terms 18
Automatic level Control (ALC) 18
Audio-frequency range 18
Buffer 18
Cavity Resonator 18
Crystal Filter 18
Driver 18
Duty Cycle 18
Efficiency 19
Linear Amplifier 19

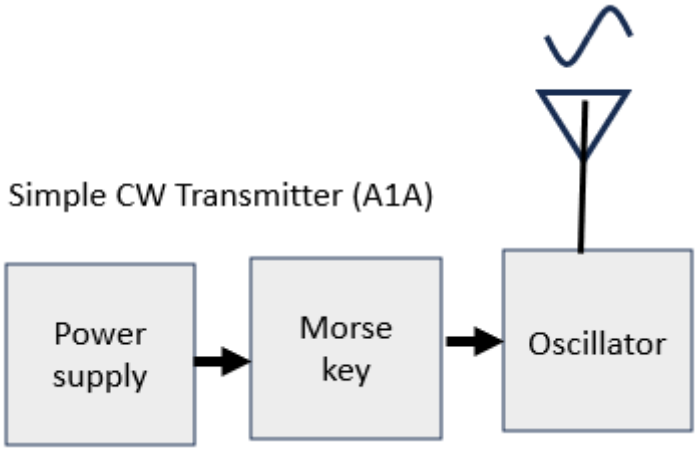
 © Jules Workshop 2026

Mixer 19
Neutralisation 19
Output Filter 19
Output Impedance 19
Output Matching 19
Power Amplifier 19
RF Shielded cabinets. 19
Spurious RF radiations 19
Transmitter Efficiency 19
Emission Modes 20

 © Jules Workshop 2026

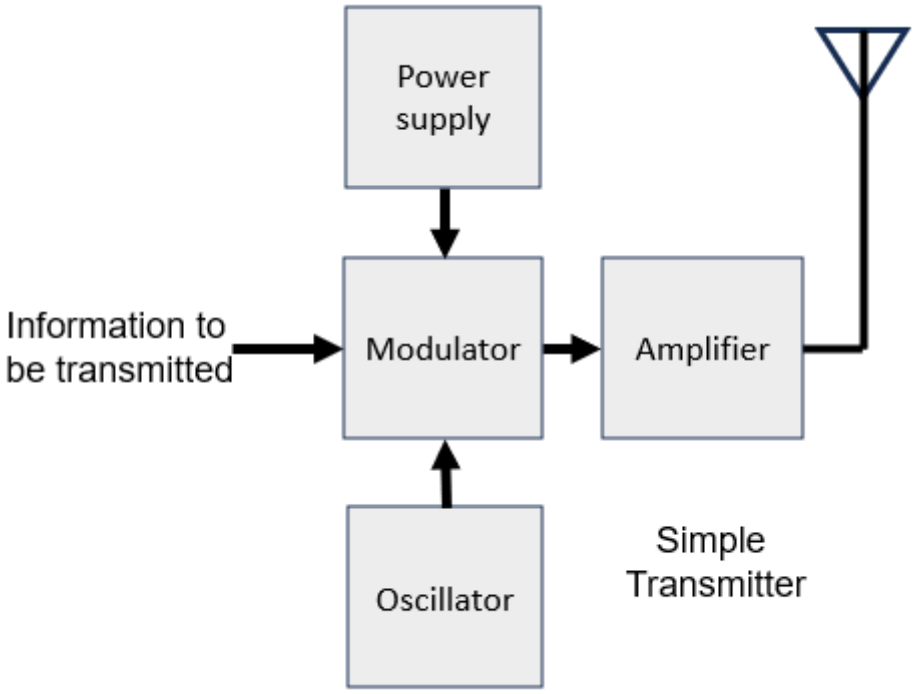
Transmitters

A radio transmitter, abbreviated as Tx, is an electronic device that generates and sends out radio frequency signals through an antenna, enabling wireless communications.



In this simplest transmitter, the oscillator which is running at the carrier frequency is turned on and off by the morse key. The signal would be weak making this transmitter ineffective.

A simple audio transmitter needs a method to superimpose the 300 Hz audio signal onto the carrier signal.

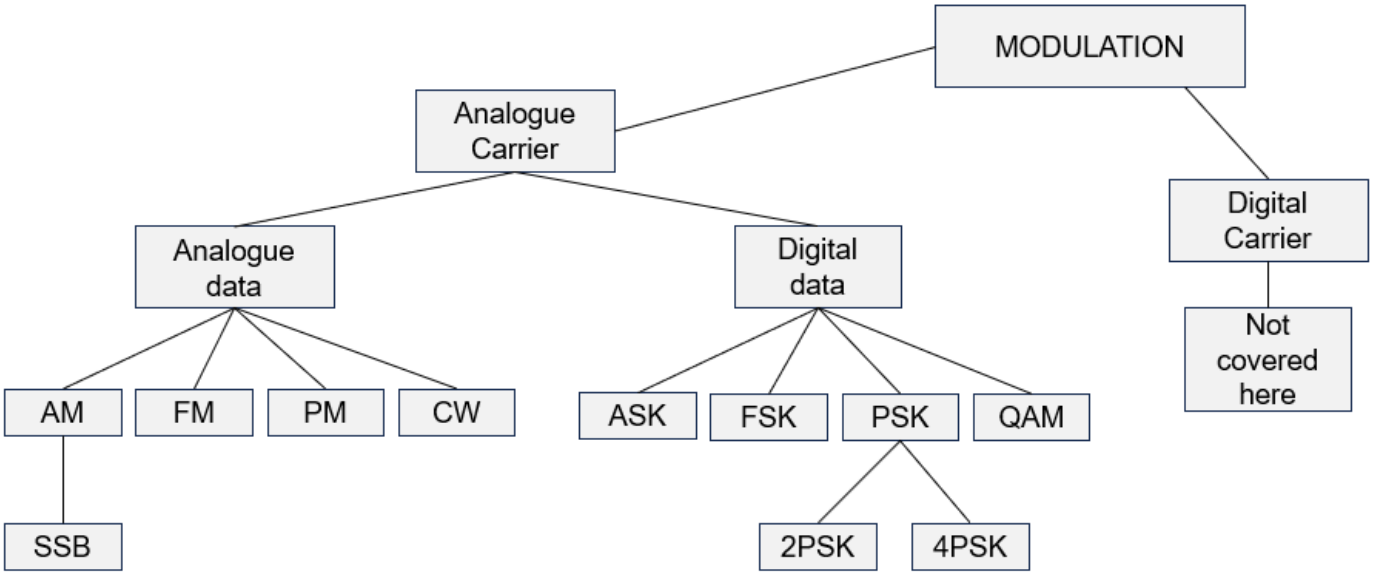


The information to be transmitted is modulated with an oscillator at the carrier frequency. This modulated signal is amplified and sent the antenna. The power supply will not be shown in future block diagrams.

