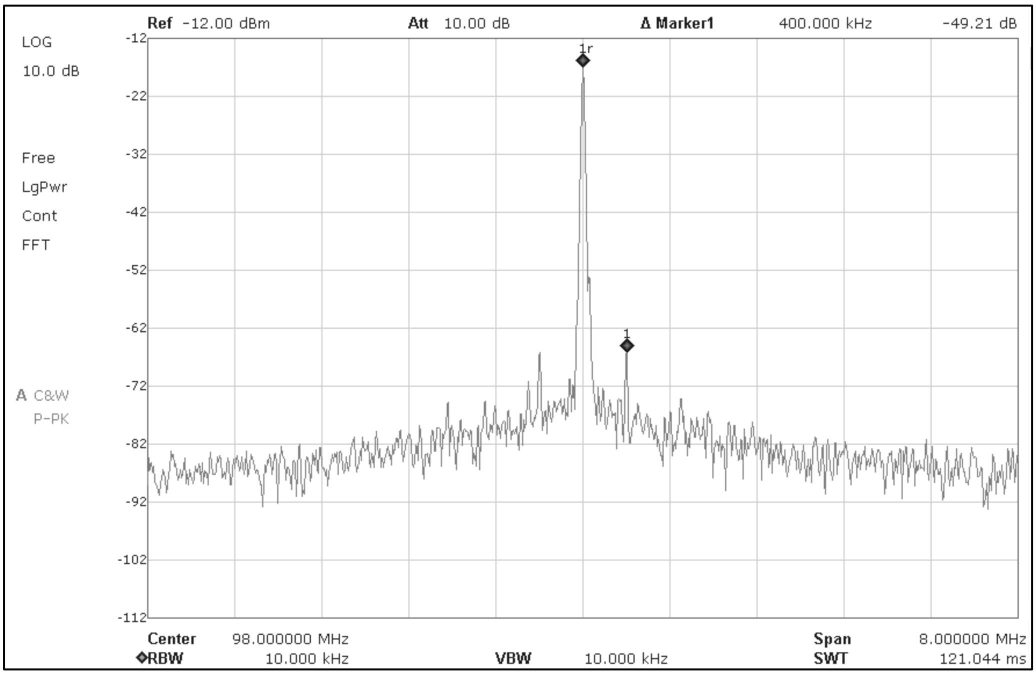
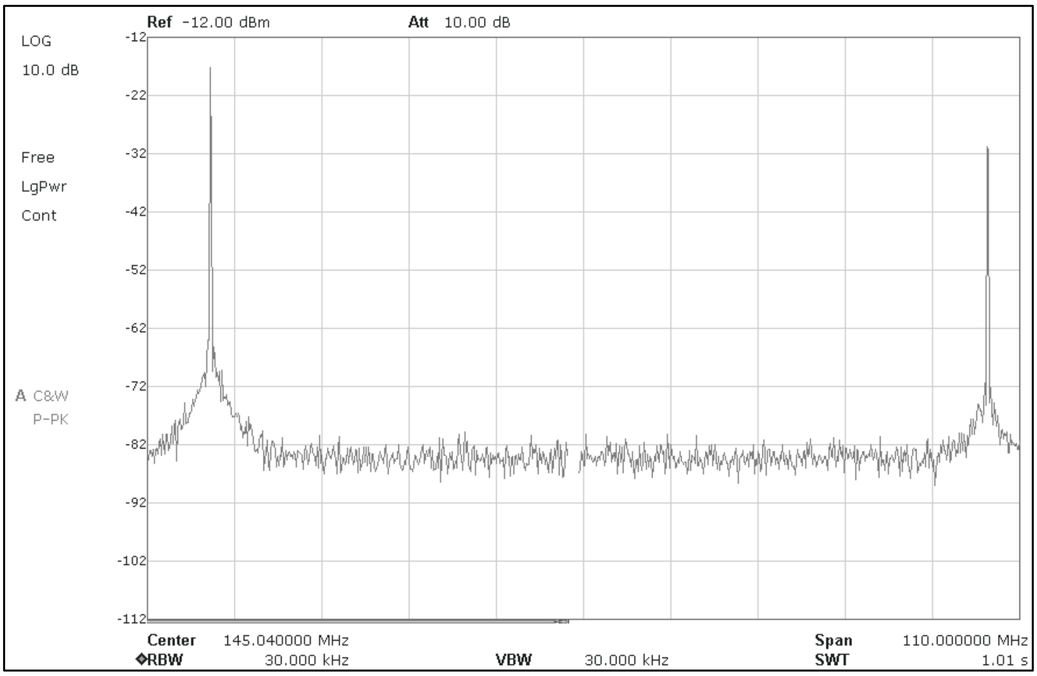
Testing the QN8007B for spectral and baseband purity.

