Lesson 8 looked at a simple transmitter *exciter* comprising of oscillator, buffer and multiplier stages.

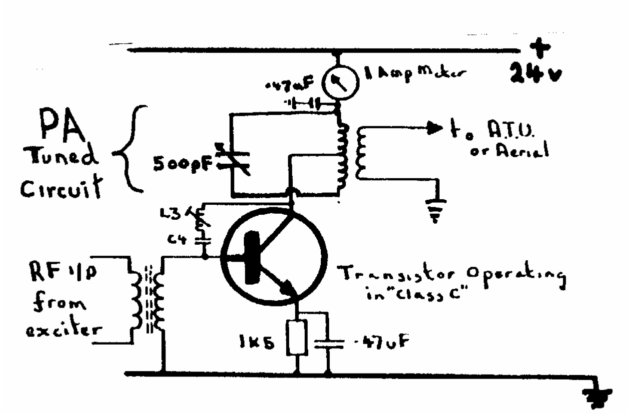
The power amplifier

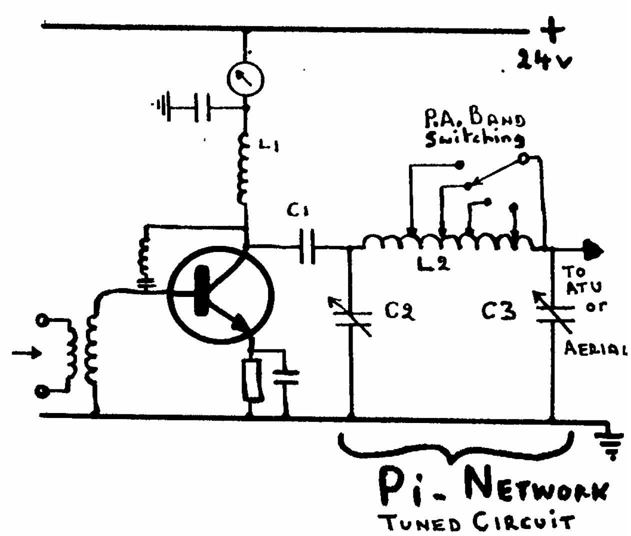
The output from the exciter is usually very low and it is necessary to amplify the signal before passing it to the aerial. This job is done by the power amplifier (PA) stage. It is designed to handle high power levels.
As there is, normally, no frequency change within a P.A. It is very important to ensure that self-oscillation does not take place. This means that the P.A. stage must be carefully designed to avoid any positive feedback. It is necessary to screen the output from the Input circuits.
P.A. stages are usually operated in *Class C* to give the best efficiency. This means that the transistor is conducting for less than a half of each cycle. The resultant output waveform is a sine wave due to the “flywheel action” in the output-tuned circuit.
Remember that an unaided tuned circuit will give rise to a *damped oscillation*, once induced. This means that the transistor has only to make up for the losses of the tuned circuit. This is further explained a little later.
A transistor (or valve) has internal capacitance and this may cause the unwanted feedback from the output to the input. This capacitance is neutralized by external components. (L3 & C4)

This P.A. circuit has the disadvantage that neither side of the tuned circuit capacitor is connected to earth.

The fixed plates of a variable capacitor are Mounted on its frame. The whole of the capacitor would have to be insulated from the radio chassis thus giving practical and operational problems.

These problems are overcome by replacing The Conventional Parallel tuned circuit with One known as a "Pi Network" or "Pi Tank". This comprises an inductor and two variable capacitors. Both capacitors have one side earthed enabling normal chassis mounting.





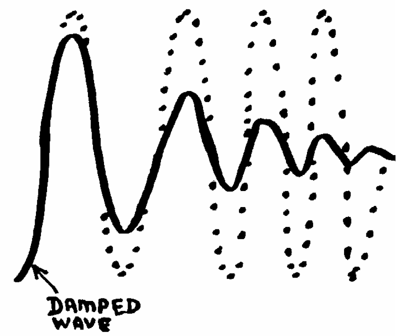
The Pi circuit has the additional advantage of much higher harmonic rejection.
The second harmonic rejection is four <u>times</u> better a conventional parallel tuned circuit.

The whole of the P1 network and the aerial Circuit can be isolated from the supply voltage by C3.

The Pi coil is usually ‘tapped’ to enable operation on several amateur bands by suitable switching.

