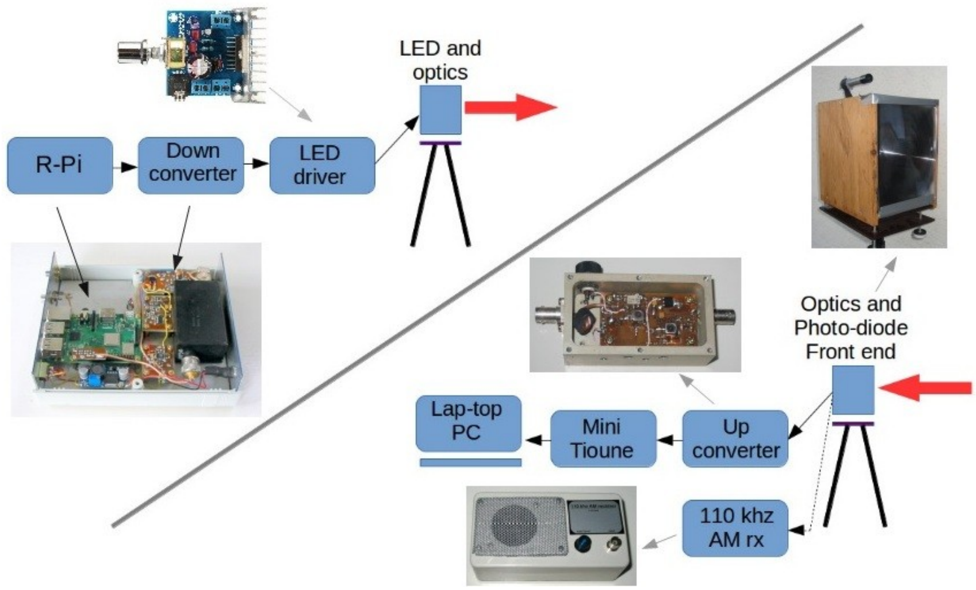
<u>Datv over optical - Part 2: interfacing the two</u>

Portsdown transmitter and MiniTioune receiver units were already available and seemed the ideal starting point for the datv part of this project – the issue being how best to use them, with this write-up concentrating on the initial thinking and first-off implimentation. Where later work provided useful additional information, notes have been added in italics. Also, in order to keep the article to a reasonable length, a fair amount of background work has been left out, hence the occasional web link to cover some of the more interesting details.
For maximum optical head sensitivity, it was assumed that the working frequency needed to be kept as low as possible, implying that we should use or regenerate the basic Transport Stream.



First off implimentation

Tx exciter

A baseband output that also has error correction coding applied direct from the Raspberry Pi is not currently available. Instead, translation to final radio frequency via I/Q outputs suitable for Weaver method phasing is provided, not forgetting the 'ugly' mode output, programmable directly to final frequency.
Three methods of obtaining a baseband or quasi-baseband signal initially came to mind:

1. Write a version of Raspberry-Pi software that outputs in the form required.

2. Use the existing I/Q outputs and a quadrature modulator to regenerate a baseband signal.

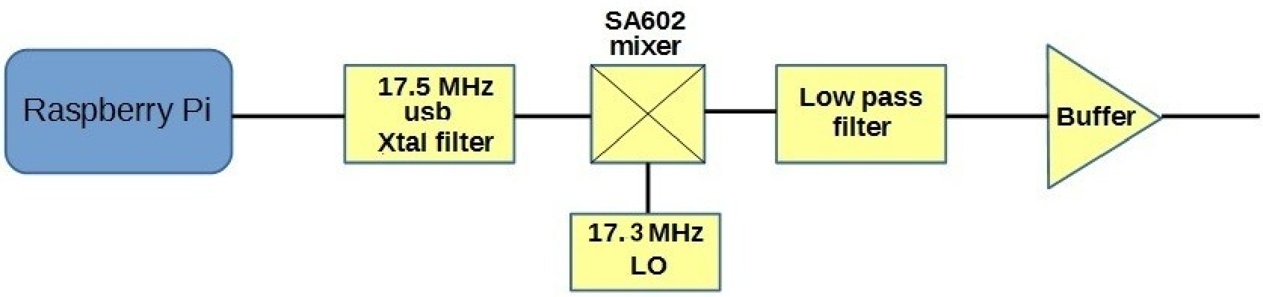
3. Use the 'ugly' output in some way.