 © Jules Workshop 2026

Modulation Methods

A modulator superimposes a low-frequency (information) signal onto a high-frequency (carrier) signal for the purpose of transmission. This is achieved by varying some aspect of the carrier wave. The information is provided to the transmitter as an electronic signal called the modulation signal. The modulation signal may be an audio, video or data. Different types of transmitters use different modulation methods to transmit information.



High level modulation is where the modulator is connected to the power amplifier.

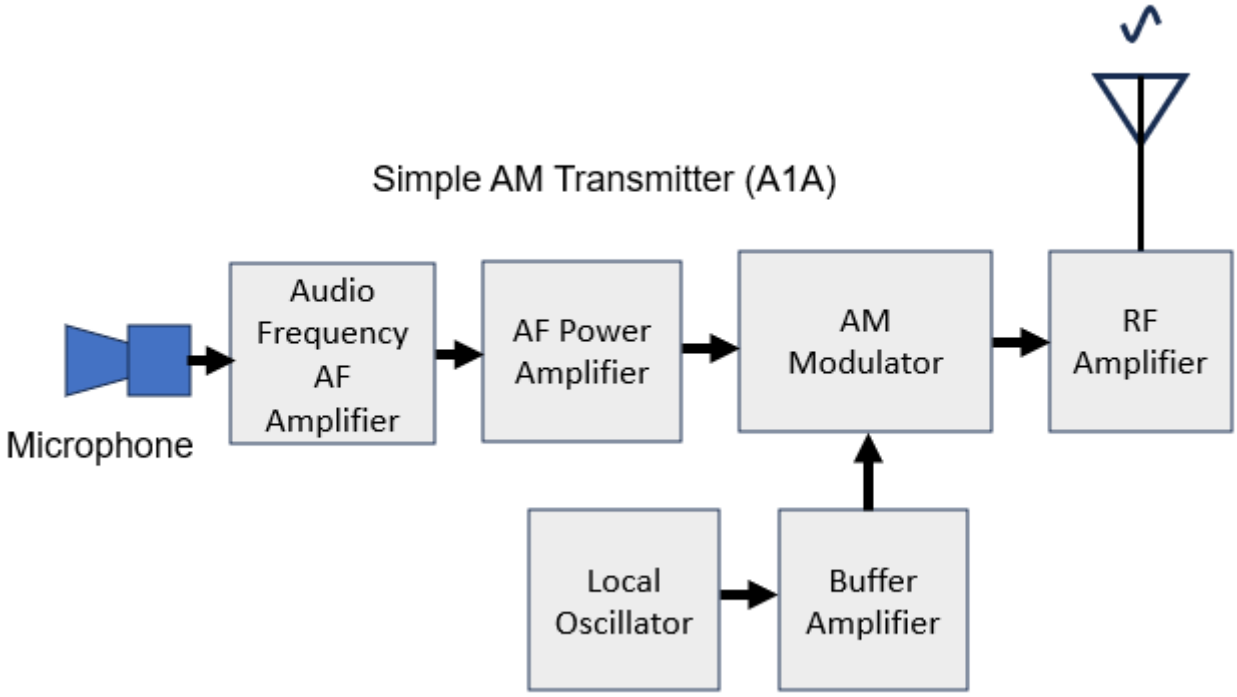
Low level modulation is where the modulator is connected a few stages prior to the power amplifier.

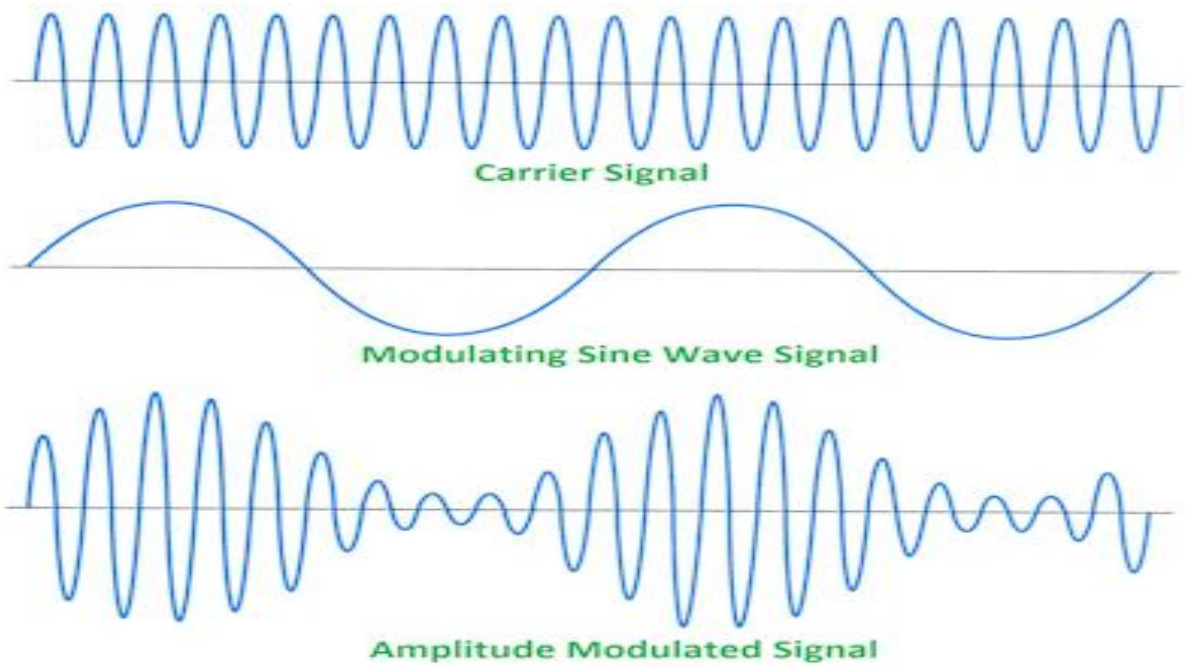
Types of Modulation

Amplitude modulation (AM)	In an AM transmitter, the amplitude of the carrier wave varies in proportion to the modulation signal.
FSK (frequency-shift keying)	A FSK transmitter for data, the frequency of the carrier is shifted between two frequencies which represent the two binary digits, 0 and 1.
Morse code (CW)	A carrier wave is turned on and off, corresponding to dots and dashes for Morse code.
Frequency modulation (FM)	A FM transmitter the frequency of the carrier is varied by the modulation signal.
Single Side Band (SSB)	Is a variation of amplitude modulation signal.
Phase modulation (PM)	Phase modulation (PM) encodes a message signal as variation in the instantaneous phase of a carrier wave. Phase modulation is one of the two principal forms of angle modulation, together with frequency modulation. The phase of a carrier signal is modulated to follow the changing signal level (amplitude) of the message signal. television. However, it is not widely used for transmitting analog audio signals via radio waves.

 © Jules Workshop 2026

Amplitude Modulation (AM) Transmitter A3E





For AM transmissions, the carrier is amplitude modulated by the message being transmitted. The disadvantage with AM is that it transmits identical sidebands with the carrier. A message of 3 kHz bandwidth requires 6 kHz bandwidth plus the carrier.

The unmodulated carrier has an amplitude of 1. Best efficiency is 100% modulation as shown in the diagram below.