FLYWHEELS or a CHILDS SWING

If a tuned circuit is perfect, then once a frequency is introduced into it the oscillations would continue Forever and a day....If no energy is taken out. There is no such thing as a perfect capacitor Inductor therefore the tuned circuit will have losses and the oscillations will gradually fade away. This is known as a damped oscillation.



If this loss is overcome, by introducing a pulse during each cycle, then the output will be maintained.

It is possible to use a transistor, that is biased well beyond cut-off, to supply the energy to sustain the output.

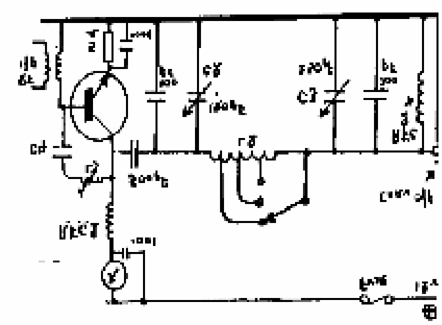
Used In this way the transistor is said to be operating in "Class C" and it passes the current for less than 50% of each cycle. The tuned circuit acts like a flywheel. The pulses of current through the PA transistor make up for the losses in the tuned circuit and create an output comprising complete cycles.

If this sounds a bit far fetched - have a swing!.

Think of a child's swing. If there were no air resistance or friction it would swing for ever, once started. In reality, each ride gets less and less until it stops altogether -*a damped oscillation*. However, if you can give a series of little pushes at the right time it will keep swinging with hardly any effort at all.

A PRACTICAL POWER AMPLIFIER CIRCUIT

Cl is to isolate the P1-Network and the aerial from the supply voltage. However, as an additional precaution, a Radio Frequency Choke (RFC2)is connected between the aerial connection and earth. The Radio Frequency (RF) will not pass through it, so the transmitted signal will not be radiated. If C1 should fail (become a short circuit) then the DC will pass to earth via this choke and blow the supply fuse (FS1). L2 Is the inductor (coil) of the Pi-Network. It is *tapped* and connected via a band switch so that the Pi-Network can be resonated on each of the required Amateurs Bands, using the same variable capacitors.



HOW TO "TUNE-UP" THE POWER AMPLIFIER

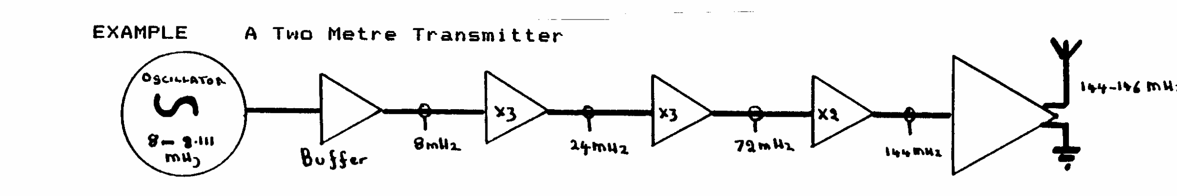
The aerial is replaced with a suitable dummy load.
Set the Loading Capacitor(C3) to maximum and adjust the Tuning Capacitor(C2) until there is a dip in the collector current. C3 is then decreased to give the required value of this current. These two capacitors are interdependent hence it is necessary to repeat this procedure several times. Transistors in the PA stage cannot normally stand the full collector for more than a few seconds so breaks should be left in the tuning signal.
The transmitter is then re-connected to the aerial and the above operation repeated on a clear frequency. This is necessary as the impedance of the aerial will not be exactly the same as the dummy load.

If an *aerial tuning unit* (ATU) is used to match the aerial, it should now be adjusted.

SIMPLE VHF TRANSMIIIERS

VHF covers the range 30 MHz to 300 MHz and this includes three Amateur Bands:-
Six Metres 50-50.5 MHz; Four Metres 70.25-70.7 MHz; Two Metres 144-146 MHz
Although it Is possible to obtain VHF crystals, it is more common to use an oscillator in the 6 to 12 MHz range and several stages of multiplication.

