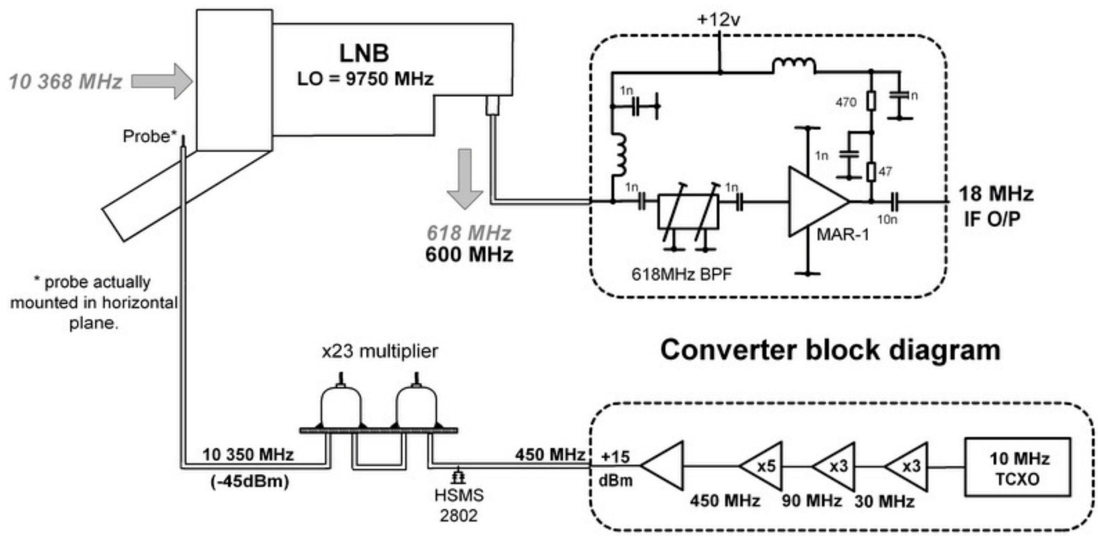
High frequency-stability 3cm reception using an unmodified satellite LNB

Pre-ramble: By down-converting not only the wanted signal but also a locally generated carrier leaked into the antenna, a satellite LNBs LO frequency drift can be totally cancelled, resulting in a receive converter whose stability is determined only by that of the locally generated carrier.
To obtain drift cancellation, the down-converted carrier is used as the LO in a second mixer. As the LNB LO drifts, both the down-converted wanted and carrier signals move by the same amount, resulting in a difference frequency, ie the 2nd IF, that remains unchanged.



In practice: This arrangement is simple to implement, and can provide sub 1dB 3cm noise figures quite easily. Two things of note:

a) Current Sky type LNBs (anything manufactured within the last ten years) have a lower satellite band edge of 10.7 GHz. On all five brands of LNB that I have measured, the image filter has (just) remained flat down to 10.368 GHz. These extended range LNBs have dual 9.75/10.6 GHz LOs, the default frequency being 9.75 GHz. Thus the 1st IF for a 10.368 GHz signal is nominally 618 MHz. Image rejection at 8.514 GHz averaged about 40 dB on the LNBs measured.

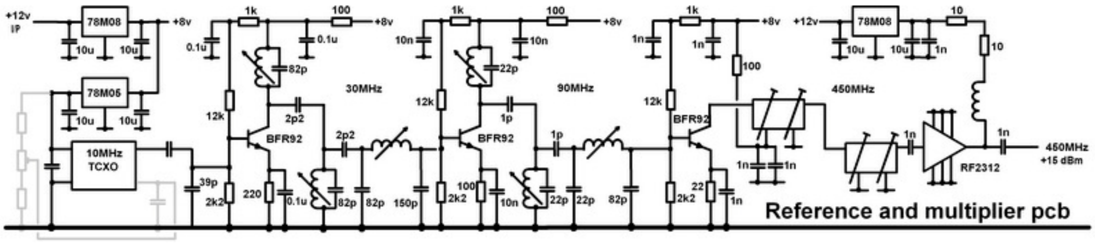
b) The level of leaked-in carrier need only be –60 dBm or so, depending on the LNB used. To put this in context, a back-to-back schottky diode taken from an old LNB, connected directly across the feed to a dual pipe cap filter produced –30 dBm at 10.35 GHz when fed with 20 dBm at 450 MHz (x23 multiplication), some 30dB more than was required in this application!

