Simple Broadband Coaxial Harmonic Mixers.

With the success of the broadband Coaxial Harmonic Mixers used in my "Simple 78 GHz and 122 GHz Transverter" Project (1), I felt that the subject of simple homebrew coaxial Harmonic Mixers to extend the frequency range of most good Spectrum Analysers would be of interest to many Amateurs.

The extension of the normal frequency range of any Spectrum Analyser requires operation in external Mixer mode. With a suitable external Harmonic Mixer, the user can then view frequencies typically from Ku Band, 18 GHz minimum through to D Band, 170 GHz and beyond to 300 GHz.
For Tektronix Spectrum Analysers, the WM490 series of 2 Port Waveguide Harmonic Mixers were developed. For the later generation of HP/Agilent Spectrum Analysers, this normally requires the mandatory use of 3 Port Waveguide Harmonic Mixers of the type HP1197x series. The use of 2 Port Mixers on these later Agilent/HP Models is not possible because it is not supported (not a Menu Option) whereas most Tektronix, Anritsu and other brands have a selectable Menu option for 2 Port or 3 Port Mixers.

These proprietary HP/Agilent and Tektronix Harmonic Mixers are however fairly rare on the surplus market. They are also VERY expensive and have a limited frequency range (Waveguide restriction) so multiple units are required to view these upper Microwave frequencies.

The reasons for the use of 2 Port or 3 Port Mixers will not be discussed here in any great detail. The reader can pursue the technical issues elsewhere. Suffice to say that most good Spectrum Analysers have the First Local Oscillator usually just marked OSC and an IF port extended to SMA connectors on the front panel.
When using 2 Port Mixers, the IF is coupled (fed) back via a Diplexer into the Analyser via the OSC Port whereas 3 Port Mixers use both the OSC and IF Ports. All 2 and 3 Port Waveguide Mixers usually contain multiple diodes to perform the Mixing functions. For HP/Agilent product's, the Conversion Loss and Reference Level Offset (both in dB) are usually available as plotted data on the HP1197x series of Waveguide Mixers to facilitate better level accuracy.

In looking for a functionally cheap alternative for my shack laboratory, I have developed a very simple homebrew alternative. The broadband "coaxial" Harmonic Mixer discussed here enables the operator to actually see these higher Microwave frequencies up to and beyond 200 GHz.

Let me emphasise this once again – the homebrew, 3 Port coaxial Harmonic Mixer shown below has been tested on my HP8562A to well beyond 250 GHz over a one metre path !!!!

The “coaxial” mechanism that I have used is not my own design. The concept however has been around for decades. The technique I have used is to simply “pump” a pair of RF/Microwave diodes connected in series in a “coaxial” environment rather than the usual Waveguide scenario. The usual term for these series diodes is “Antiphase”. I then couple my IF Port to these “pumped” diodes via a simple RFC/Diplexer function.

In developing these broadband Microwave Harmonic Mixers, I have tested many RF diodes - mostly Schottky. The development of my 78/122 GHz Transverter prototypes was dependent on 2 critical performance issues. The selection of a specific diode as a harmonic multiplier is NOT solely its ability to generate harmonics into the 100’s of GHz region but also its Rx Mixer sensitivity performance. Subsequently, I have found that some diodes are excellent at generating the necessary broadband harmonics but they performed poorly as Rx Mixers.

In this application, to provide an efficient Microwave Harmonic Mixer which extends the frequency range of a/any Spectrum Analyser, the goal is simply to provide good/excellent Rx Mixer sensitivity. For this application, we do not need the ability to generate high level harmonics as per the Transverter project previously described.