EXAMPLE **A Two Metre Transmitter**



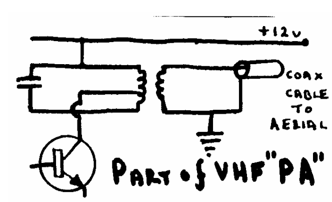
The crystal oscillator used in the transmitter multiplier must be in the range 6.0 to 6.111 MHz to give a final frequency between 144 ~ 146 MHz The total multiplication can be obtained in a number of ways. For example:- a multiplication of 16 could be: Times 3 Times 3 and Times 2
or : Times 2 Times 3 and Times 3
However, it is better to avoid a multiplication greater than 4 In a single stage. Hence it is not a good idea to try Times 2 with Times 9

Some VHF transmitters use crystals in the range 6 to 6.063 MHz with a total multiplication of 24 Times, or in the range 12-12.165 MHz with a total multiplication of 12. It is necessary to choose multiplication that will not give problems in your own shack...
For example, it would not be a good idea a stage operating at 16MHz (16-18.250) if operation in the 17 MHz Amateur Band (16.066-16.166 MHz) is envisaged.

It is still quite common to use crystal controlled transmitters for VHF. This is useful for mobile operation where it is easier to switch to the required channel rather than trying to "tune in" the other station. In the *two metre band* certain frequencies between 145 and 146 MHz are given channel numbers. For example 145.5 MHz is known as V40 (S20); 145.525 is V42 (S21):145.550 is V44 (S22) and 145.5875 is V47. The channels are 12.5 kHz apart.The old spacing was 25 kHz and these channels were given the “S” numbers shown in brackets.

When VFO operation is used, great care must be taken to ensure that the oscillator is stable as large frequency multiplications are involved. For example, an oscillator in the 6 MHz range that drifts 500 Hz would result in a 12 kHz change in the final 144 MHz transmitted signal!

VHF transmitters often use traditional parallel tuned circuits in the PA rather than Pi-Networks. VHF components are small are easily mounted on insulating mounts.



TRANSMITTERS : Shall we ADD, SUBTRACT or MULTIPLY?

As we have seen the final frequency of a transmitter may be obtained by multiplication of the oscillator frequency. The alternative, Is the method called mixing.

Frequency multiplication has the following disadvantages:

a) The final output is likely to contain many unwanted harmonics
b) A small change in the oscillator will be exaggerated in the final output.
c) The dial graduations will differ for each band.

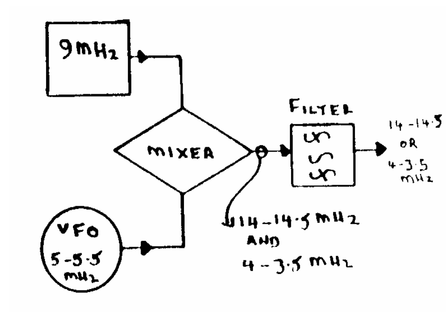
MIXING

Remember[1] when two frequencies are fed into a non-linear device, the output will contain the following:

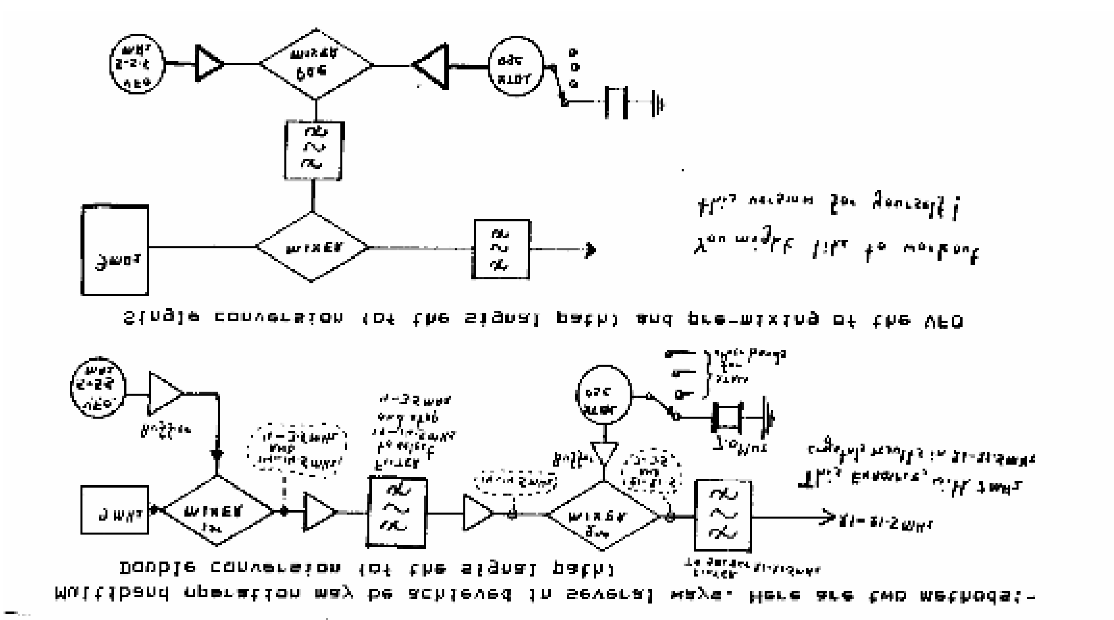
<u>Both</u> the input frequencies The <u>sum</u> of the input frequencies

