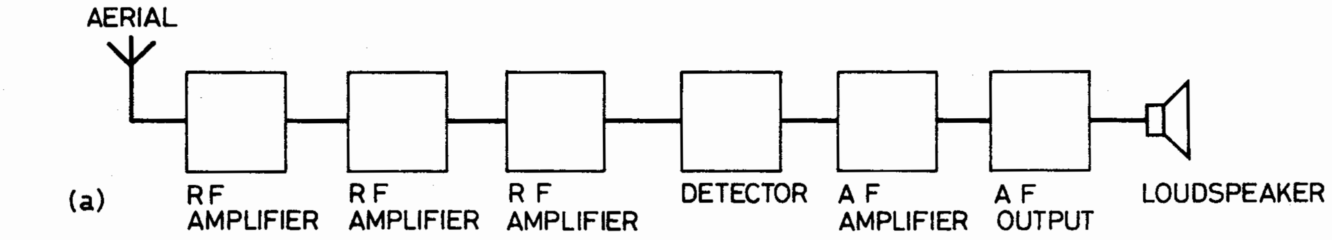

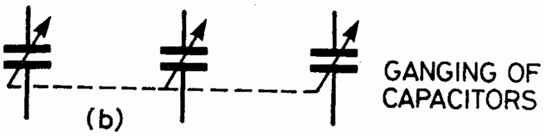

Fig. 6b. Using ganged capacitors to tune several stages simultaneously.

frequencies are very close, we need a lot of tuned circuits. It's not entirely impossible, because we can make *ganged* tuning capacitors, variable capacitors with one shaft operating several capacitors, but it's difficult. In addition, and just to make a difficult job almost impossible, we have our old friend positive feedback lurking around. We may have to amplify the radio signal by quite a bit using perhaps a gain of one thousand or so. With so much amplification of a carrier that can launch itself off a piece of wire so easily, it's very hard to stop some of the amplified signal from getting back to the input. Working on the 'butter-side-down' principle, such feedback is always positive at some frequency or other, so that the whole amplifier oscillates.

The fact that an oscillating receiver is useless as a receiver is bad enough, what makes it worse is that it radiates the oscillating signal back into the aerial and so to any other receivers that are around. When your receiver oscillates, no one listens to the show. We don't like TRF receivers, folks.

Supersonic Changes

All is not lost, though, because a brilliant invention of more than fifty years ago lets us have lots of tuned circuits, along with easy changes of frequency and less chance of feedback. It started with the name of supersonic heterodyne but not surprisingly lost a few letters and ended up being called the superhet receiver. How does it work? Pin your eyelids up and read on.

At the input of a superhet receiver, the signal is tuned in the usual way, using a variable capacitor which is part of a two-gang capacitor set. Instead of amplifying this tuned signal, though, its frequency is changed in a mixer stage. Two frequencies are fed into the mixer stage — the carrier signal that has been selected by the tuning, and a sinewave generated by an oscillator (called the *local* oscillator) which is part of the receiver. Most small receivers do not use a separate oscillator stage; the mixer is connected so that it will oscillate. Now we've mentioned the idea of signal mixing before (beat-frequency oscillator, remember?) but let's run over it again. When we feed two radio signals into an amplifier which is not biased for linear amplification, the output signal will consist of the sum and difference frequencies as well as the frequencies we put into the mixer. More remarkable and useful is the fact that if one of the input frequencies is modulated, then the sum and difference frequencies will also carry the identical modulation. We choose the difference frequency, called the intermediate frequency (IF) and use as the load of the mixer a tuned circuit which will resonate at this intermediate frequency.

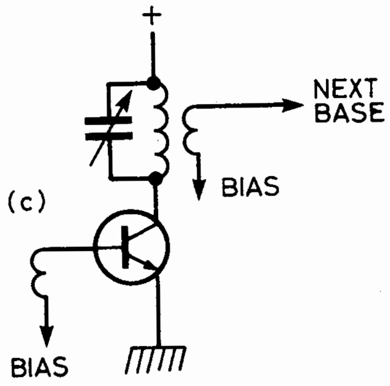

Fig. 6c. A single RF stage and connections to the next stage.