For the most part, I have generally used the smaller, low signal level Schottky X and Ku band Tx and Rx Mixer diodes because they were low $cost and they produced the best results. I have also tested some higher power Varactors, SRD’s and various other diodes but I generally found they were usually poor Rx Mixers.
One example of a relatively low level RF Schottky diode used in Ku band mixers is the dual diode, HSMS-8202 in the SOT-23 package with the SMD symbol 2R. Single diodes connected in an “Antiphase” format will also work but I’ve found they were not as efficient as the smaller SOT-23 packaged diodes in this application.
In developing my homebrew “coaxial” Harmonic Mixers, I have tended to use the higher sensitivity Schottky SOT-23 and other similar packages because their small size means they fit nicely in a coaxial arrangement on the end of the .085 hardline inside a Feed Horn.

WARNING : One disadvantage of using these quite sensitive signal diodes as “coaxial” Harmonic Mixers for Spectrum Analysers is that are easily overloaded by high level signals.
In my testing, I have found the absolute level of a/any Harmonic displayed on the Spectrum Analyser can vary quite considerably due to the magnitude of ALL the signals focussed on the homebrew coaxial Harmonic Mixer. This is particularly noticeable with the scenario of extreme signal levels. So, where we have a mix of weak signals, one of which we want to look at - in the presence of a much higher level signal(s) which causes the overload.

In an overload situation, I’ve found the diodes themselves do not actually “fail” but they seem to suffer from some form of “compression”. As a result, they give false (low) readings on the Spectrum Analyser. This problem is easily overcome by either increasing the spacing (adding attenuation) between the signal source and the coaxial Harmonic Mixer or by optimising the Mixer Bias derived from the Spectrum Analyser for the desired Harmonic.
This adjustable DC Bias is only used when External Mixer mode is selected. The DC voltage (or current) optimises the performance of the diodes used in external 2 and 3 Port Harmonic Mixers.
I have also found that the magnitude of this DC Mixer Bias when optimising weak signals is NOT the same as when looking at higher level signals. When viewing a specific Harmonic, any (all) higher level signals interact with this DC Bias on the Mixer so it must be monitored closely for optimum display level of the weaker Harmonic(s) of interest.

Fabrication of homebrew Coaxial Harmonic Mixers.

The use of .085 hardline has the obvious benefit of reduced losses when compared with the larger .141 hardline.

I suggest that you make the 2 Port Mixer as per the following technique and then add the IF connection later. Some of the Photo's are a bit hard to see because my Digital Camera does not do "macro", so we have Focal length issues.

Firstly, I cut a slot of roughly 10 mm in either side of the .085 hardline with a Dremel or similar. Flatten and bend these flaps of copper 45 degrees away from the .085 inner. Trim and round off the ends so that a length of 4 to 5 mm is retained. Pre solder (tin) each end. Strip back the insulation on the inner conductor.

Solder the single tab of the diode package to the inner conductor as per below.

Being careful not to crush the easily damaged diode package, bend the .085 flaps towards the diode body to permit soldering to the 2 connection points of the diode.
Try to be quick with the soldering to minimise the chance for heat damage.

Feed Horn fabrication.

The Feed Horn hardware can of course be made and fitted prior to preparing the .085 hardline for mounting the diode but for this exercise we will fit it after the diode has been mounted.
With the diode package now mounted on the end of the .085 hardline, it's now time to fabricate the Feed Horn with its sliding collar. This does present some minor difficulties.

In my development, I've tested various shaped Feed Horns. Cylindrical Horns up to 1 cm in diameter gave poor results probably because they were not resonant for the specific frequency of operation. Tapered Feed Horns of the same outer diameter worked very well with excellent broadband performance. The optimum positioning of the Feed Horn relative to the diodes for best performance is however VERY critical. With the diodes positioned well down inside the conical Horn, this can result in unwanted metallic contact. Because of this possible contact, I try to mount the diodes on the .085 hardline in a tapered angular fashion so they are more parallel to the inner Feed Horn surface.