Mixing of the two down-converted signals can be achieved quite simply by adding gain after the LNB to the point where the amplifier starts to become non-linear. In fact, with more leaked-in carrier level, the last IF stage of the LNB can be made to mix, but there are good reasons for using external gain. For one thing, it allows some selectivity at 618 MHz to be added prior to mixing (both to reduce the effect of any far-out spurious response and also to provide some second IF image rejection), and for another, where a relatively low second IF frequency is used, the output impedance of the LNB will look like a low value inductive reactance, due to the dc coupling choke that all these units employ at their output. This will short out most of the IF signal present. It particularly applies in the design described, with its 18 MHz IF.

A receive converter with an IF output at 18 MHz

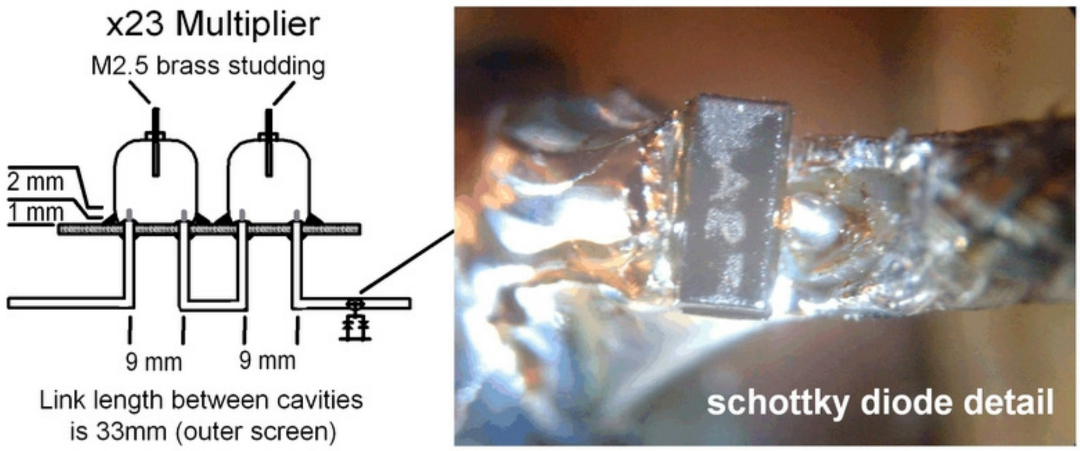
Several of these units have now been produced, housed either in a single stand-alone box with integral LNB or as three discrete modules, more suited for use with an external dish mounted LNB.

LO multiplier pcb: A 10 MHz TCXO is used as the reference, which is then multiplied up to 450 MHz in three stages (x3 x3 x5). This is followed by an RF2312 mmic amplifier to bring the power level up to +15 dBm. Toko 7.5mm coils and helicals are used, allowing this multiplier assembly to be fitted within a 110 x 60 x 27 mm die-cast box.



Final multiplier: Multiplication from 450 MHz to 10.35 GHz is done in a single stage. A pair of 15 mm pipe-cap filters are used to select the 23rd harmonic generated by placing a back-to-back schottky diode pair directly across the filter feed coax, as mentioned earlier. No attempt is made to match the diode, either at it's output or input. Despite the mismatch, the RF2312 driver has remained stable on all eight units so far produced.

The pipe cap multiplier was manufactured as a separate item, with no attempt made to integrate it with the main multiplier pcb. This was done for one major reason. By using coax feed and interconnect between sections, hop-over is automatically kept to a minimum. The price to pay for this is the physically difficult task of cutting away part of the input coax shield to reveal the inner conductor. Even more difficult is soldering the SOT-23 schottky diode to that inner conductor!, but with care, practice and a few lost devices onto the carpet, it is possible. Units have been made with RG405 semi-rigid and/or flexiform cable, and even RG316.
Another advantage in keeping the final x23 multiplier separate is that it allows the multiplier and probe to be located up at the dish whilst feeding a relatively long interconnect coax at 450 MHz into the shack, where the main multiplier with it's 10 MHz reference can be kept at a more even temperature. Typical 2ppm TCXOs appear to have a temperature coefficient of about 6 degrees per KHz. Of-course, there is no reason why an OCXO 10 MHz reference should not be used to keep the drift to a much lower level.



Given that the multiplier is not short of output, it is logical to keep the pipe cap filter sections lightly loaded to obtain the maximum selectivity, and filter probe lengths of 2mm will suffice. This translates to a filter loss of about 6 dB, and keeps adjacent 450 MHz components 50 dB down.

The location of the schottky diode is not particularly critical, but it makes sense to keep it reasonably close to the filter end of the feed coax – say 5 to 10mm from the filter pcb.

This assembly fits very comfortably into a Maplin 75 x 50 x 27 plastic box, where weatherproofing is required.