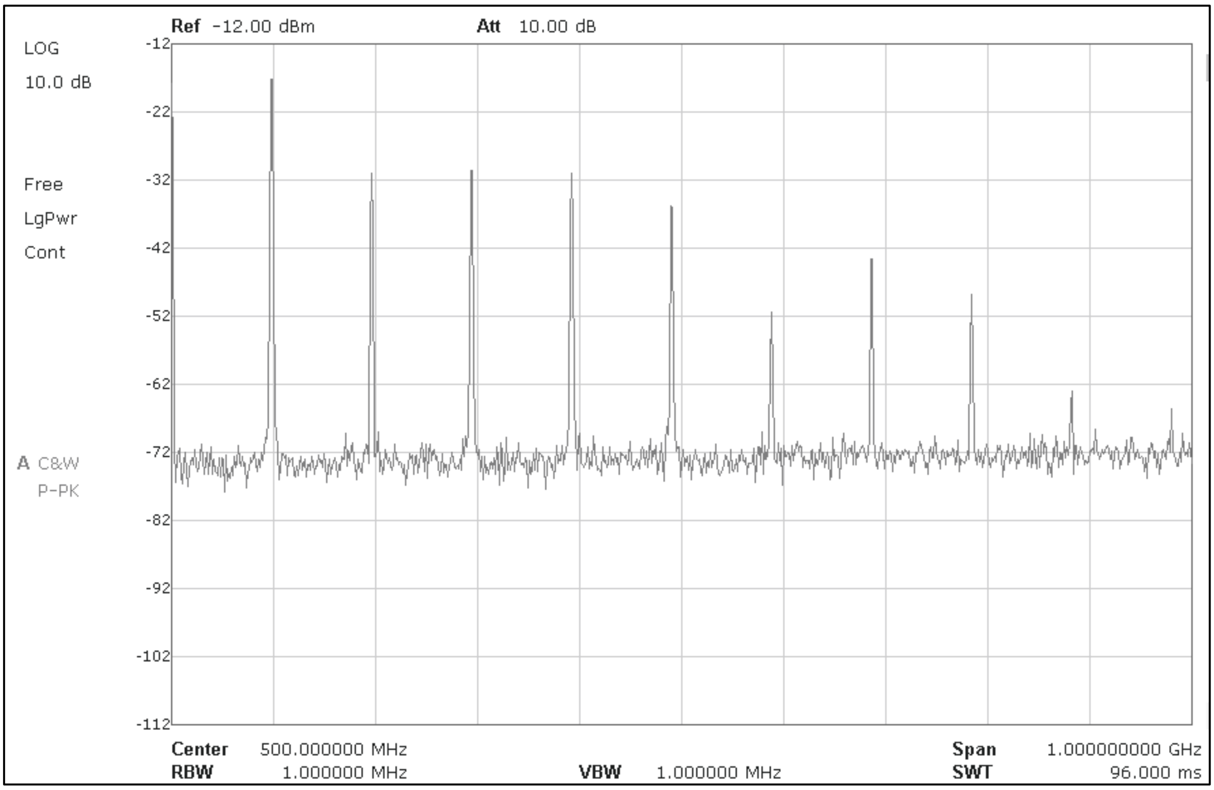
1. Spectrum



8 MHz Span. A fair amount of phase noise is present, but better than -50dBc, so performance is excellent for this type of device and its intended use. PLL reference sideband spurs can also be seen at ±400kHz which are -49.21dBc.