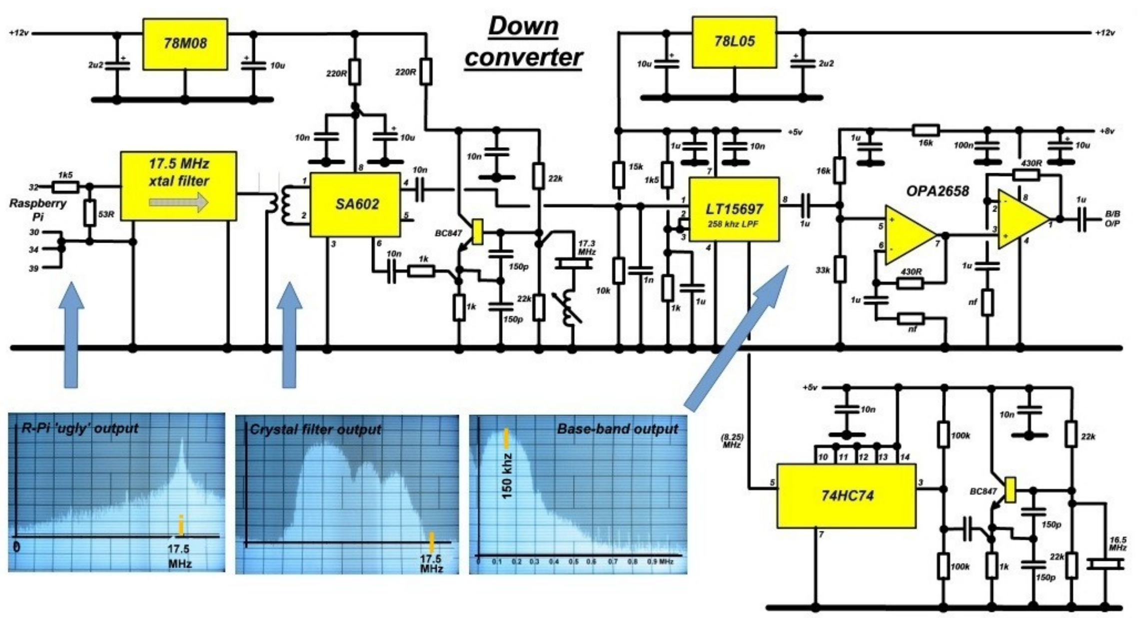
The first of these is clearly the most elegant solution, but is beyond my abilities, so not an option without enlisting the help of others, and at such an early stage this did not seem a reasonable thing to do. However, Heather M0HMO has been contemplating the requirement and may well be able to provide modified code as part of other ongoing work at some point in the future.

As a hardware-only solution, the use of the I/Q signals and a balanced modulator would seem the next best way forward, but using the 'ugly' output simply appealed more, and a quick check was made of how low the output frequency could be programmed. All seemed well down to about 1 MHz, and as a suitably wide bandwidth crystal filter at 17.5 MHz was sitting in the junk box just waiting to be used, this was added to the output and found to be quite effective at cleaning up the 'ugly' mode signal when using a symbol rate of 333 ks/s. A check was made of the MER when the combination was up-converted to 146.5 MHz and applied as a reasonably strong signal to the MiniTioune receiver to see if variation of Group delay through the crystal filter, or whatever, was going to be a problem. The result was 18 dB, which was considered good enough to continue with this approach. *(In fact, group delay is not the main cause of this relatively low MER ceiling, but rather the combination of SR and output frequency programmed into the R-Pi – see later).*

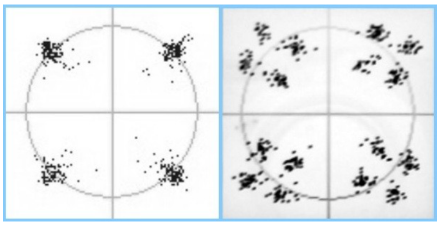
Although the 333 ks/s SR signal looks quite suitable for up-conversion to 146.5 MHz (http://www.earf.co.uk/333khz.jpg), for optical work, I wanted to at least start with a lower symbol rate in an attempt to maximise range and 150 ks/s seemed to be lowest that still resulted in a reasonable picture quality. With this narrower bandwidth, it made sense to offset the signal to one edge of the crystal filter to make full use one filter edge stop-band slope. Doing this for the lower side obviously results in plenty of unwanted sidebands at the upper end, but once down converted to base-band, a switched capacitor LPF was able to remove these components easily enough.