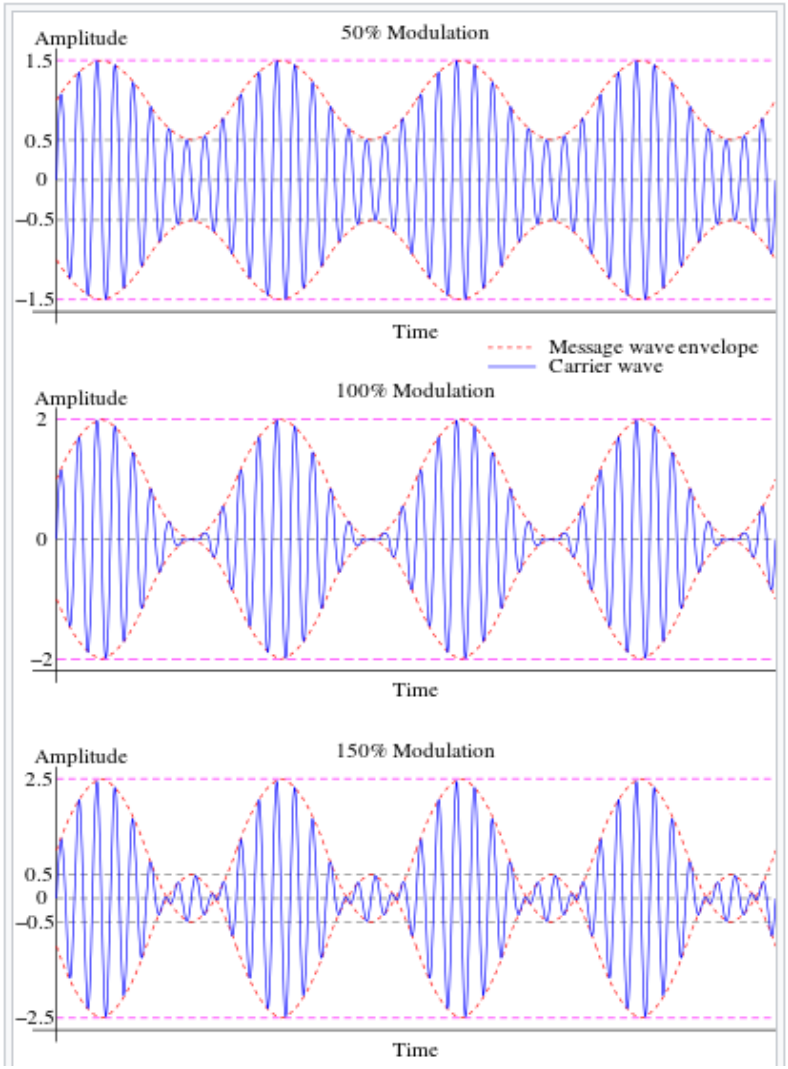
 © Jules Workshop 2026

The power of an AM transmission is spread between the carrier and two side bands. Each side band has approximately a quarter of the transmitted power and the carrier accounts for 50 % of the power. So that a transmission of 40 W would have 20 w in the carrier and 10 W in each side band.

Overmodulation

Overmodulation of the signal as shown in the bottom of the next diagram will cause inference in adjacent stations. Overmodulation is called **splatter**. The common cause of overmodulation is by excessive microphone gain.

The bottom diagram shows overmodulation in the AM signal.



This diagram is copied from Wikipedia at [Amplitude modulation - Wikipedia]

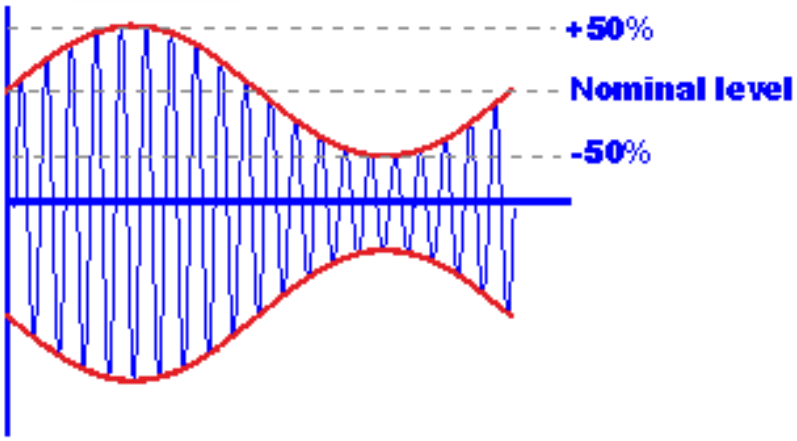
High-power AM transmitters for broadcasting are modulated by varying the supply voltage to the power amplifier stages

 © Jules Workshop 2026

AM Modulation Index

The amplitude modulation index describes the amount by which the modulated carrier envelope varies about the static level. The amplitude modulation index expressed as a percentage. For a Modulation index of 0.75 would be 75% modulation.

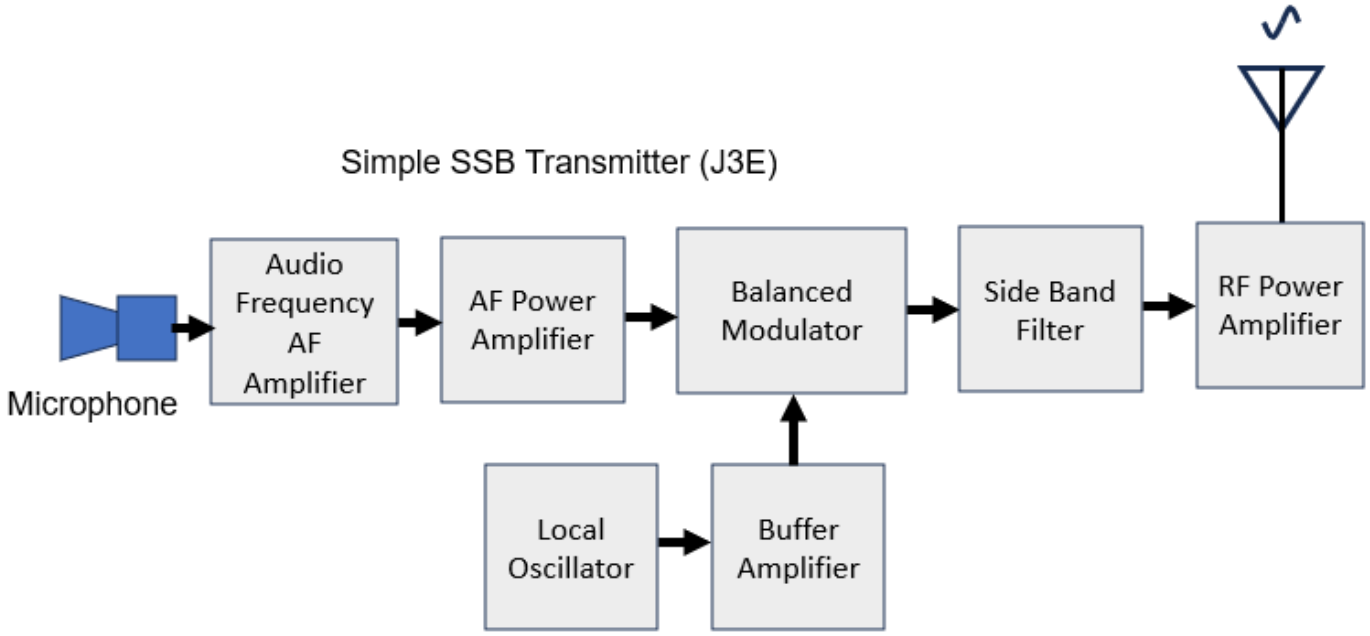
Example: An AM signal has an amplitude of 4 V peak and the modulation signal had a peak of 2 V. the modulation index is 50%.