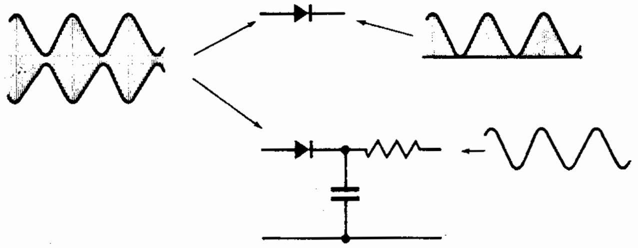

Fig. 5. Using a diode and CR network for detection and demodulation.

Tracking Down the IF

What's so smart about changing the frequency? Well, it's not just that we change the frequency, but that we change *any* input carrier frequency into the same IF frequency. The frequency of the local oscillator is controlled by a variable capacitor, the other half of the ganged pair whose first half is used to tune the carrier. Now with a bit of cunning we can arrange it so that these two tuned circuits, the input and the oscillator, will 'track' together, meaning that when we change the tuning of the carrier by 50 kHz, then the tuning of the oscillator will also change by 50 kHz. If this tracking is accurate, then the difference between oscillator frequency and carrier frequency stays constant, so that when we tune from one carrier to another the frequency at the output of the mixer, the IF, stays constant.

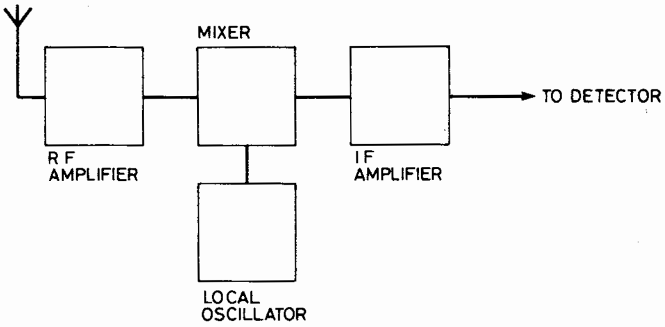

Fig. 7. Block diagram of a superhet receiver up to the detection stage.

We now have the easy job of amplifying a signal which is at a fixed frequency. The tuned circuits for this lot can be kept inside metal cans to reduce radiation of IF signal, so that positive feedback can almost be eliminated. Any feedback to the input of the mixer is not particularly important, because it's at a different frequency from the carrier frequency and will be rejected by the tuned circuit at the input. A few high-class receivers use an additional IF trap at the input, just to make sure. Very cunning, very useful.

Automation

Summing it all up so far, Fig. 7. shows a block diagram of a superhet receiver up to the detector stage, and Fig. 8. shows the actual circuit diagram of a typical pocket transistor radio. There's one little bit of cunning that we haven't mentioned yet — it's called the AGC circuit, meaning Automatic Gain Control. This AGC is needed because of the way in which radio waves reach us. Radio waves are electromagnetic waves, like light, and they travel through space in the same way, at the same speed of 300 million metres per second, obeying the same laws. Apart from the effects of diffraction, the only way a radio wave can reach us from a distant transmitter (because of the curvature of the Earth) is by reflecting from the Heaviside or Appleton layers. These are belts of ionised gas that surround the atmosphere, with lots of loose electrons floating about, and they reflect radio waves at most of the lower frequencies. Any radio signal of up to around 30 MHz can then reach us by several paths, a direct path if the transmitter is not too far away, and various reflected paths (Fig. 9.) depending on the height of the reflecting layers, which is generally around 30 to 50 miles.

