

# Online Radio & Electronics Course

## Reading 36

Ron Bertrand VK2DQ  
<http://www.radioelectronicschool.com>

### TRANSMITTER FAULTS

It is obvious by looking over old exam papers that the examiner has a 'bias' toward testing the knowledge of the amateur radio operator, regarding the building and use of their transmitter **without causing interference to other services**. Now, you may have no interest in building your own transmitter equipment, but your Certificate Of Proficiency along with a License enables you to do this if you so choose. Even if you do not build your own equipment you will most likely make internal adjustments and or modifications to your equipment. This reading will cover some material already covered and some new material, all relating to what can go wrong with a transmitter and cause interference.

#### CHIRPING

Chirping only applies to CW (Morse) transmitters. Keying chirps are **quick changes in the frequency of a transmitter and occur each time the telegraphy key is closed**. Keying chirps are usually caused by an oscillator stage in the transmitter being pulled off frequency each time the transmitter is keyed. Chirping was more of a problem when many amateur operators used to build their own equipment and when CW was more popular.

In CW mode, if the stage being keyed is too close to the oscillator, then the oscillator may shift slightly off frequency each time the key is closed. These quick changes in frequency sound very much like a canary chirping, hence the term 'chirping'. Chirping can also occur if the voltage regulation to the oscillator stage is inadequate.

#### KEY CLICKS

Key clicks also only apply to a CW transmitter.

Key clicks occur when the CW transmitter is being turned on and off by the Telegraph Key (Morse Key if you like) too quickly. When the telegraphy key is closed the transmitter begins to transmit, when the key is opened it stops. **The clicks occur when the telegraphy key is opened and closed**. If the transmitter is **keyed on and off too sharply, then the leading and trailing edges of the Morse signal will have a rapid rise and short decay time, like the leading and trailing edges of a square wave do**.

This results in sidebands being produced on each side of the carrier frequency. The diagram in figure 1 shows the telegraphy character 'R' as it would appear on an oscilloscope. **The key clicks are identified by an almost vertical attack and decay time of each element in the character**.

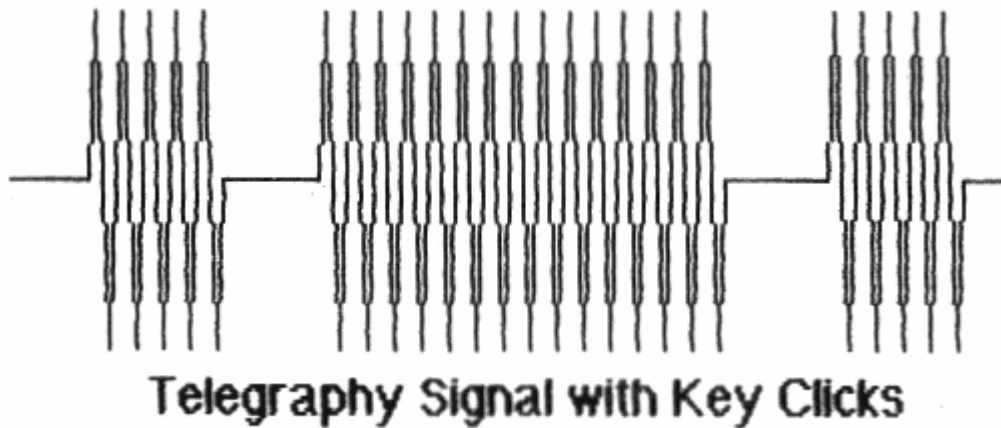


Figure 1.

Taking any sinewave and adding its harmonics can produce a square wave. The more harmonics that are added, the more perfect the resulting square wave. If a fundamental sinewave plus its harmonics can produce a square wave, then a perfect square wave must be made up of its fundamental plus all of its harmonics. If a series of square wave dots is transmitted (dots with key clicks), then the signal must be made up of the dot frequency plus the many harmonics of the dot frequency. If the dot frequency is 10 Hz (10 dots per second), and the wave shape of the dots is square (it has key clicks like in the oscilloscope diagram of figure 1), then there may be 50 or more strong harmonics present that will produce sidebands on both sides of the carrier, extending the band with the telegraphy signal by 1 kHz ( $2 \times 10 \times 50$ ). The resultant received signal sounds broad and a clicking sound can be heard.

