NEWSLETTER ARCHIVES

A BOX TOO FAR?
by Brian Kendal G3GDU

For many years I have been an admirer of the navigational systems used by the Luftwaffe in the early 1940s to bomb the United Kingdom, if only because of personal experience of their accuracy during the "Blitz" on Sheffield when I was a schoolboy.

The most advanced of these was Y-gerat. It used a ranging system in which 300 or 3000 Hz tone was transmitted from the base station on a frequency of 42.5 MHz. This tone was received by equipment on the aircraft and retransmitted on 46.9 MHz. At the base station, the audio phase difference between transmitted and received signals were measured, and from this result, the range of the aircraft was calculated.

One afternoon, when I was rather less busy than usual (only about a hundred urgent tasks pending!), I fell to thinking whether it would be possible to reproduce this technique using the equipment in the shack to measure the distance of the local 2M repeater.

My gear consisted of two transceivers, each connected to its own antenna and an IC2E H-T. To simplify things I decided to use the 1750 Hz access tone rather than a separate audio oscillator (there is nothing magical about the original Luftwaffe frequencies).

The minimise the risk of blocking, the IC2E was used to access the repeater and provide the measurement tone. The retransmitted access tone could clearly be heard by either transceiver. The remaining task was to display the time difference between transmitted and received signals on an oscilloscope.

To display the access tone directly would have required delving into the IC2E with a soldering iron. I sought a simpler solution by using one transceiver to monitor the outgoing signal and the other to monitor the signal from the repeater. In each case I coupled the audio signals from the headphone sockets to the oscilloscope inputs . At this point I could lock the oscilloscope trace onto the modulation of the transmitted signal and clearly see the phase shift of the received signal. All that remained was to interpret the results.

The access tone used was 1750 Hz so the length of one cycle was approximately 571 microseconds. By expanding the oscilloscope trace, the phase difference between transmitted and received signals was measured as about 35 microseconds. A quick calculation gave the time for a signal to travel a statute mile and return as approximately 10.74 microseconds The distance to the repeater, therefore, is just over as just over 3 miles, a fair approximation a fair approximation of that distance as shown on the map.

At this point I was feeling very pleased with myself - but I had forgotten one of the basic rules of radio. That is, if everything seems to work out right on the first attempt, something is definitely wrong!

Recently I decided to repeat the experiment and from the moment I started, everything went wrong. The transceivers which I had used on my previous experiment had both been disposed of and had been replaced by and IC821 and an IC746. Additionally a pair of IC-2Es was on hand.

When I repeated the experiment, the delay of the received signal varied from one rig to the next, and the signal's "round trip" time was far greater than expected.

To sort out the problem, my first task was to compare the signal delays through my equipment. I measured these values by using one equipment to provide a modulated signal while monitoring this on the other two and comparing their signal outputs on the oscilloscope. From this I saw that the IC2Es had the shortest delay, that a trip through the IC821 was some 25 microseconds longer and the IC 746 added a further 12 microseconds.

If outgoing tone and the returned signal were monitored on identical receivers, any errors due to receiver delays would cancel out and the phase shift of the returned audio would represent the signal transit time plus any delay in the repeater itself. Any signal delay in the tone transmitter would be irrelevant as the transmitted signal was being monitored at its output.

At this point I realised that my original intention of directly measuring the distance to the repeater was not possible because I could not directly measure the signal delay within the distant equipment (the repeater)t. The other alternative was therefore to assume the distance to the repeater (which I knew reasonably accurately from the map), measure the "round trip" time and from that deduce the repeater signal delay. Then, having effectively "calibrated" the repeater, I could measure distances from other locations.

Using this technique, the "round trip" time was measured as about 115 microseconds, the distance of the repeater is 2.6 statute miles, the signal transit time is 28 microseconds giving a repeater delay of about 87 microseconds.

The time was now ripe to attempt some serious ranging. Accompanied by Derek Atter, G3GRO, I drove to a point some miles away where we knew there was a car park, a tea bar and good repeater coverage. The weather was a typical English autumn day - thick fog and intermittent rain. Despite this, we set up our equipment in the rear seat of our car with the oscilloscope running from a spare battery and an inverter in the trunk. A ground plane aerial was erected on a short mast to minimise possible interference from the inverter.

The repeater was not in use so it was immediately possible to synchronise the oscilloscope and measure the signal's "round trip" time as 225 microseconds. From this we could deduct the repeater delay of 87 microseconds, giving a signal transit time of 138 microseconds. Dividing this by 10.74 gave a distance to the repeater of 12.8 miles.

When we returned home we compared this with an accurate map which gave a measured distance of 12.6 miles. We felt that our technique was remarkably accurate considering its home grown nature. If the weather been less inclement, perhaps we could have taken several other readings.

Once the equipment had been connected, the initial measurement, which included synchronising the oscilloscope time base, took less than half a minute and subsequent measurements could be taken in a few seconds.

I was lucky with both experiments in that the repeater provided a strong signal to both locations. To use this technique for long range measurement, narrow band RF filters would be required between the transceivers and their respective antennas to prevent desensitisation.

Ex-radar mechanics may be surprised that my calculations are based on a "radar mile" of 10.74 microseconds and not the 12.36 microseconds with which we are all familiar. The reason for this is that radar equipment always uses nautical miles whilst the former figure refers to a "Radar Statute Mile".

What has been achieved by this experiment? Not much really. The basic principles were developed by the German researchers before WW2 and the same techniques were used in surveying in the days before GPS. We did prove, however, that reasonably accurate range measurements can be made using only the equipment available in an average ham shack. The process also gave me a renewed respect for the German scientists of some 60 years ago.

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