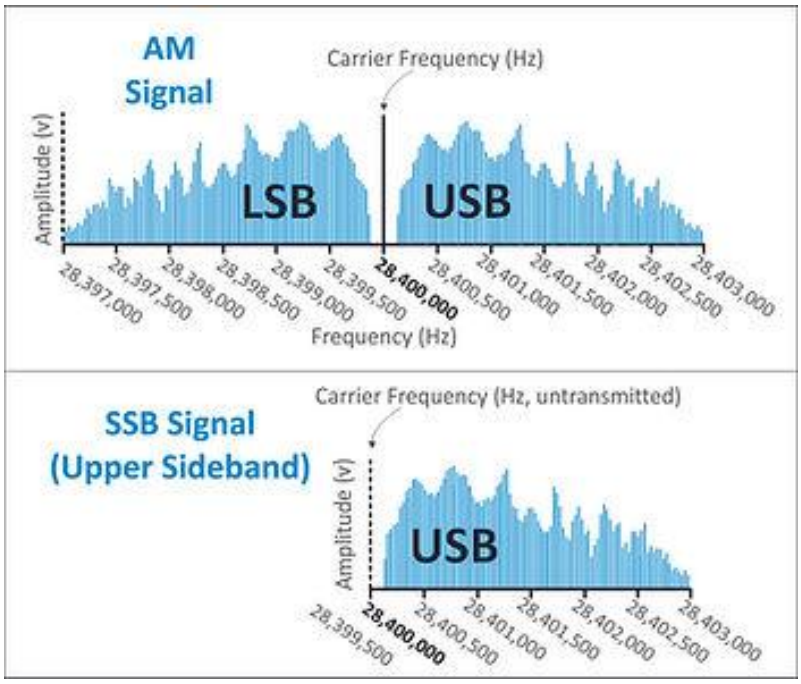


(source: radio-electronics.com)

 © Jules Workshop 2026

Single Side Band (SSB) Transmitter J3E

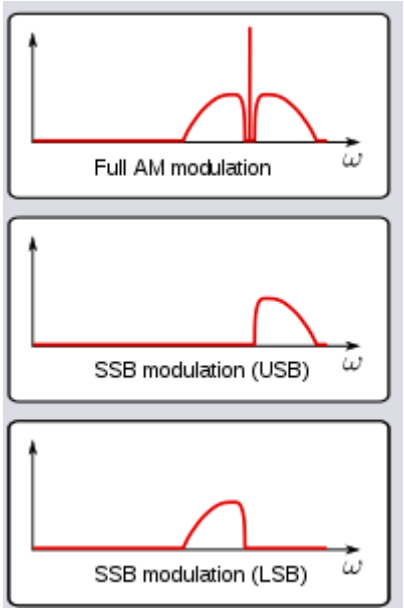




Single sideband suppressed carrier is the correct term but the is reduced to Single Side Band or SSB. SSB is a variant of AM.

A balanced modulator adds the message to the carrier so that only the sideband signals come through the output modulator. This creates a balanced signal, as there is less noise because the carrier signal has been removed.

 © Jules Workshop 2026



Wikipedia Single-sideband modulation - Wikipedia

The upper side band (USB) or lower side band (LSB) can be selected. Amateur radio convention is that for frequencies greater than 10 MHz USB is used. For frequencies below 10 MHz, LSB is used.

SSB requires approximately half the bandwidth of AM and uses transmitter power more efficiently.

So, for a 3 kHz message using SSB, the bandwidth is half that of an AM with the same message.

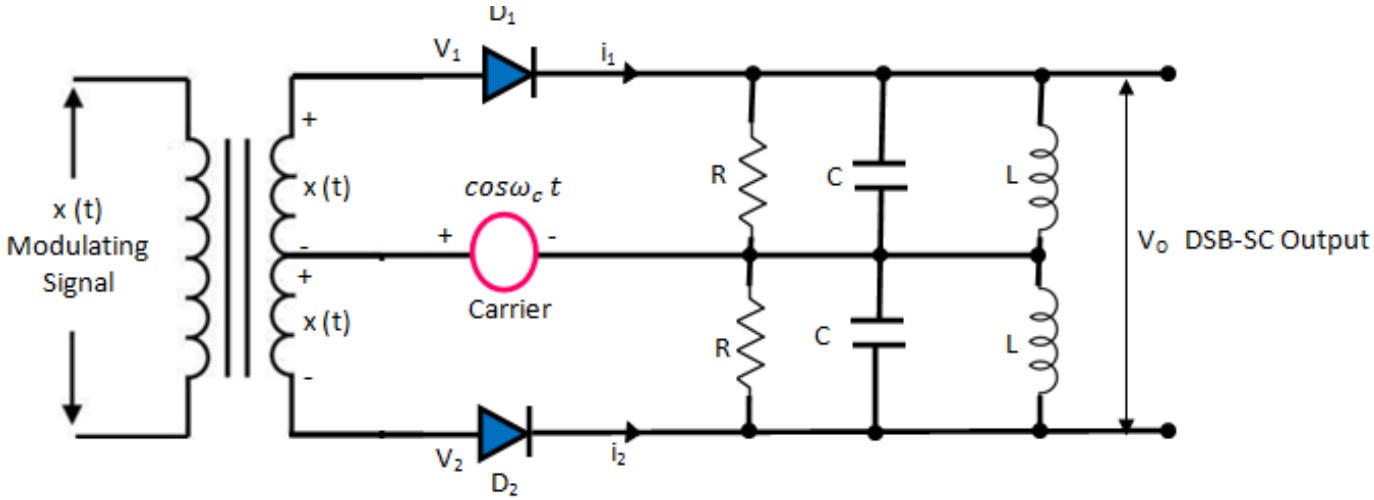
Balanced Modulator

A balanced modulator produces a Double-Sideband Suppressed-Carrier (DSB-SC) signal.

The balanced modulator mixes a modulating signal (information) with a carrier signal, then suppresses the original carrier.