Installing a “key-click filter” in the keyed stage will prevent amateur transmitter key clicks. The filter normally consists of a simple RC time constant that prevents the bias of the keyed stage from turning on and off too quickly. **The waveform of the Morse letter 'R' without any key click is shown in figure 2.**

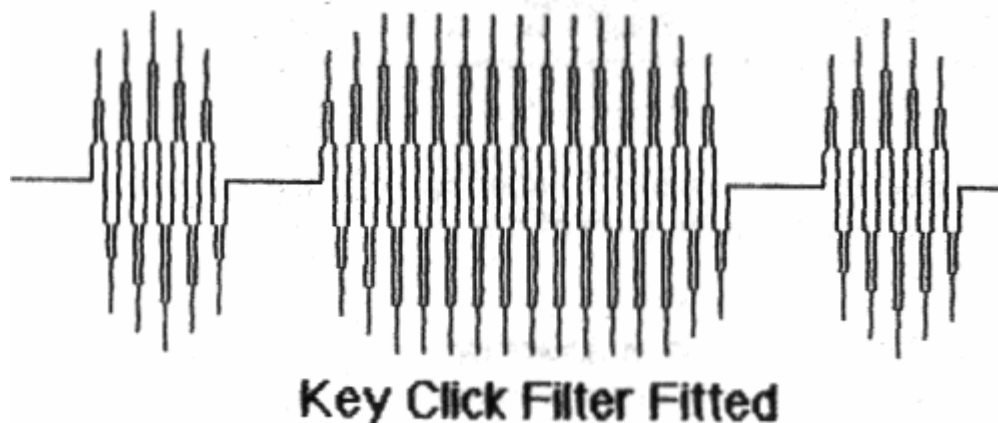


Figure 2.

It is a fallacy that key clicks are caused by dirty telegraphy key contacts. Dirty contacts may cause the key to stick closed or become sloppy. This is called squawking. The examiner is well aware of the fallacy and is known to use it as one of the multiple-choice options.

## SELF-OSCILLATION

Self-oscillation is caused by **unwanted positive feedback** (regeneration) in an amplifier. If the positive feedback is sufficient, the amplifier will break into oscillation on the operating frequency, and therefore no longer operate effectively as an amplifier. Self-oscillation in an RF stage of a transmitter could cause that transmitter to come 'on air' by itself. To prevent self-oscillation, an **equal amount of negative feedback** (degeneration) is applied to the amplifier, cancelling out the unwanted positive feedback. This process is called **neutralisation**.

**All active devices have some unwanted capacitance between the input and output terminals.** In a bipolar transistor it is the capacitance between the collector and the base; in the FET it is the capacitance between the drain and the gate; in the electron tube it is the plate to control-grid capacitance. At low frequencies this capacitance is not a problem as the capacitive reactance is high. At higher frequencies this reactance decreases and more signal is coupled from the output to the input. This feedback is regenerative and if it becomes too high it will cause the amplifier to oscillate.

The partial schematic diagram in figure 3 illustrates one method of applying an equal and opposite amount of negative feedback to prevent self-oscillation.

The capacitance shown dotted as ' $C_{bc}$ ' is the internal capacitance of the BJT - it is not external as shown. For practical purposes, the internal capacitance  $C_{bc}$  is in effect an external capacitor connected as shown.

Figure 3.

Negative feedback is applied by the variable capacitor  $C_n$  (a trimmer capacitor). Notice that the collector supply is connected to the centre tapping of the inductor in the collector tank circuit. Since the supply is bypassed to ground, the centre tap is at RF ground potential. When the top of the tank is positive, the bottom must be negative and vice versa, hence negative feedback is available at the bottom of the tank circuit.