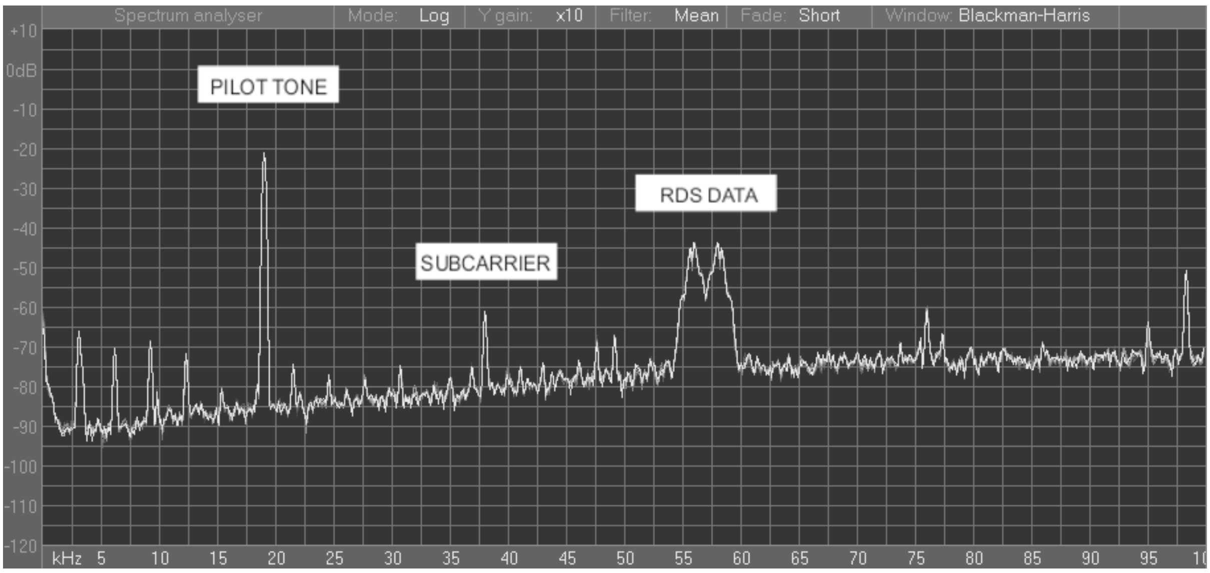


Spectrum between Fc and the first harmonic (encompassing the ‘Air band’ frequencies) is clean. With a suitable RF filter, all harmonics can easily be attenuated to better than -70dBc.

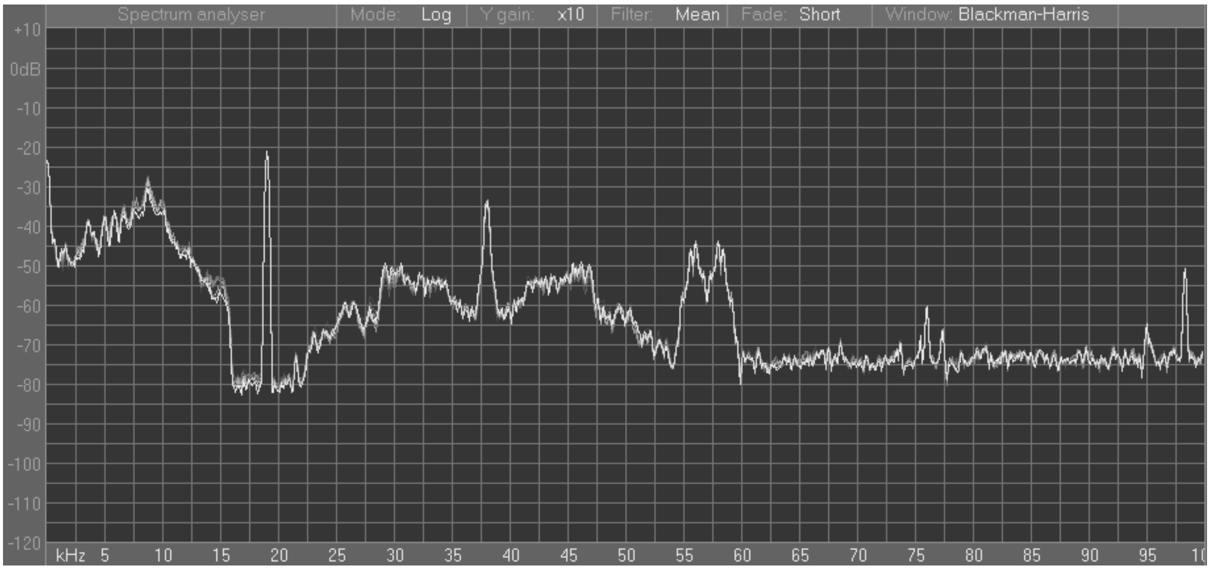


Nothing scary here, but just for interest, these are the harmonics from the entire circuit[1] used. Harmonic levels were entirely acceptable for this type of device and its intended use. Also, with a suitable harmonics filter, all harmonics could easily be attenuated to better than -70dBc (but not necessary for nanoWatt broadcasting).