To avoid loading problems at the LPF chip output, a high output current op-amp was used as a buffer. Up-converting to 146.5 MHz again to measure the large signal MER resulted in the same 18 dB figure being obtained.
The output of the exciter is a signal centred at 150 khz, with nulls at 0 and 300 khz (though intermod distortion has obscured these somewhat in the thumbnail spectrum image shown).





(The constallation diagram reveals extra information regarding the low ultimate MER figure, in that dependant on circuit arrangement, sometimes the four quadrant groupings can appear as random deviations, and sometimes as an additional four groupings within each quadrant. In the former case, the errors are not synchronised with the symbol rate and therefor appear totally random. They are the result of timing approximations in the R-Pi software. In the latter case, the errors are synchronised to the SR, because changes in group delay in both the crystal filter and the LPF [where the turnover point is set to too low a frequency] correspond to signal frequencies directly related to the symbol rate modulation).



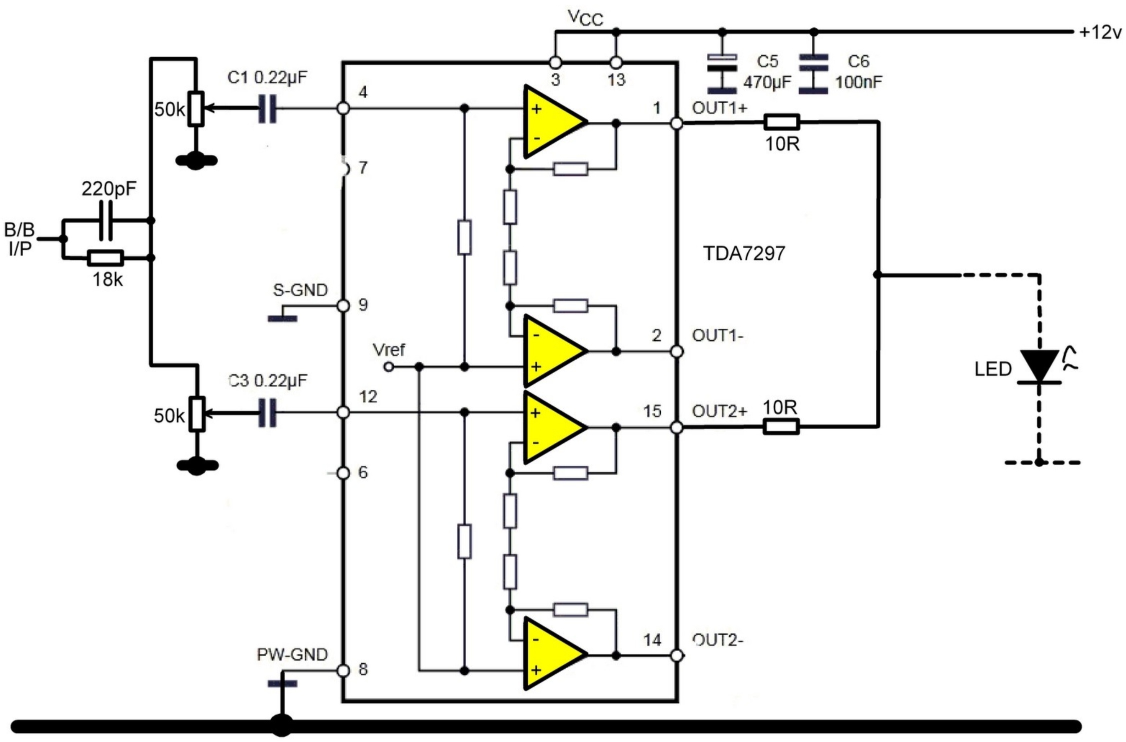
Non signal level related distortion:

Far Left: Non-synchronous (R-Pi 'ugly' mode s/w)

Near Left: Combination of both synchronous (Group delay and non-syncronous (R-Pi 'ugly' mode s/w)

Transmit LED and LED drive amplifier

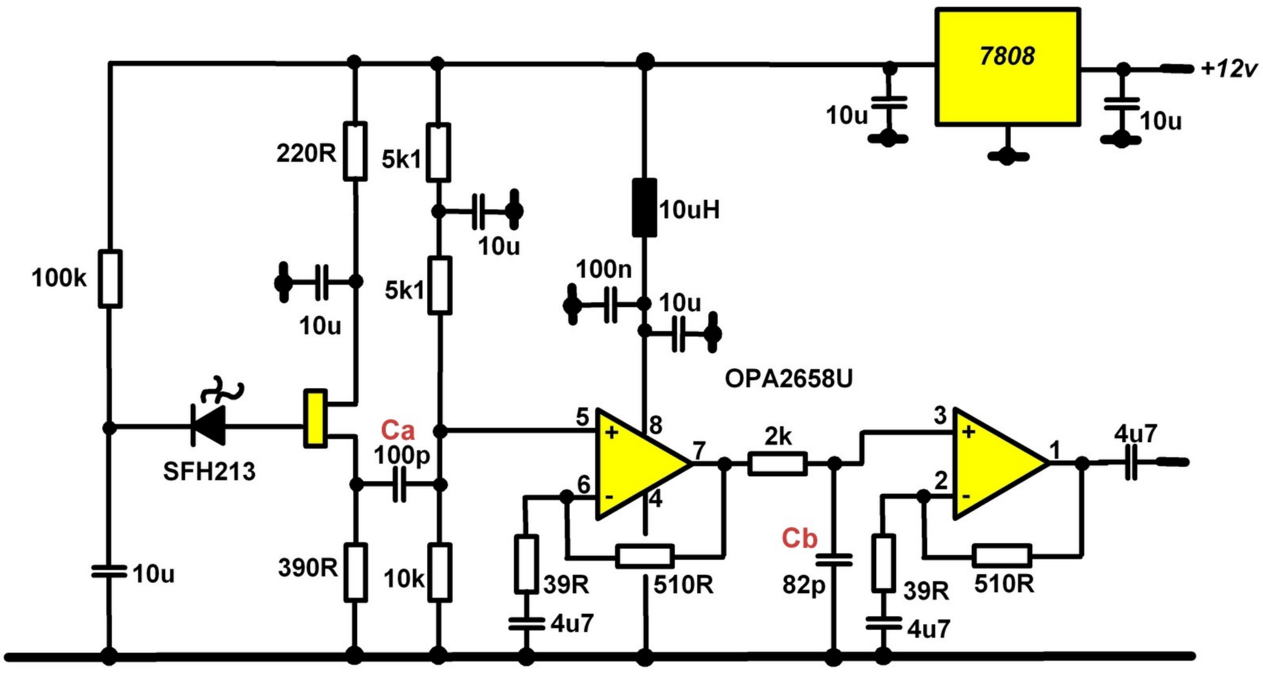
As mentioned in Part 1, two popular LED types used for audio optical work are the Osram 'Golden Dragon' series (1.5W) and the red Luminus Devices 'Phlatlight' (24W). Early measurements erroneously indicated that the Phlatlight would be too sluggish to operate at 150 khz carrier frequency, so a red Golden Dragon was used for all first-off testing. Light output is pretty much proportional to LED current, with the terminal voltage remaining fairly constant, and a power FET would normally be used as a current source driver, but for a second time, an alternative appealed more, assuming it would work at these higher frequencies - thus one of the low cost stereo amplifier boards available from China on ebay was tried. One that was already on hand used a TDA7297, and on measurement was found to have a frequency response that had only dropped 3dB at 300 khz, ie, adequate for the task in hand.