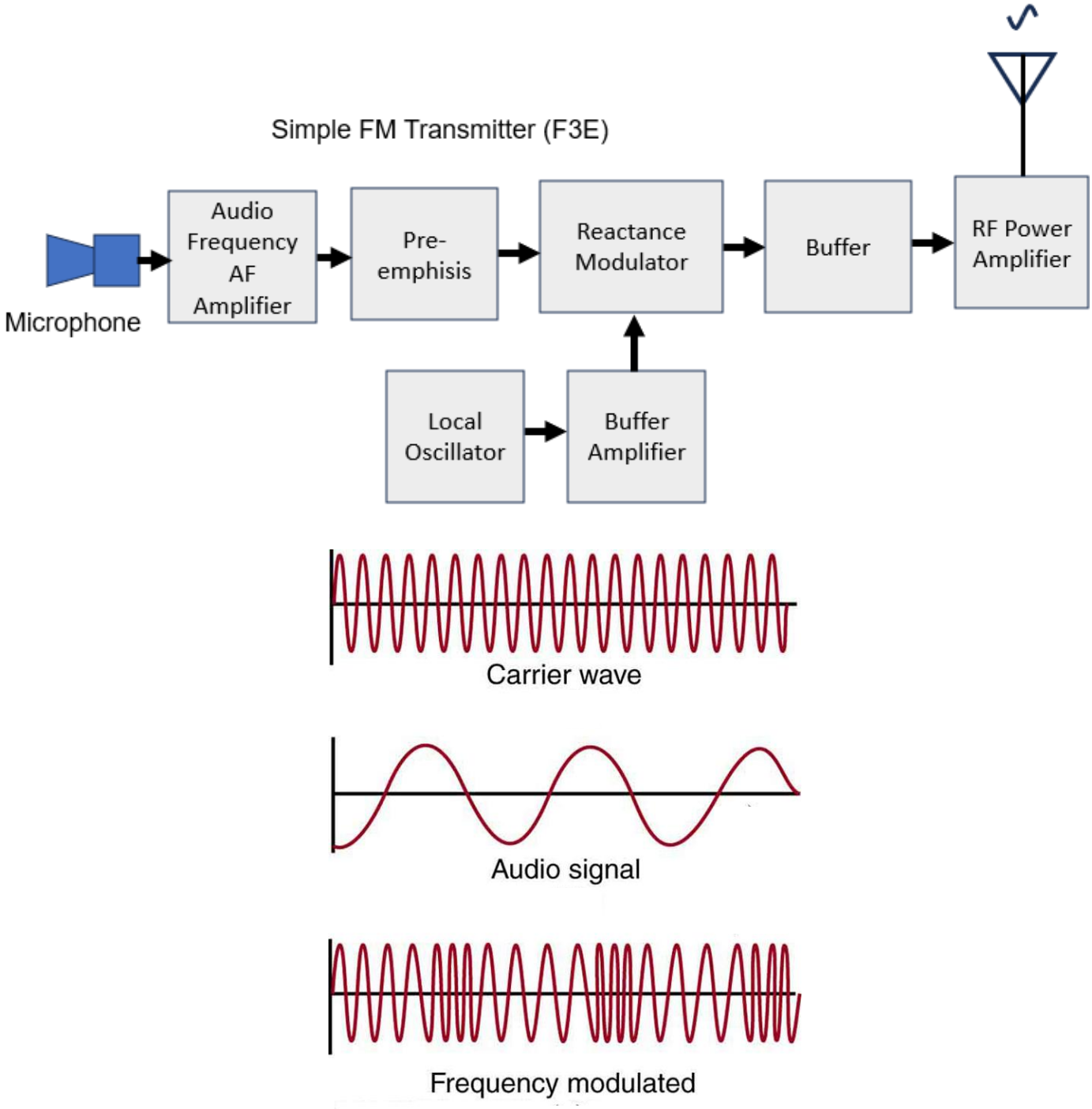
This leaves the sum and difference frequencies at the output.

This process improves efficiency of the signal by eliminating the carrier.



 © Jules Workshop 2026

Frequency Modulation (FM) Transmitter F3E



FM (Frequency Modulation) transmits information by varying the frequency of a carrier wave in accordance with the information signal amplitude.

FM keeps the carrier amplitude constant, making it less prone to static, noise, and interference.

FM generally requires a wider bandwidth than AM to operate, which allows for higher fidelity audio (less noise).

The message may go through a pre-emphasis stage which boosts the higher frequencies of the audio signal to improve its transmission and reception quality. De-emphasis occurs in the receiver.

 © Jules Workshop 2026

A FM transmitter has a reactance modulator where the carrier frequency is varied by the message sent.

FM Modulation

There are several modulation methods for an FM signal.

Direct FM modulation

Direct FM modulation is performed by feeding the message into the input of a voltage-controlled oscillator.

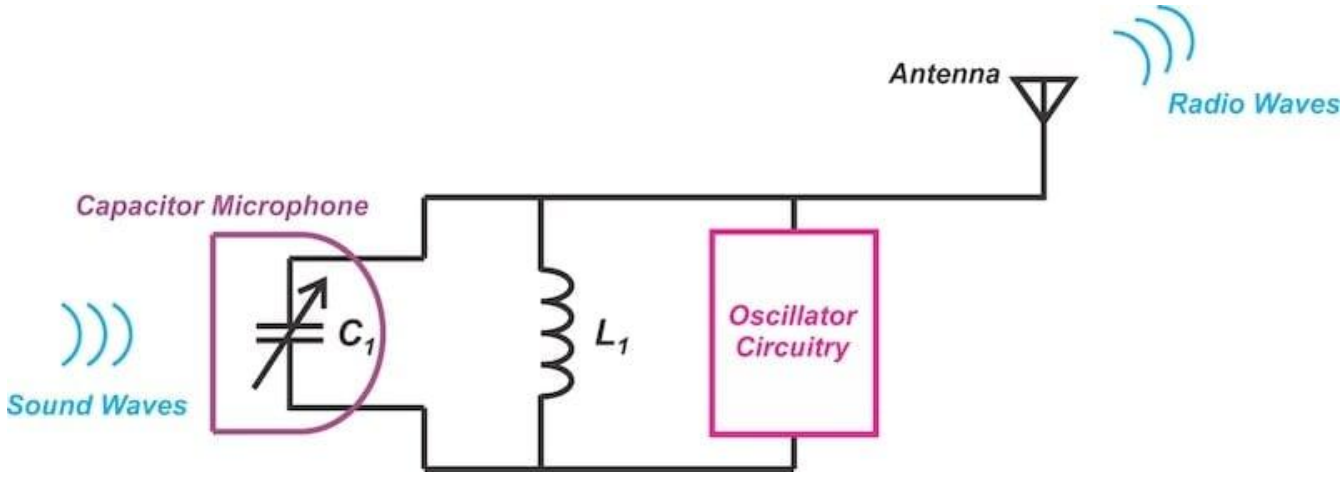
Indirect FM modulation

This is performed when the message signal is integrated to generate a phase-modulated signal. This is used to modulate a crystal-controlled oscillator, and the result is passed through a frequency multiplier to produce an FM signal.

Reactance Modulators

A reactance modulator is a circuit that varies the reactance (capacitance or inductance) of an oscillator's tank circuit.