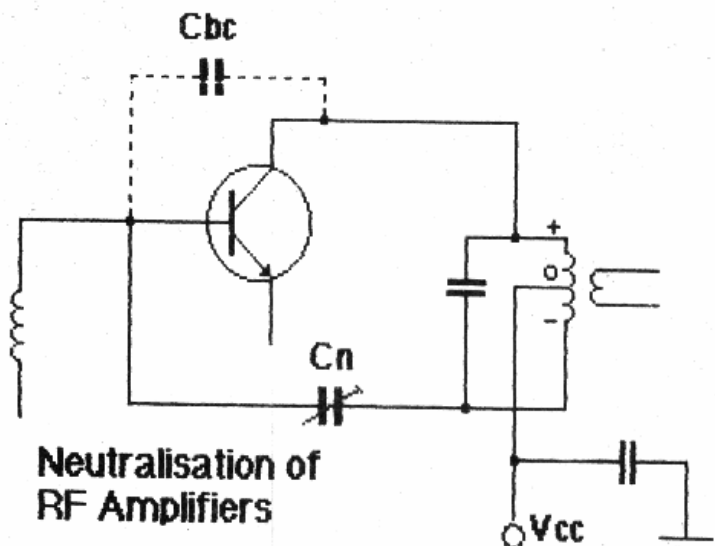


Figure 4 shows another popular method of obtaining neutralisation. In this circuit the negative feedback is taken from the secondary winding of the RF transformer. Since transformer action induces a 180-degree phase change between primary and secondary, the secondary voltage provides the necessary negative feedback.

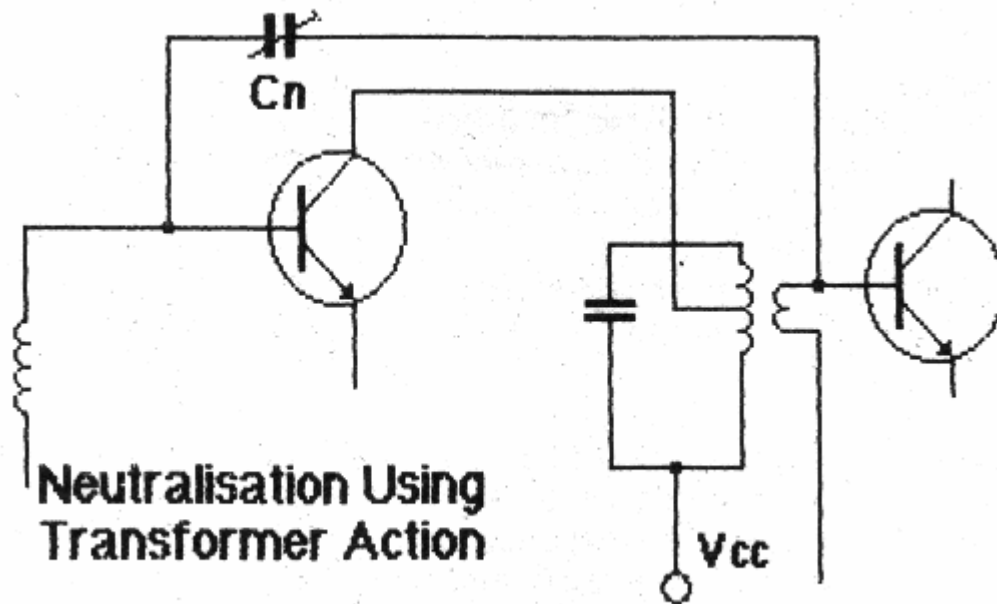


Figure 4.

## PARASITIC OSCILLATIONS

A parasitic oscillation is an **unwanted oscillation on any frequency other than the operating frequency**. A parasitic oscillation is caused by stray resonant circuits in an amplifier causing the amplifier to act as a tuned-input tuned-output oscillator.

The tuned-input tuned-output oscillator has not been mentioned before and it is not in the syllabus. Basically a tuned-input tuned-output oscillator is an RF amplifier with a tuned resonant circuit at its input and at its output. Both these tuned circuits are resonant on the same frequency. Add some positive feedback, and we have a pretty good oscillator.

Parasitic (unwanted) resonant circuits could be created by bypass capacitors and radio frequency chokes. If the stray reactances are high then **'low-frequency parasitics'** can be created. On the other hand, if the stray resonant circuits are created by wiring loom capacitance and inductance, the parasitic oscillation will be near to or even above the operating frequency, and in this case they are called **'high-frequency parasitics'**.