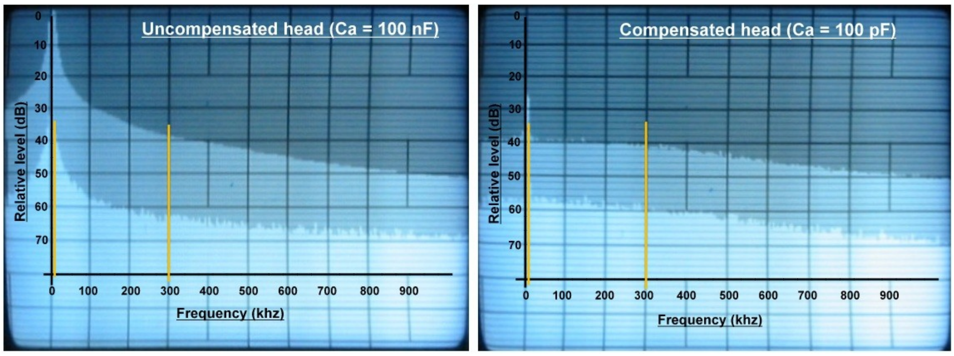
A small amount of frequency compensation was added to the amplifier input to redress the high end 3dB droop. All testing was done with the LED operating linearly in Class A, simply by dc coupling it to one half of the bridge output, and setting the quiescent current by appropriate choice of series resistor. It seemed sensible to use both of the stereo amplifiers in the IC package to spread the load, though one alone is adequate to drive a 1.5W Golden Dragon LED to full output. The arrangement is obviously not very power efficient, but for such a low power LED, this didn't seem important and it has resulted in a simple and reliable modulator.

Receiver optical head

Although optical detectors based on current mode photo-diode operation have bandwidths well in excess of what is needed here, they are far less sensitive than their voltage mode counterpart (http://www.earf.co.uk/IVphotodiode.htm), even at bandwidths well beyond the -3dB figure of the voltage mode detector used here. The input FET buffer is fairly standard and one interesting feature is that despite the gain starting to fall above 1 khz due to the input shunt capacitance, the noise output falls almost in step, right up to 0.5 Mhz or so, loosing only about 5 dB S/N in the process. High frequency video-amp type op-amps have been used following the FET to add extra gain. These also provide a low resistance output drive capability suitable for 50 ohm loads, which has been useful during testing. Frequency compensation is via a suitable choice of value for capacitor Ca, and this alone is adequate for use up to 300 khz.



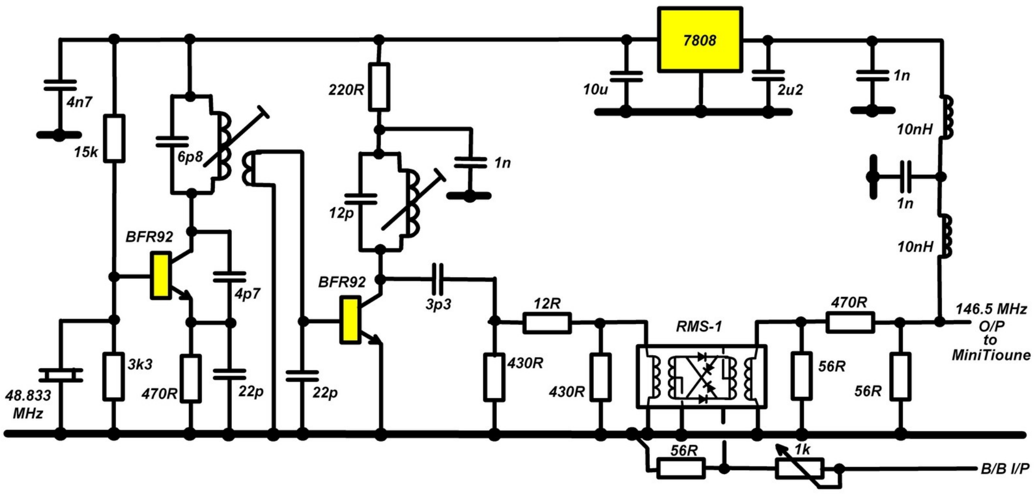
The OPA2658U op-amp maintains its gain well into the VHF spectrum, so to avoid any issues of amplified 2m noise making its way into the MiniTioune receiver, shunt capacitor Cb was added to the input of the 2nd op-amp stage.