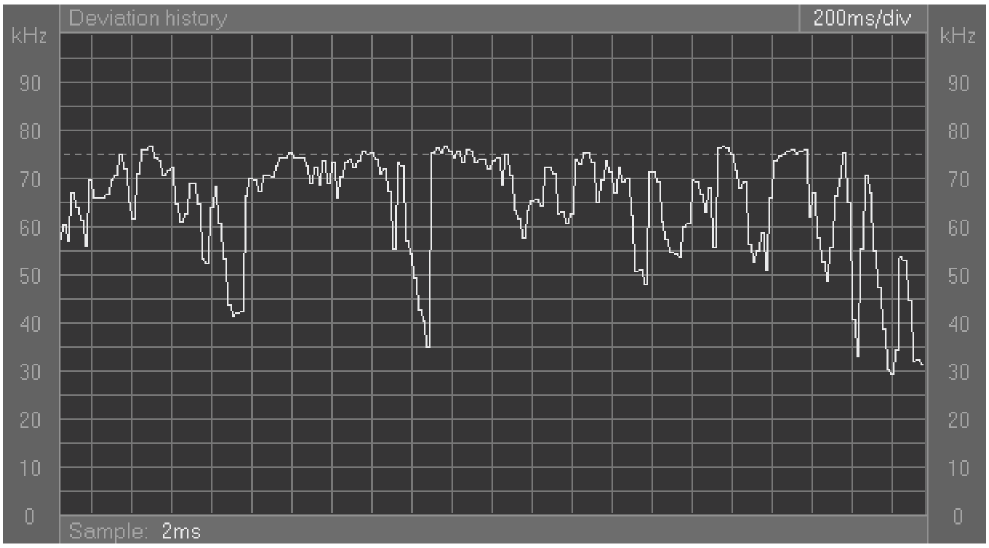
2. Baseband



Baseband spectrum with no audio content present. A number of in-band spurs can be seen. The first prominent signal is the 19kHz pilot. The second is the 38kHz carrier for the stereo difference signal, which should be nulled as much as possible. Because the pilot's first harmonic is also on this frequency, it's often impossible to null completely, and the level seen is very acceptable for this type of device and its intended use. The third prominent signal (the 'bunny ears') is the RDS carrier. Phase noise can be seen, and there's a notable spur at around Fc+98kHz[2]



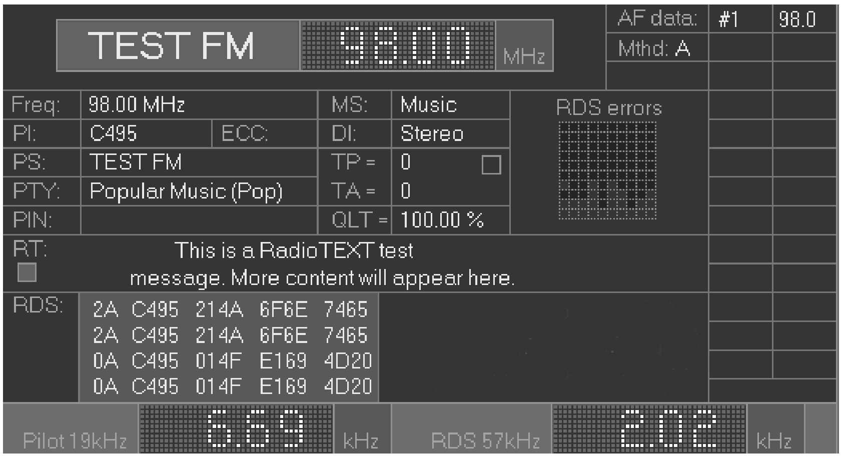
Baseband with modulation (audio content) and RDS. Note the very impressive sharp 15KHz audio filtering; similar in performance to today's professional digital audio processors. This ensures treble content reaches right up to the permitted maximum 15KHz, whilst protecting the Pilot Tone and subcarriers.



This is possibly the most impressive part of the QN8007B. The internal soft-clipping limiter does an excellent job of keeping deviation precisely to ±75kHz without overshoots. The above shows the device using default settings. The maximum deviation level can be precisely 'trimmed' in firmware.