The modulator uses a transistor, FET, or varactor diode to change the oscillator's frequency in proportion to an input modulating signal.

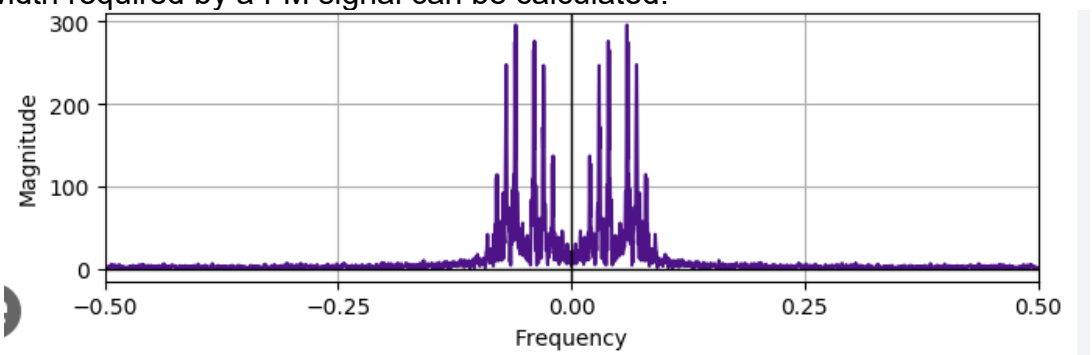


Frequency modulation index

The frequency modulation index is equal to the ratio of the frequency deviation to the modulating frequency. The modulation index is independent of the carrier frequency.

FM Signal Bandwidth

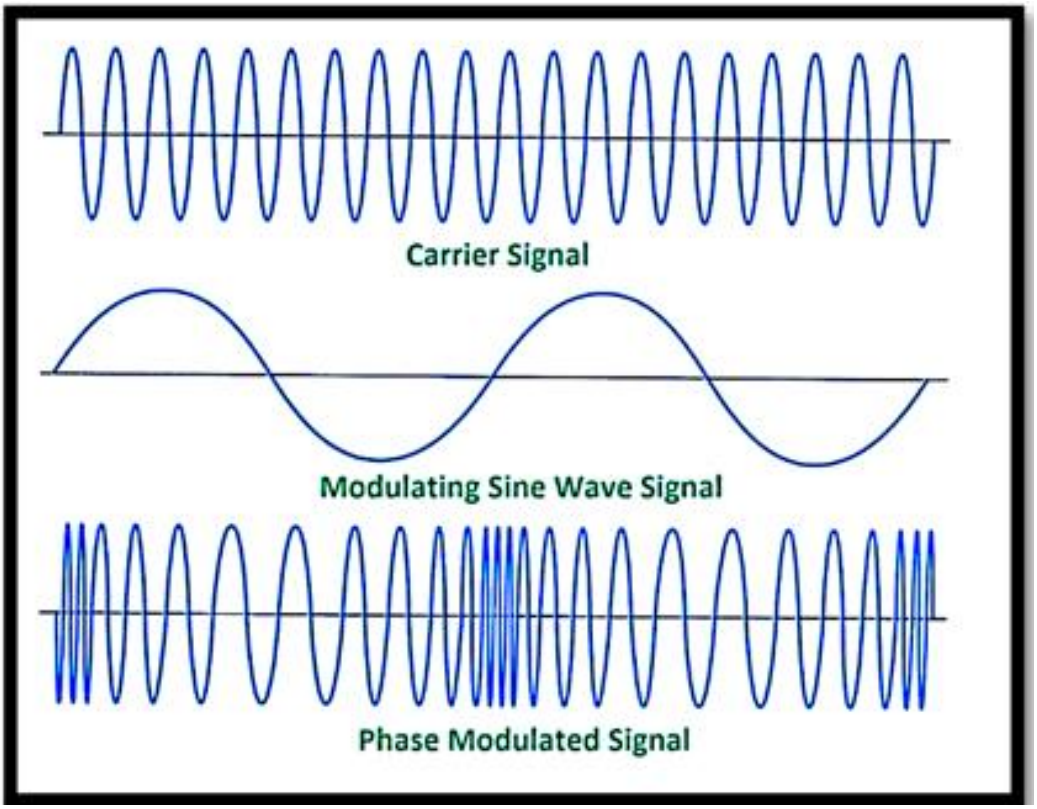
An FM signal bandwidth represents the range of frequencies the signal occupies.
The bandwidth required by a FM signal can be calculated.



 © Jules Workshop 2026

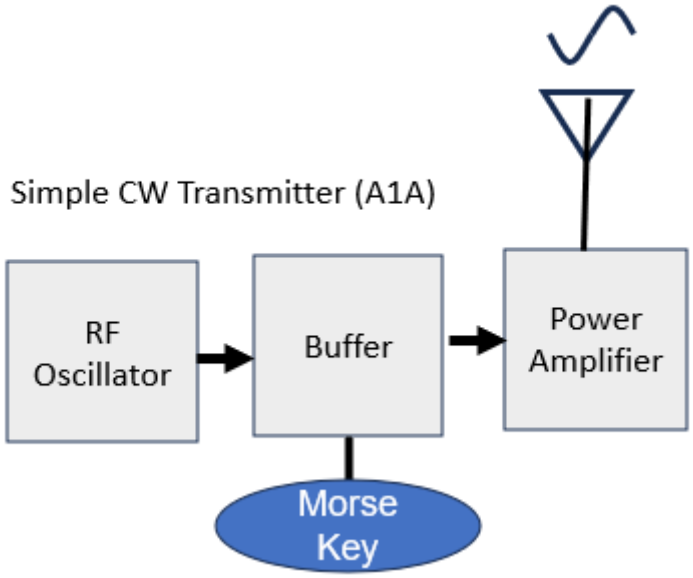
Phase Modulation (PM) Transmitter P3E

An RF phase modulator is a device that alters the phase angle of a high-frequency carrier signal in proportion to a message signal, while maintaining constant amplitude and frequency.
A phase modulator is a type of angle modulation used extensively in RF communication systems. The instantaneous amplitude of the message signal directly modifies the phase of the carrier signal.