Frequency response of optical head before and after frequency compensation
(in each case, the lower trace shows the no-signal noise floor)

Receive up-converter:

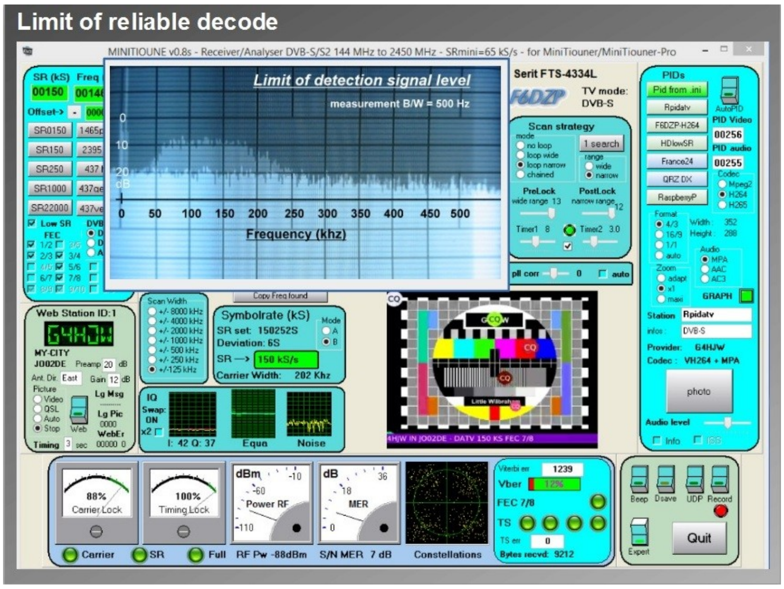
Since a second wide-band crystal filter was available, initial up-conversion to 146.5 MHz was done in two stages, with the first producing a usb signal at 17.5 MHz.. Thus, after final conversion to 146.5 MHz, an identicle, but frequency translated base-band signal, was available to feed the MiniTioune receiver (http://www.earf.co.uk/upconv.JPG).
Later work, however, showed that a dsb signal could just as easily be decoded by the MiniTioune software, so a single mixer with a 146.5 MHz LO was found to be all that was actually needed, and it is this circuit that is shown in the accompanying diagram. With this simpler arrangement, LO leakage is within the Minitioune IF bandwidth, so an input level pot has been included to ensure that the datv signal can be kept at a maximum level, consistant with non-overloading of the mixer. The dc supply for the up-converter is conveniently taken from the MiniTioune receiver.



Receive
up-converter

Results and conclusions:

It is difficult to arrange full-blown tests here in Cambridge, so a 30m long test range was put together in the back garden. For this, the transmit LED was run at 0.75 mA, with no Fresnel lens ahead of it, representing in both cases a 30 dB reduction in signal (ie, 60 dB total). The receive optical head was fitted into a light box using an A4 size Fresnel lens. Although the received signal was on the limit of reliable detection (7 dB MER), this still equates to a potential range of 30 km at the full 1.5W drive level into the Golden Dragon LED/Fresnel lens combination, which is really quite encouraging when you contemplate what the 24W Phlatlight LED should be capable of achieving on a clear dark night, though the effect of light scintilation could be a issue, as others have pointed out, so it does really need trying.



Test range reception equating to 30 km range

Lining up the optics is made much easier by adding a simple AM receiver to the optical head output and listening to the rise in noise as the lightbox is swung across the incoming light beam, the MiniTioune display having way too much delay to use that. Likewise, a portable LW radio placed near the feed to the transmit LED is a useful way of confirming that the LED is actually being modulated.

As mentioned, quite a lot of work has been done since this first off testing, from which interesting snippets of information have emerged. For instance, the discovery that in 'ugley' mode, when the output frequency was set to eight times the SR setting, the ultimate MER acheved rose to 31 dB. Likewise, the ability of the receive head to operate effectively at a much higher frequency than expected, simply because the noise floor was decreasing at a similar rate to the gain fall-off – something I had never really looked at closely when using voice-only modulation, allow higher symbol rates be contemplated. It may also be useful to raise the carrier frequency further away from its current minimal frequency.

The next step here is to try an I/Q modulator and temporarily move away from using the 'ugly' mode output, but there is clearly lots of room for alternative ideas and improvements, particularly on the receive head design for anyone who wants to have a go, and who knows, I might even manage an optical QSO with someone one day…

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