The <u>difference</u> of the input frequencies (and the various harmonic mixing products)

A simple two band transmitter can be made with a VFO and one stage of mixing. The filter must be designed to pass the wanted mixing product and suppress the other. If no filter were included, transmissions would occur on two bands at the same time!. This example shows a VFO covering 5-5.5MHz mixing with a 9 MHz oscillator. This results (by adding) 14-14.5 MHz and (by subtracting) 4.0-3.5 MHz . In the latter case you will notice that as the VFO frequency Is increased, the output frequency decreases.



This example would permit operation on Metres(3.5-3.6MHz) or 20 Metres(i4-14.35MHz) bands.



The above circuits have a 9 MHz source as this is convenient when considering SSB. High quality 9 MHz SSB filters are readily available.

Mixing has the following advantages

a) The dial calibration is the same for all bands.
b) The mixing Is done at low signal levels avoiding unwanted outputs.
c) It Is easy to adapt this form of transmitter to SSB by fitting a SSE generator In place of the 9 MHz oscillator.

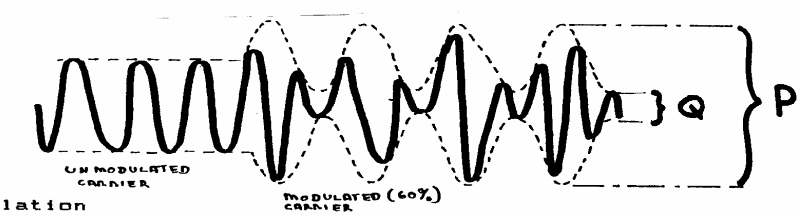
MODULATION

There are several methods of impressing speech on to the carrier wave. The process is known as "modulation". Generally, the speech will modulate either the amplitude or the frequency of the carrier. The rest of this lesson will deal with Amplitude Modulation (AM) leaving Frequency Modulation (FM) for a later lesson.

AMPLITUDE MODULATION

Assume a Morse transmitter has been built and a continuous wave is being transmitted. The supply voltage to the PA is kept constant and this will give a carrier wave of constant amplitude. If, however, the PA supply voltage is raised, the amplitude of the carrier will increase. Conversely, a reduction in the PA supply will produce a carrier wave of reduced amplitude.

Thus, if It can be arranged for the PA supply voltage to be varied In sympathy with speech, then the carrier wave would be Amplitude Modulated by the speech. The speech is then known as the Modulating Frequency.