IF selectivity and mixer: There is very little to this section – just a Toko helical filter (252HXPK-2733F available through BEC) tuned to 618 MHz, and a MAR-1 mmic amplifier acting as the mixer. Power for the LNB is also fed in here, as shown in the overall bock diagram. Note that the supply rail is 12v, and the MAR-1 supply bias resistor values reflect this. This value of supply voltage will select the LNB vertical mode in it's normal orientation, so it is necessary to turn the unit through 90 degrees to obtain horizontal polarisation.

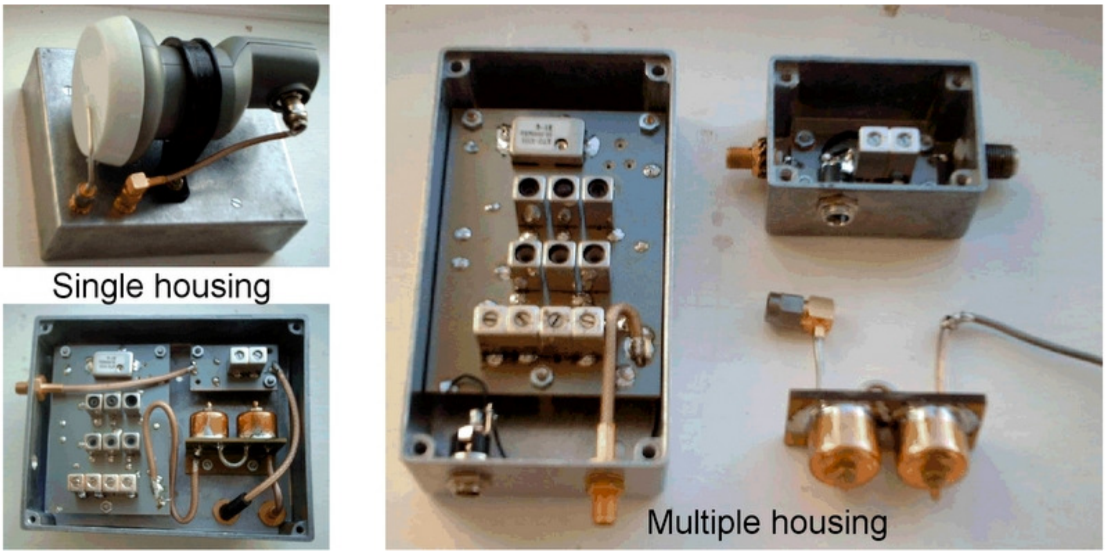
Suitable LNBs: So far, no mention of LNB models has been made. Quite a variation of output level is noticed between types. This is primarily due to the degree of high pass filtering and the turn-over frequency that has been applied to the IF chain of the LNB. Nearly all units show a decrease in IF level below 800 MHz, although the Thomson 13553 remains flat down to about 200 MHz. Not surprisingly, this particular LNB requires the least level of carrier injection, and will show some life right down to –70 dBm at the probe. Other suitable LNB types are the MTI AP8-XT2EBL, available on Ebay for about £5, the older Cambridge G88 and the Fortec FSKU-V [including the Lidl IP-401, which seems to be a re-badged FSKU-V]. Most of the Grundig items are not too suitable, likewise the Skyware SX1019/S (these require a huge –20 dBm or so of injection power). However, to put things in perspective, at least 75% of the LNBs in my increasingly large collection were happy with –50 dBm injection.

Increasing the gain of the external mmic stage will tend to compensate for the lower output LNB types, but this will also increase the amount of noise generated at the IF frequency by this stage. On all but early builds, a MAR-1 has been used, having a data-sheet gain at 618 MHz of 17 dB. This assembly will easily fit within a 52 x 38 x 29 die-cast box.

Dish fed probe placement: Alan, G3NYK pointed out that when applied near the focus of the dish, ie, directly in front of the LNB feed-horn, the effective level of injected carrier is going to increase 30 dB or so in the forward direction. This may be seen as undesirable. However, as mentioned, with most LNBs there is about 20 dB more injection than is required, so the probe may be placed in a well de-focussed position in front of the dish. In fact, for a mesh dish, it is quite sufficient (and convenient) to feed the probe through the back of the dish and fix 5 – 10 mm in front of the dish surface. Adjustment is made easy by the noticeable amount of noise increase as the probe is brought towards the LNB. Fixing at a position that gives at least a 10 dB noise increase should suffice.