When exceeding the specified maximum audio input level, clipping distortion floods the Pilot Tone and RDS subcarriers with intermodulation hash. As to be expected, this results in (1) spectral occupancy exceeding the intended FM channel (2) corruption of transmitted RDS data bits, causing RDS reception errors. It must be pointed out that this only to be expected and is no fault of the QN8007B; it would happen in all high-end FM broadcast modulator and processor systems under the same conditions.

To protect the QN8007B's excellent audio performance at excessive input levels, an additional external AGC and limiter circuit (with peak clipping) could be added, ahead of the device's audio inputs.



The default Pilot Tone and RDS injection levels are perfect 'out-of-the-box', and would comply with UK regulatory levels. Due to the ‘transparent’ way in which the QN8007 handles RDS groups and content sent from the host MCU, extended RDS features can be broadcast, like PI Codes, TP and AF data, plus RadioTEXT (for dynamic “Now playing…” updates).

3. Conclusion

On a properly constructed PCB and programmed correctly, the QN8007 exhibits truly amazing performance relative to other such devices. Audio quality is excellent. Audio test tone sweeps indicate that the audio performance is flat from 20Hz to 15kHz (taking the pre-emphasis curve into account, which is also very accurately implemented). Bass audio performance down to 20Hz is a sign of a nicely implemented PLL design, which allows bass content to shift the carrier frequency, without attempts to frequency-correct it (which would result is weak, distorted bass). This is usually achieved by using a wide bandwidth loop filter which, in turn, can affect the PLL's lock speed. However, the PLL locks very quickly indeed. As mentioned earlier, the treble content is also preserved, right up to the maximum permitted 15kHz, with impressive steep cut-off evident (suggesting digital FIR filter performance).

The device is perfect for its intended purpose and could be made entirely compliant with nanoWatt broadcasting regulations, plus CE / FCC product certification requirements. A professional manufacturer will easily be able to realise a commercial product for micropower FM audio applications (like in-car MP3 player or Digital Radio player adaptors) using the QN8007B. This is the intended application for which it was designed, and for which it will perform incredibly well. This modern device will certainly provide an improvement in spectral purity, audio quality, and features, over similar devices historically offered for this purpose.

Because these results are likely to be of interest to hobby broadcasters - and possibly even transmitter manufacturers - speculating as to whether the QN8007B could be used as part of a higher power broadcast transmitter, the following additional information is provided as a guide.

The QN8007B is significantly better than devices like the BA1404 - historically popular with hobbyists - in terms of spectral purity, performance and quality. It also adds RDS functionality.

Hypothetically, due to its incredibly good performance, flexibility in programming, and full RDS capabilities, a full broadcast service could be implemented. In fact, at RF outputs up to 1 Watt, it could *almost* be compliant with broadcast regulations. For example, taking stringent UK regulations, as an example[3] :

Spectral Occupancy, Spurious Emissions and Harmonics for transmitters with output greater than 250 mW, and less than 25 W: Limit = 25 µW. Which at 1 Watt (0dBW) = -46.02 dBc relative to a 1W carrier. (Air Band 108 – 137 MHz: Limit = [46 + ERP in dBW] dB below unmodulated carrier power. Which at 1W (0dBW) = -46.00 dBc)

Test	Specification Limit	Result of 50mW test board	
Frequency	+/- 2kHz	98000197Hz	PASS
Pilot Level	6.75kHz (+/- 0.75kHz)	6.69kHz	PASS
RDS Level	2kHz nominal	2.02kHz	PASS
Peak Deviation Level	75kHz maximum	75kHz	PASS
Spectral Occupancy	<-46.02dB at +/-150kHz	-49.00dBc	PASS
Worst In-band Spurious	<-46.02dBc	49.21dBc	PASS
Worst Air-band Spurious	<-40.00dBc	Better than -70dBc	PASS
Worst Harmonic	<-46.02dBc	Not implemented/tested	See notes

But NOT at powers above 1 Watt. …And, regrettably, NOT in reality. …All commercial broadcast transmitters must not only meet these site performance specifications imposed by broadcast regulators; they must also meet CE / FCC overall product standards, if they are to be used in Europe or America. Use of a QN8007B would NOT result in a transmitter (designed to radiate more than 0.01 microwatts) meeting these requirements. The phase noise, alone, is too high. This means that they cannot be lawfully imported or sold within these territories, despite often being seen for sale on internet marketplace sellers, incorrectly badged as compliant[4].