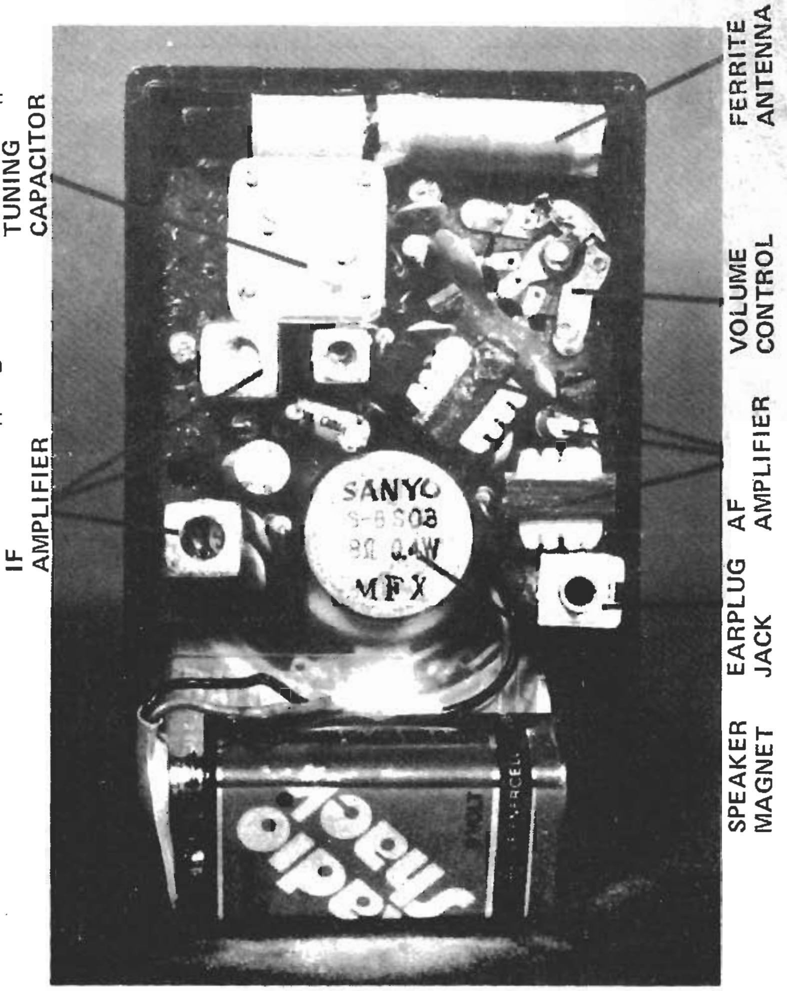

Fig. 8a The various parts of a pocket A.M. ratio.

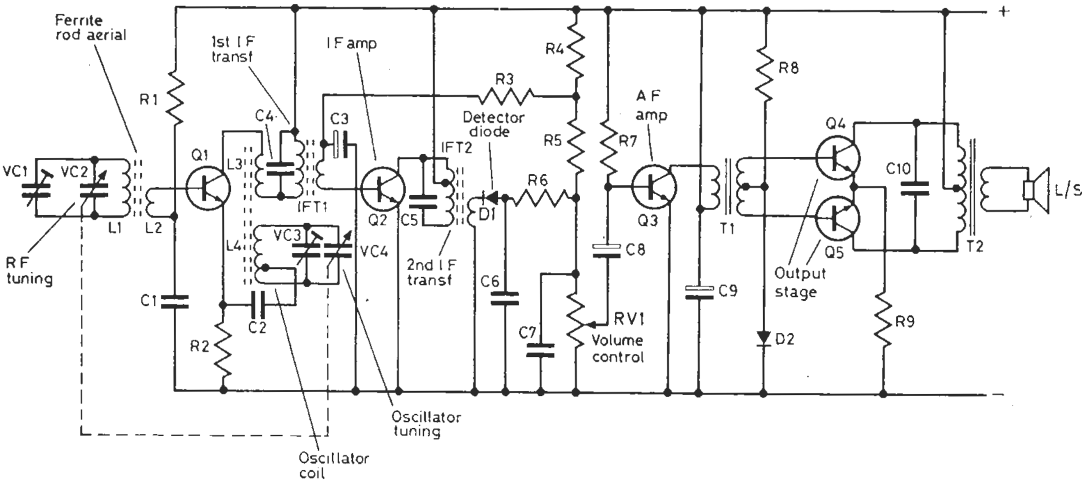

Fig. 8b Circuit diagram of a typical pocket transistor radio.

To Be Or Not To Be. . In Phase

At the receiver, then, signals arrive from several different directions having travelled by different path lengths, and there is no chance that they will always arrive perfectly in step. At 1 MHz for example, the wavelength of a carrier is 300 metres. A path difference of only 150 m at this frequency will cause one wave to be inverted relative to the other, and any odd multiple of 150 m difference in path length will also cause the waves to be in antiphase.

The reflecting layers are constantly on the move, so that reflected waves have to cover different distances from one minute to the next. At one instant, the waves reaching the receiver may reinforce each other, at the next instant they are just as likely to cancel. The result is that the signal received at the aerial varies greatly in amplitude from one moment to the next.

We could, of course, sit with one hand on the receiver volume control turning up the gain each time the signal became faint and turning it down again when the signals were strong, but it's easier to use a form of negative feedback to do the job. AGC makes use of the fact that the detector diode rectifies the carrier signal, so that there's a steady (DC) voltage at the detector. The