Parasitic oscillations generally produce a large number of harmonics. If a transmitter operating on 28 MHz has a low frequency parasitic on 500 kHz, spurious signals will be heard from the transmitter across the spectrum every 500 kHz up to and beyond the operating frequency. The fundamental frequency of the parasitic can be determined by using a receiver and a 'dip oscillator' (to be discussed). With the dip oscillator tuned to the parasitic frequency, it can be moved around the circuit (inside the transmitter which is turned off). Tuned to the parasitic frequency, a dip will indicate the location of the parasitic circuit.

## PARASITIC STOPPER

In electron tube amplifiers that only carry a low current, the easiest method of eliminating parasitic oscillations is to install a low value resistor (10-100 ohms) in the grid and plate circuits as close to the electron tube as possible. In high current circuits, 10-20 turns of wire can be wound over the resistor and soldered to each end. **This, in effect, creates a low-Q RF choke.** Such a device is called a 'parasitic stopper'

For exam purposes, you need to know: (a) what are parasitic oscillations, (b) the difference between high and low frequency parasitics, and (c) what a parasitic stopper is.

In transistor amplifier stages, a small ferrite bead can be threaded over the leads of the active device to form a parasitic stopper.

## HOW PARASITIC STOPPERS WORK (FOR INTEREST?)

All types of parasitic suppressors work by increasing the resistance in the parasitic circuit to a value equal to or higher than the **critical resistance**. When any resonant circuit has a resistance equal to  $2 \times \sqrt{L/C}$  (called the critical resistance), the circuit is said to be **critically damped** and will not oscillate. By critically damping the parasitic circuit, oscillation is prevented.

## OVER DRIVING A LINEAR RF AMPLIFIER

Over driving a linear RF amplifier stage will cause 'splatter', and therefore a widening of the occupied bandwidth and possible interference.

Remember that you may over drive linear amplifiers in a transmitter simply by turning the microphone gain up too high.

When a complex waveform such as a SSB signal is fed to a linear RF amplifier, it is increased in amplitude by the gain of the amplifier. All linear amplifiers have some non-linearity that results in some distortion. Non-linearity causes the individual frequency components within the signal to mix and produce new signals. New signals (frequencies) are distortion. Normally the amount of non-linearity is so low as to be insignificant. **When a linear amplifier is over driven it ceases to behave in a linear** fashion and severe distortion results. Excessive harmonics and spurious side frequencies are created, which almost certainly produce interference to other services such as television reception, and other nearby operators will report 'splatter'.

## FLAT TOPPING

Flat topping results from over driving an amplifier stage. The input signal becomes so high that the amplifier is driven into saturation and/or beyond cutoff. The resultant waveform on an oscilloscope appears as though the top and bottom peaks have been flattened. The term 'Flat Topping' is applied to SSB signals only.

## PI-COUPPLING AT A TRANSMITTERS OUTPUT

The schematic diagram of pi-coupling is shown in figure 5(a), and redrawn in 5(b) to emphasise that a pi-coupling network is just an extension of the output 'tank' circuit.

Figure 5.

**The pi-coupler does a few important things, namely:**

- a) Matches the impedance of the power amplifier of the transmitter to the transmission line (feedline).
- b) Acts as a low pass filter for suppression of harmonics.
- c) It can if necessary, supply the flywheel effect (FM or CW).

It is obvious from the configuration that the circuit will function as a low-pass filter. If this is not clear to you then I suggest you revise the reading on filters.

To see how the pi-coupler is used to obtain impedance matching, it is best to visualise the circuit as redrawn in figure 5(b).

The pi-coupler is simply a parallel tuned circuit with a tapped capacitance across the inductor. The impedance of the parallel tuned circuit at resonance is very high. However, the impedance seen across A-B and B-C will depend upon the ratio of C1 and C2.