 © Jules Workshop 2026

Continuous Wave (CW) Transmitter A1A

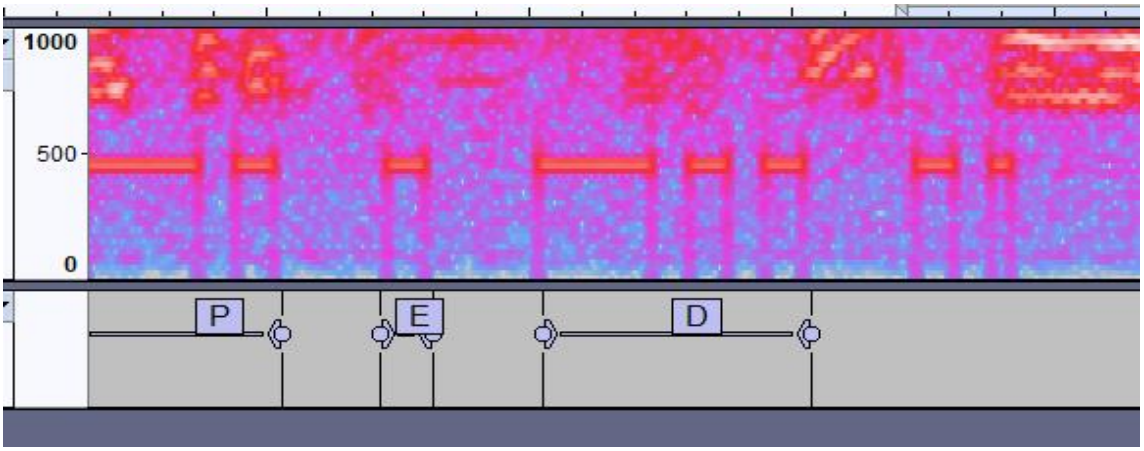


The CW transmitter is the simplest transmitter and still very effective. CW takes the least bandwidth for transmission and can be heard is the worst operating conditions.

Morse code signals are not binary (digital) as in having two states.

The carrier on and off for varying periods.

- Dit (dot): 1 unit long.
- Dah (dash): 3 units long.
- Intra-character space: Gap between dits / dahs within a character is 1 unit long.
- Inter-character space: Gap between letters is 3 units long.
- Word space: Gap between words is 7 units long.



In the CW transmitter, the oscillator generates the carrier, and the buffer separates the signal from the Power amplifier (PA). The carrier is turned on and off by the morse key. The power supply for each stage is separated to prevent one stage interfering with other stages. This is called decoupling. The method of decoupling is by using either capacitive or inductive. Capacitive coupling is cheaper, but the downside is that transient spikes can still pass through a capacitor. The alternative is inductive coupling such as a transformer with either ferrite or air core. The

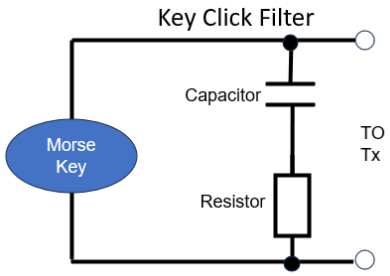
 © Jules Workshop 2026

primary and secondary windings can be tuned to the desired frequency to eliminate unwanted signals.

A common form of keying is “block based” where the amplifier is biased on and off.

Two issues with CW transmitters are Key clicks and chirps.

- **Key Clicks**. CW transmitted with poor waveform shaping causes interference. This is heard as clicks and thumps by other CW operators on nearby frequencies. Key Clicks can be reduced by using a Key Click filter to shape the transients between transmission bursts of morse code. This filter can be a simple RC network to shape the attack and decay times of the transmissions.



- **Chirps**. Oscillator stability is essential for a clean transmission. Any variation in the frequency as the transmitter is keyed is called a chirp. This is an unpleasant signal to receive.

 © Jules Workshop 2026

Varying the Transmitter Frequency

An amateur transmitter is of little value if it can only transmit on one frequency.

Array of crystals. This allows the transmitter to be used on several different frequencies.

Variable-frequency oscillator (VFO) - A VFO is an oscillator whose frequency can be tuned over some range.

Phase-locked loop (PLL) - A PLL generates an output signal whose phase is related to the phase of an input signal.

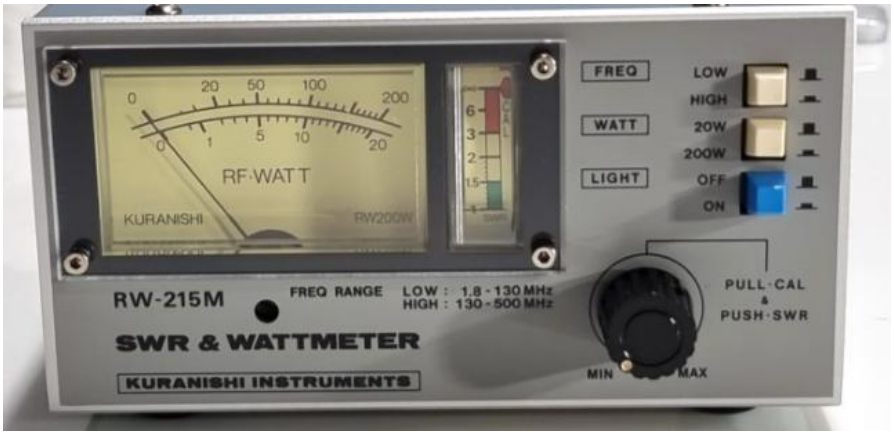
Direct Digital Synthesis (DDS) - DDS is a method to generate a sine wave using digital techniques.

 © Jules Workshop 2026

Transmitter Power

Measuring Transmitter Output Power

Performed using a power meter.

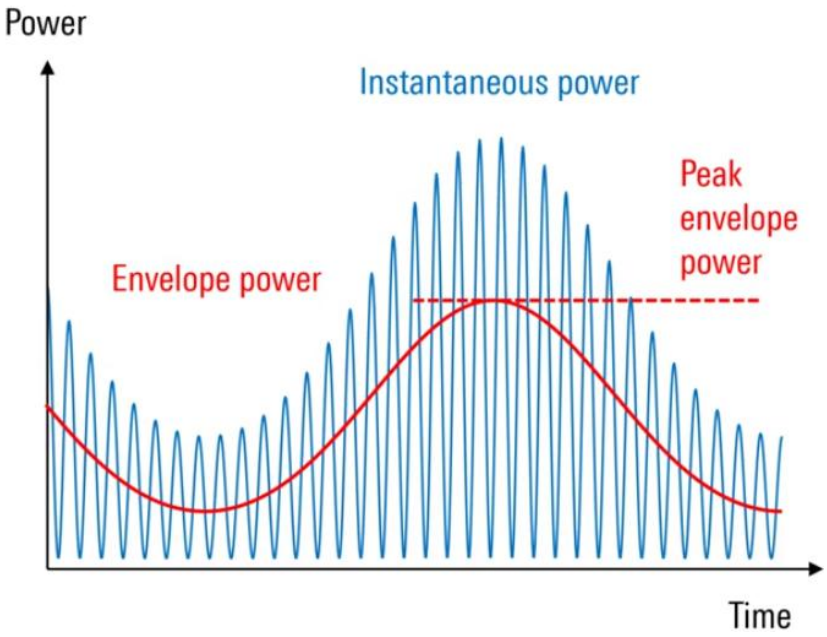


Peak Envelope Power (PEP) or Px

PEP is the average power over a single radio cycle. PEP is equal to steady carrier power of a FM, FSK, or RTTY transmission.

PEP is defined as the average power over a single RF cycle at the highest point (crest) of the modulation envelope.

With AM, 100% modulation of a carrier (PEP) is four times its carrier PEP; in other words, a typical modern 100-watt amateur transceiver is usually rated for no more than 25 watts carrier output when operating in AM.