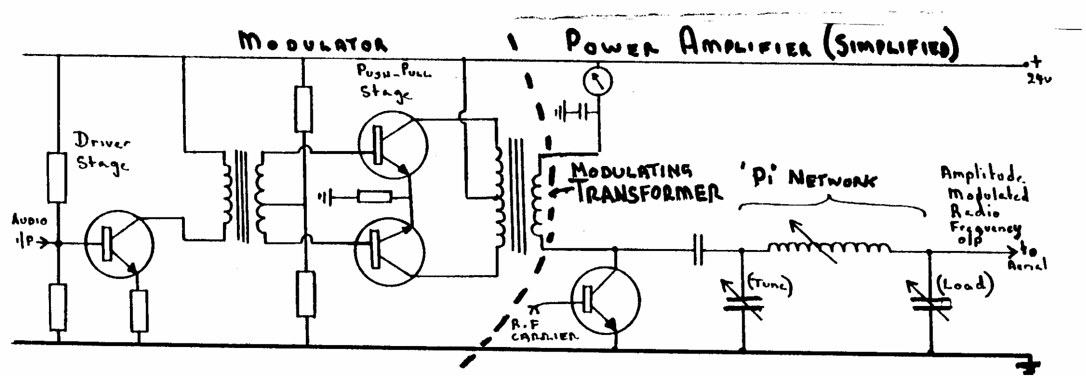
Depth of Modulation

This is normally expressed as a percentage $= \frac{P - Q}{P + Q} \times 100\%$

A TYPICAL A.M. TRANSMITER

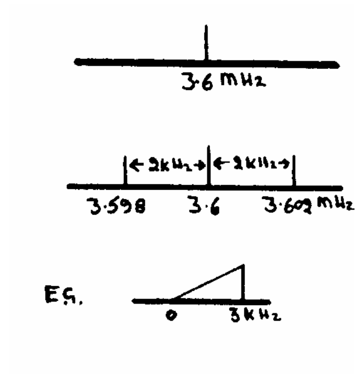
For 100% modulation, the modulator itself must be able to provide power equal to half of the DC input power that is supplied to the PA.

For example, to fully modulate a transmitter, having a DC input of 150 Watts, will require a 75 Watt audio amplifier (modulator). It is usual to use a push-pull amplifier.



It is very Important to ensure that over-modulation never occurs. This would produce many harmonics and spurious sidebands. These extra side bands will result in a very 'wide' signal taking up far too much of the frequency band. It is best to aim for a maximum of 90%. This will leave a safety margin of 10%

AMPLITUDE MODULATION

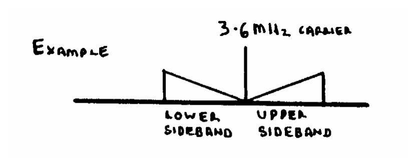


A carrier wave of, for example 3.6 MHz, is a single frequency. This is shown on the frequency spectrum as a Single line.

This carrier is then amplitude modulated by a 2 kHz tone creating two side frequencies - each 2 kHz from the carrier.

This triangle Is used to represent a band of audio frequencies. The lower end, in this case on the left, represents the lowest frequency. The higher end, on the right, represents the highest frequency. The triangle Is used to show the relative positions of the high and low audio frequencies and not give any indication of their amplitude or power.
This symbol shows where frequencies will appear in the frequency spectrum after modulation or after mixing.

If a carrier Is modulated by a band of frequencies, such as speech, then both upper and lower sidebands will be produced.
You will see, from the lower sideband triangle, that the speech frequencies are Inverted. In other words, the lower speech frequencies come out higher than the high speech frequencies on the other hand, the upper sideband is erect. You will have to think about this



However, the most Important point to notice is the bandwidth of the amplitude modulated wave.

The TOTAL BANDWIDTH taken up by the signal will be TWICE the HIGHEST audio frequency.

Therefore the speech should not contain frequencies higher than absolutely necessary. For communications (Amateur Radio) it is adequate to use up to 3 kHz. (The BBC, which transmits music, uses greater than 12 kHz.) A typical Amateur Radio transmitter will restrict the audio to the range 300 Hz to 2.5 kHz. It is possible to restrict the frequency response even further but this will make it difficult to recognize the speaker, even though the words will be readable.

<u>LESSON 9 QUESTIONS</u> **(Lengthy answers are not required)**

Q9.1 In a VFO, why is it necessary to use short stiff wiring between the inductor and the capacitor to reduce drift?
Q9.2 How is an Amateur Radio License revoked?
Q9.3 What audio bandwidth should be used in an Amateur speech transmission?
Q9.4 What is the advantage, to the Radio Amateur, in using SSB?
Q9.5 You whistle a pure note of I KHz into the microphone of a perfect SSB transmitter. What is the bandwidth of the transmitted signal?
Q9.6 Why Is a Frequency Modulated transmission less likely to cause any interference to a near-by television receiver?
Q9.7 A simple two band transmitter uses a 9 MHz oscillator and 5-5.5 MHz VFO, both fed into a mixer. How is the required band selected?
Q9.6 Draw the circuit of a transistor MODULATOR and POWER AMPLIFIER.
Q9.9 What type of modulation has your circuit produced?
Q9.11 What are the advantages of Morse communication?
Q9.12 What is the purpose of a Pi-Network In a PA stage?
Q9.13 Why is the collector, of the transistor on page 1 of this lesson, connected to a tap on the coil rather than the lower end?
Q9.14 What is meant by the "shape factor" of a tuned circuit?