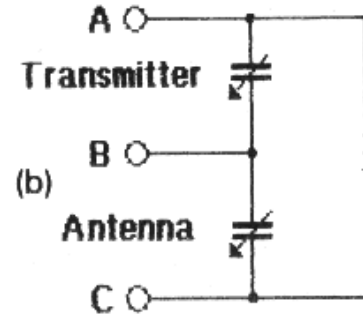
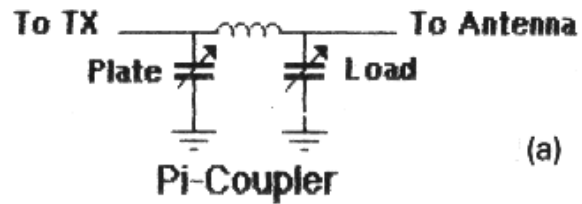
When the transmitter is tuned properly, that is, the pi-coupler is tuned to match the transmitters impedance to the transmission line, the output impedance of the transmitter will be equal to the impedance seen between A and B, and the impedance between B and C will equal that of the transmission line.

When the output of the amplifier is matched to the input impedance of the transmission line, maximum power transfer will be obtained. In practice, the operator simply adjusts C1 (TUNE CONTROL) and C2 (LOAD CONTROL) for maximum power output. When either C1 or C2 is adjusted by the operator, the circuit will be pulled off resonance. For this reason, the operator alternately adjusts C1 and C2 until further adjustments result in no increase in power output.

It is possible to adjust the pi-coupler by monitoring the circuit current drawn in the output of the final amplifier. At resonance the circuit impedance will be high and anode (or equivalent) current drawn will 'dip' to a minimum. The operator will see the 'dip' by monitoring the anode current or collector current. Either method (dip or maximum RF output) can be used alone, or in conjunction, to tune any transmitter output stage. All transmitters with tunable pi-coupling in the output, or some variation of it, work this way.

**INTERMODULATION INTERFERENCE**

Two or more signals can, upon entering a non-linear device, mix together to produce new signals. The new signals are called intermodulation products and they may be on frequencies that can result in interference. **The difference between modulation and intermodulation is that modulation (or mixing) is deliberate.**



**A Pi-Coupler redrawn as a Parallel Tuned Circuit**

The most common place for this mixing to occur is in a receiver, however mixing can occur in the power amplifier stages of two or more transmitters operating in close proximity.

Transmitted signals from two or more transmitters can be received by some metallic structure such as a tower. Rusted or bad metallic connections can cause the connection to act as a rectifier (non-linear device) causing intermodulation and re-radiation of the new unwanted signals.

Intermodulation can also occur in the output stage of a transmitter (since it is often non-linear). This is called transmitter intermodulation. Now, many amateur operators do not understand transmitter intermodulation. Imagine two or more transmitters in close proximity to each other. Do you really think that if two transmitters were transmitting on different frequencies and perhaps even different modes, that signals from each transmitter would not enter the other transmitter? They do! Transmitters transmit to other transmitters - they are not smart enough to know that the antenna is a transmission antenna.

Signals are received and mixed in the output stages of transmitters and are sometimes re-radiated causing interference to other services.

You do not need to go any deeper into intermodulation interference for examination purposes. However, if you would like more information on this subject, check with me or look in the supplementary downloads.

## CARRIER SUPPRESSION

Operating on SSB means transmitting one sideband, either upper or lower, by getting rid of the unwanted sideband using a band-pass filter and suppressing the carrier. Carrier suppression in amateur SSB transmitters should be 40 dB or more. **The stage looking after carrier suppression is the balanced modulator.**

The carrier balance is one of the 'inside controls' you will most probably adjust. If you are 'on air' talking to another station on say USB, transmit but do not send any audio to the SSB transmitter (just be quiet). The only thing being transmitted now will be your suppressed carrier. Have the nearby station you were just talking to tune down about 2.8 kHz, and they will hear and report back to you that they can see your suppressed carrier on their 'S-meter'. They will report a tone as well, but their receiver produces this tone when it picks up your suppressed carrier.

A better way is to use another receiver at your station, and have your transmitter going into a dummy load. You can then do the same thing and adjust the 'carrier balance' control in the balanced modulator for maximum carrier suppression.

I have heard SSB stations on air with such badly adjusted carrier balance that they were transmitting single sideband full carrier, or at least close to it.

End of Reading 36

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E-mail: [manager@radioelectronicschool.com](mailto:manager@radioelectronicschool.com)

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