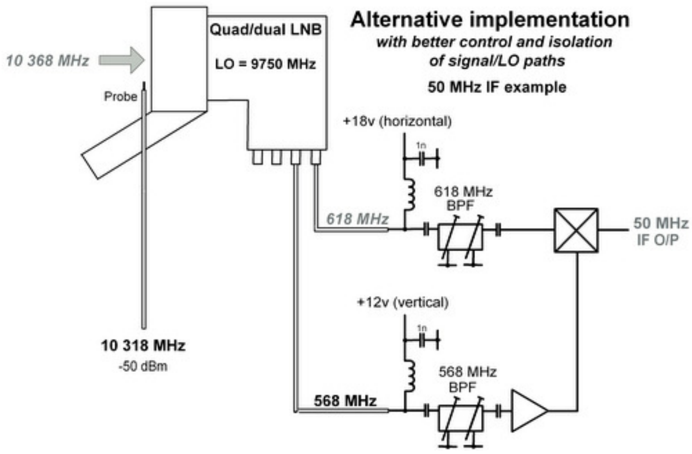
An alternative approach that would keep all the pcbs indoor, on say a chimney mounted dish installation, where cable lengths are not too long, would be to feed/make the probe from RG223. If it were fitted directly in front of the LNB, a feed length of up to 6 - 7m would be possible before cable loss proved too great.

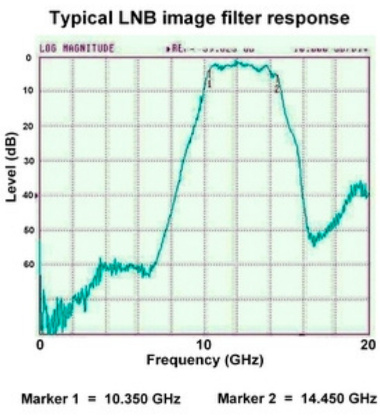
Compact portable version: A compact 3cm monitor converter can be achieved by fitting all the boards into a 120 x 94 x 32 die-cast box, and attaching an LNB to the base. Note that in this application, the LNB is again mounted 90 degrees out from it's normal orientation so that horizontal polarisation can be obtained with a 12v supply rather than the 18v that it would otherwise require. If the same thing is done on a dish mounted LNB, remember that the unit will require additional waterproofing in that plane. Also, if a mini-dish is being used, the dish and LNB should both be rotated together since the illumination angle is different for the two planes.



Strong signal handling: To get a feel for the converters strong signal handling performance, a weak signal was tuned in and a signal generator set to give a signal 60 dB above noise. The generator frequency was swished around the narrow band segment of the band. No degradation of the weak signal was noticed, as long as the generator signal was kept further than 5 -10 KHz away from the wanted signal. Not as meaningful as an intermod measurement, of-course, but still interesting. In practice, there can't be many amateurs who suffer from a surplus of strong signals on the 3cm band, so the issue is somewhat accademic for most people.

Gilding the lily: A purist might not be too happy with the 618 MHz selectivity block placed between the LNB output and the external mmic stage. After all, it has to pass enough of the down-converted carrier at 600 MHz yet provide sufficient 2nd IF image rejection a further 18 MHz down at 582 MHz. With the Toko item used, image rejection is 25 dB, which might not be considered enough. Adding a second Toko filter would give better image rejection, but it would also reduce the level of the 600 MHz carrier too much. A more complicated approach that would remove this compromise and allow more control (and which would be necessary anyway for someone wanting a higher final IF frequency), would be to separate out the signal and carrier paths and have selectivity in each path tuned to the appropriate frequency. The signals could then be recombined for mixing.
If the purist was still not happy, and didn't like all that carrier being amplified along with the wanted signal, an additional change (and complication) would be to use a dual or quad output LNB. It would then be easy enough to put the probe in the vertical plane and take that signal from an output biased for the vertical plane. The wanted signal would be taken from a second output, biased in the horizontal plane. In this way, the amount of carrier signal present in the wanted signal path could be nulled out by 20 – 30 dB or so.





Conclusions: Despite the low cost and simplicity of the basic version of this converter, performance is good and provides an excellent way to monitor the 3cm band. The design described seems to be quite docile and easy to set up – the hardest part being to align the x23 multiplier cavities. It is intended to take the current pcb artwork and productionise it, so that kits can be made available for the local radio club to use as a 3cm project. Legend and solder resist should simplify construction. If there is wider interest, more boards could be made available.

For anyone wishing to use a different final IF, beware the LNBs integral image filter (see typical response plot) and remember that as the IF is taken higher in frequency, the external carrier frequency will become lower and may fall in to the lower slope portion of the image filter response, reducing the level of carrier passing through. On the plus side, of-course, the image response will be even further down the slope..

There are more comments at http:// http://www.earf.co.uk/ext_lo.htm