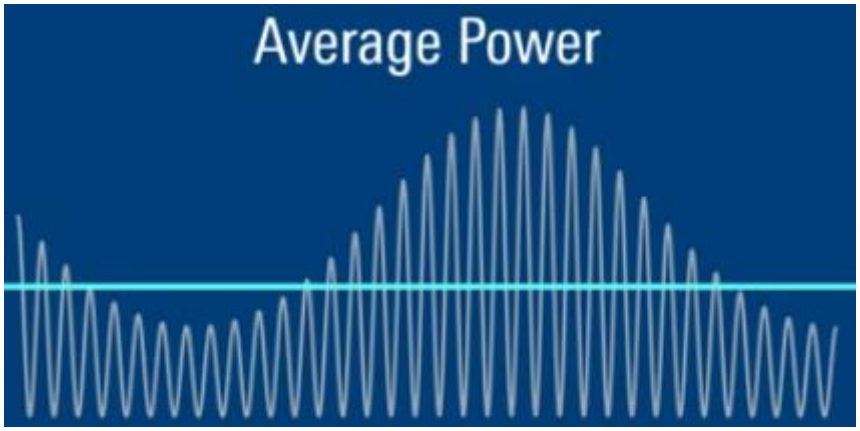


Average Power or Py

PEP is equal to the average power in a steady FM, FSK, or RTTY transmission.

Typical average power of a SSB voice transmission is 10-20% of PEP.

 © Jules Workshop 2026



PEP level control.

Most modern amateur transceivers use an ALC (automatic level control) system to monitor the output.

Operators must be aware of this as overdriving the ALC can cause distortion in the output.

Transmitter Field Strength

Electric field strength is a quantitative measure of the intensity of an electric field at a particular location. The standard unit is the volt per meter (V/m or V·m-1). A field strength of 1 V/m represents a potential difference of 1 V between points separated by 1 meter.

 © Jules Workshop 2026

Transmitter Terms

Automatic level Control (ALC)

ALC circuit controls the signal strength at the input to the power amplifier in a ham radio transmitter. This stops the power amplifier from being driven into non-linearity. Overdriving the ALC circuit can distort the signal and cause interference.

Audio-frequency range

The human audio range is 20 Hz to 20,000 Hz is commonly referenced frequency range.

Buffer

A buffer stage matches one stage to the following stage. This may be impedance matching, circuit separation and decoupling.

Cavity Resonator

A Cavity Resonator is used at the higher frequencies. The cavity resonator has a high Q so is ideal for oscillation and amplification. The cavity is a closed compartment made of a conductor with a hollow interior and works as an amplifier.

Crystal Filter

A crystal filter allows selected frequencies to 'pass' through while attenuating undesired frequencies. Quartz crystals can exhibit mechanical resonances with a very high Q factor (from 10,000 to 100,000 and greater.

Driver

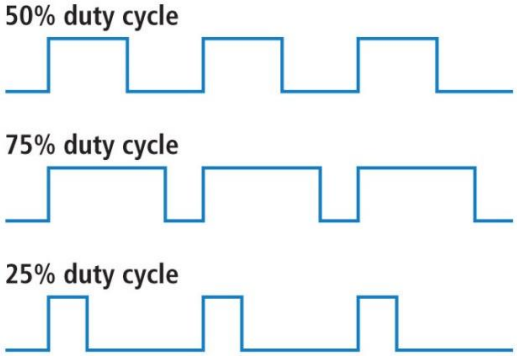
Driver or output stage of the transmitter.

Duty Cycle

The duty cycle is the ratio of the on time to off time.

An amateur transmitter is not designed for 100% transmission time so has a duty cycle included in the design and should be operated within the manufacture’s parameters.

- FSK, RTTY, AFSK SSB uses a 100% duty cycle.
- Morse code uses a 40% duty cycle.



 © Jules Workshop 2026

Efficiency

Efficiency can be shown as a ratio of the power output ÷ power input.

This number can also be shown as a percentage by multiplying the ratio by 100.

Efficiency% = (Power out / Power in) x 100

Linear Amplifier

Linearity refers to the ability of the amplifier to produce signals that are accurate copies of the input and at increased power levels. No amplifier can provide perfect linearity.

Mixer

Mixers shift signals from one frequency range to another, a process known as heterodyning. Frequency mixers are also used to modulate a carrier signal in radio transmitters.

Neutralisation

Neutralisation is a technique used to cancel feedback in bipolar junction transistors (BJTs) and field-effect transistors (FETs) that can cause instability over certain frequency ranges. This is done by introducing an additional feedback signal of equal amplitude but opposite phase to cancel the original feedback.

A completely neutralized amplifier must fulfill two conditions. The first is that the interelectrode capacitance between the input and output circuits is cancelled. The second requirement is that the inductance of the screen grid and cathode assemblies and leads be completely cancelled.

Output Filter

The output filter would have 50 ohms input and output impedance and ensure the output does not exceed the designated frequency range.

Output Impedance

Maximum power is transferred when the transmitter output impedance is equal to the load impedance of the antenna. Amateur radio standard is 50 ohms.

Output Matching

The transmitter output impedance must be matched to the load impedance for maximum power transfer.

Power Amplifier

A radio-frequency power amplifier (RF power amplifier) converts a low-power radio-frequency signal into a higher-power signal, and the output drives the antenna.

RF Shielded cabinets.

These are specialized Faraday cages designed to protect sensitive electronics from radio frequency (RF) interference and prevent sensitive, classified, or hazardous RF radiation from escaping. These cabinets are used in telecommunications, military, medical (MRI), and industrial settings to ensure operational integrity and safety by attenuating electromagnetic fields, often by over 100dB.

Spurious RF radiations

Spurious radio frequency (RF) radiations, or spurious emissions, are unwanted, unintentional, or incidental electromagnetic transmitted signals. If they are too strong, can cause harmful interference to other electronic devices and increase the overall noise floor.

Transmitter Efficiency

Transmitter efficiency measures how effectively a transmitter converts input power (DC) into output power (RF signal).

Modern solid-state transmitters, particularly for broadcast, can achieve RF efficiency >70% while older model transmitters may only be 15–18% efficiency.

 © Jules Workshop 2026

Emission Modes

Emission modes are defined in Schedule 1 of the Radiocommunications Licence Conditions (Amateur Licence) Determination 2015 (LCD). The three characters are the:

- Modulation component,
- Signal nature component.
- Information nature component

These are seen in the receiver and transmitter diagrams.

A1A

A =Main carrier is amplitude modulated and uses double-sideband
1 = Signal modulating the main carrier is a single channel containing quantified or digital information without the use of a modulating subcarrier.
A = Telegraphy for aural reception

J3E

J = Main carrier is amplitude modulated and uses a single-sideband, suppressed carrier
3 = Signal modulating the main carrier is a single channel containing analogue information
E = Telephony

F3E

F = Main carrier is angle modulated and uses frequency modulation
3 = Signal modulating the main carrier is a single channel containing analogue information
E = Telephony

Go to Unit 14 Questions.

 © Jules Workshop 2026