4. Test Set-up

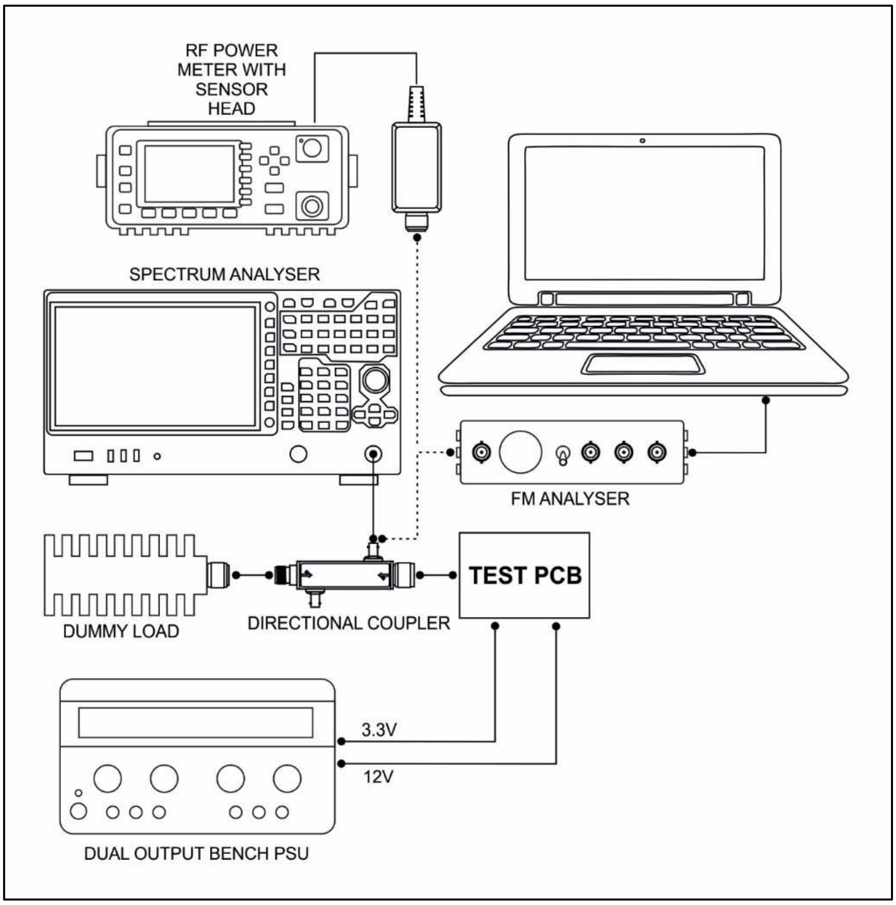
A PCB was made, using good RF layout discipline, on a double-sided PTH circuit board. A buffer circuit was added, and wideband RF coupling transformer output in order to make accurate measurements. It's entirely possible that a buffer circuit could affect harmonic levels[1] but there was little change when testing the QN8007's own output, unbuffered (±1 or 2 dB over the entire range of harmonics). In any case, harmonics were ignored during these tests, for the most part, as they can be easily filtered by implementing additional RF circuitry.

Components used were the datasheet recommended values. A crystal oscillator was used to drive the QN8007B's XCLK input, rather than implementing a passive crystal. The external oscillator was considered best for achieving optimum RF spectrum performance. Indeed, both arrangements were tested and proved comparable. A high-Q loading coil was used. Additional experiments were performed using various AC and DC coupling of the crystal oscillator output, plus various resistive padding, without any improvements noted.

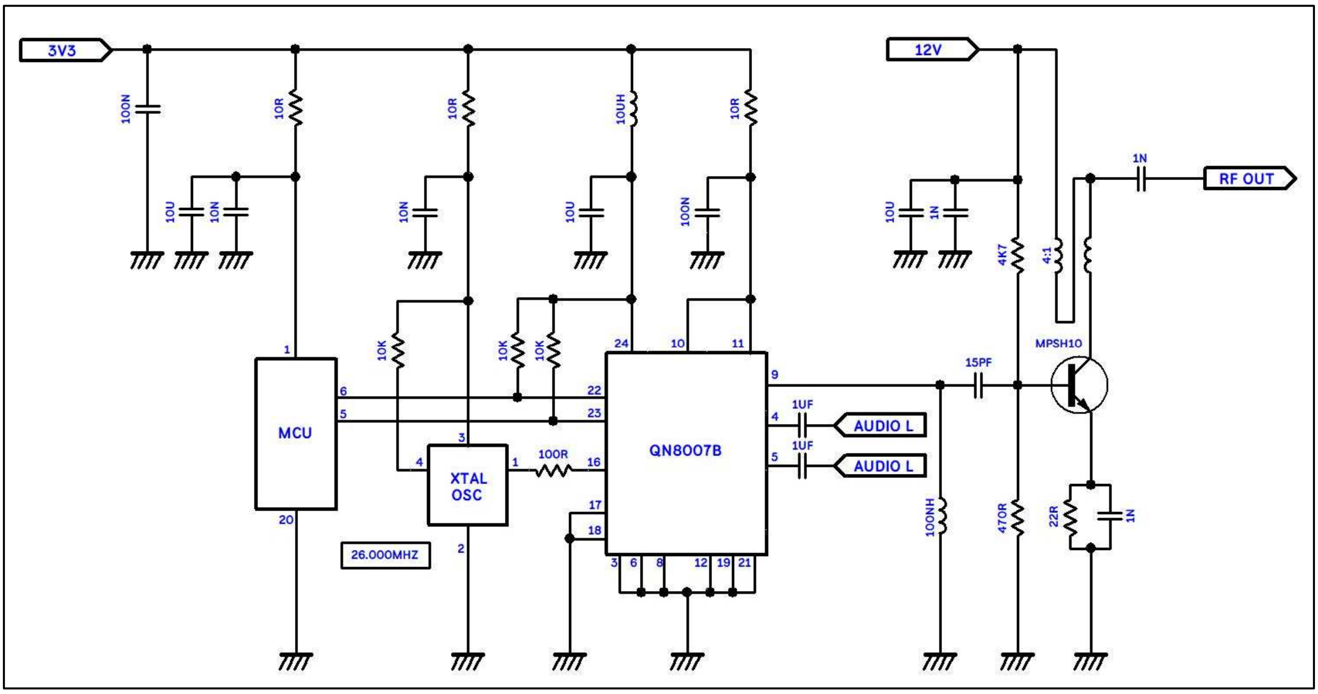
Similarly, the following experiments were also performed (whilst monitoring the RF purity generated by the QN8007B):

Change power supply decoupling components and their values.	No discernible change
Disconnect MCU power (after boot data transfer) to remove possible RF spurs resulting from digital circuit noise, particularly from the continuous RDS data present on I^2C lines.	No discernible change
Optimise inductor value for efficient matching	No discernible change
Change 15pF series RF output coupling capacitor value	No discernible change

With optimal matching of the loading coil, the RF output power of the circuit was accurately measured to be 50mW.



Equipment used



Circuit schematic

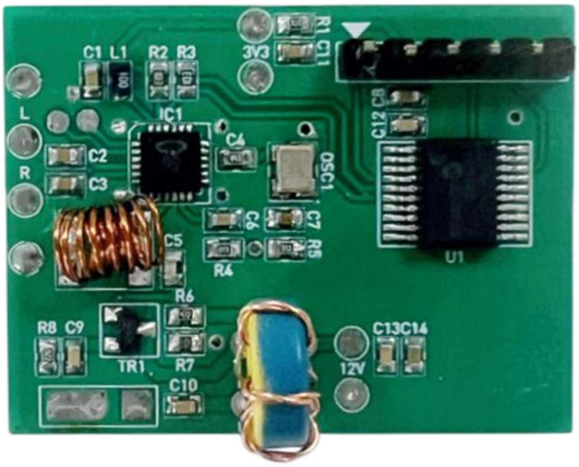


Photo of test PCB

Notes:

[1] The circuit includes a buffer transistor. Additional RF amplification stages can often change harmonic levels, maybe increasing or decreasing harmonics, or even introducing harmonics across a wider range, compared to a previous RF circuit stage. However, levels were similar when disconnecting the buffer circuit completely and connecting the Analyser to the QN8007B output directly.

[2] Most of the evident in-band spurious content would be below the noise floor on the signal received by most FM receivers, meaning RF performance is, comparatively, and in reality, quite impressive.

[3] This is a simplified interpretation of some of the site testing requirements published in Ofcom's 'Analogue Radio Technical Code' in the UK. Additional requirements exist.

[4] As a starting point, see ETSI EN 302 018 document as a (non-exhaustive) example of test criteria applied to FM transmission equipment products placed on the market, outputting powers greater than nanoWatts.

E&OE.