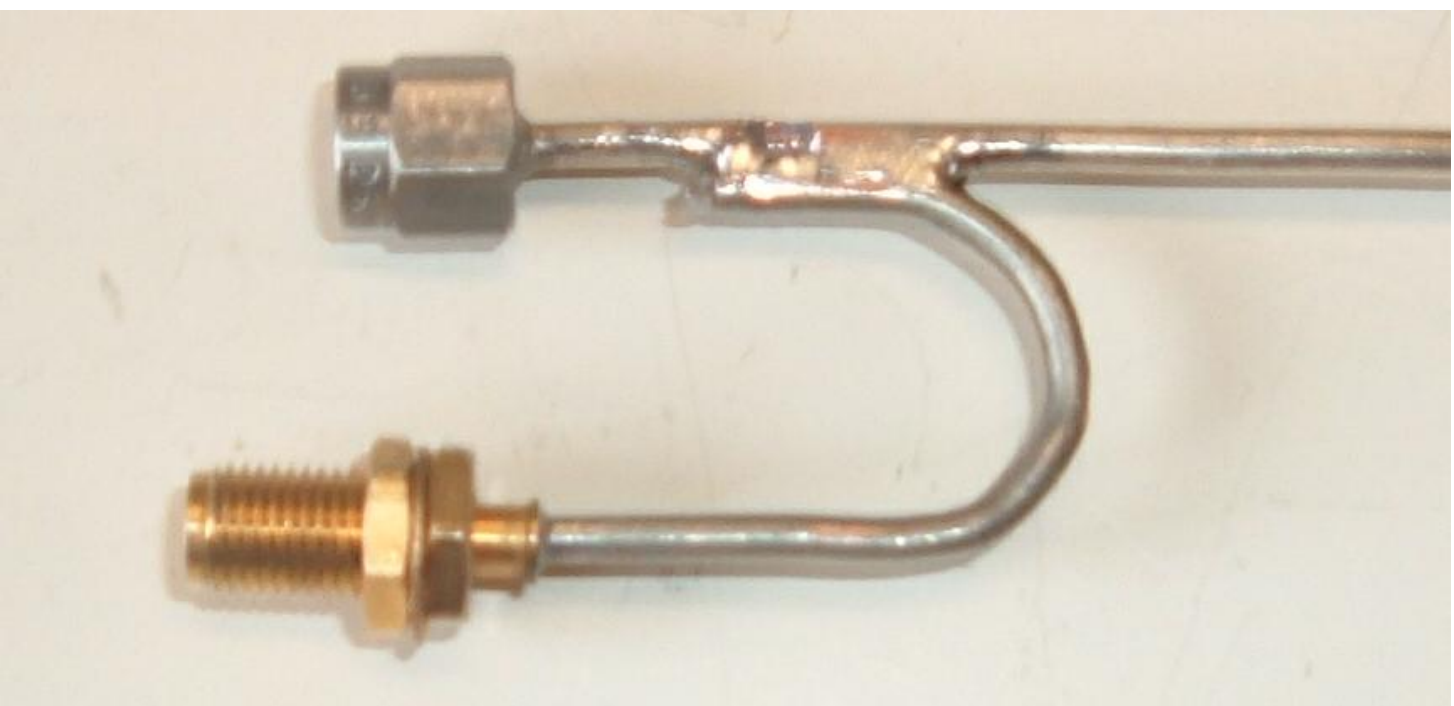
I've used soft copper sheet for my Feed Horns. The outer diameter is roughly one centimetre. Its tapered length to the diameter of the .085 hardline is not critical being about 20-25 mm. I roll the Horn shape, fit it over the .085 hardline and then lightly solder the edges of the Horn. Its shape etc. can be trimmed later. The sliding collar needs to be wrapped firmly around the .085 hardline and its edges soldered. It needs to be about 10-20 mm long. It must be a tight fit. It cannot be a loose fit ! This collar seems to be providing an RF "earth" for the Horn.
It also provides frictional drag allowing the Feed to be slid along the .085 hardline while supporting the Horn centrally around the diode package.

Here is an example of what your Feed Horn should look like prior to optimising.

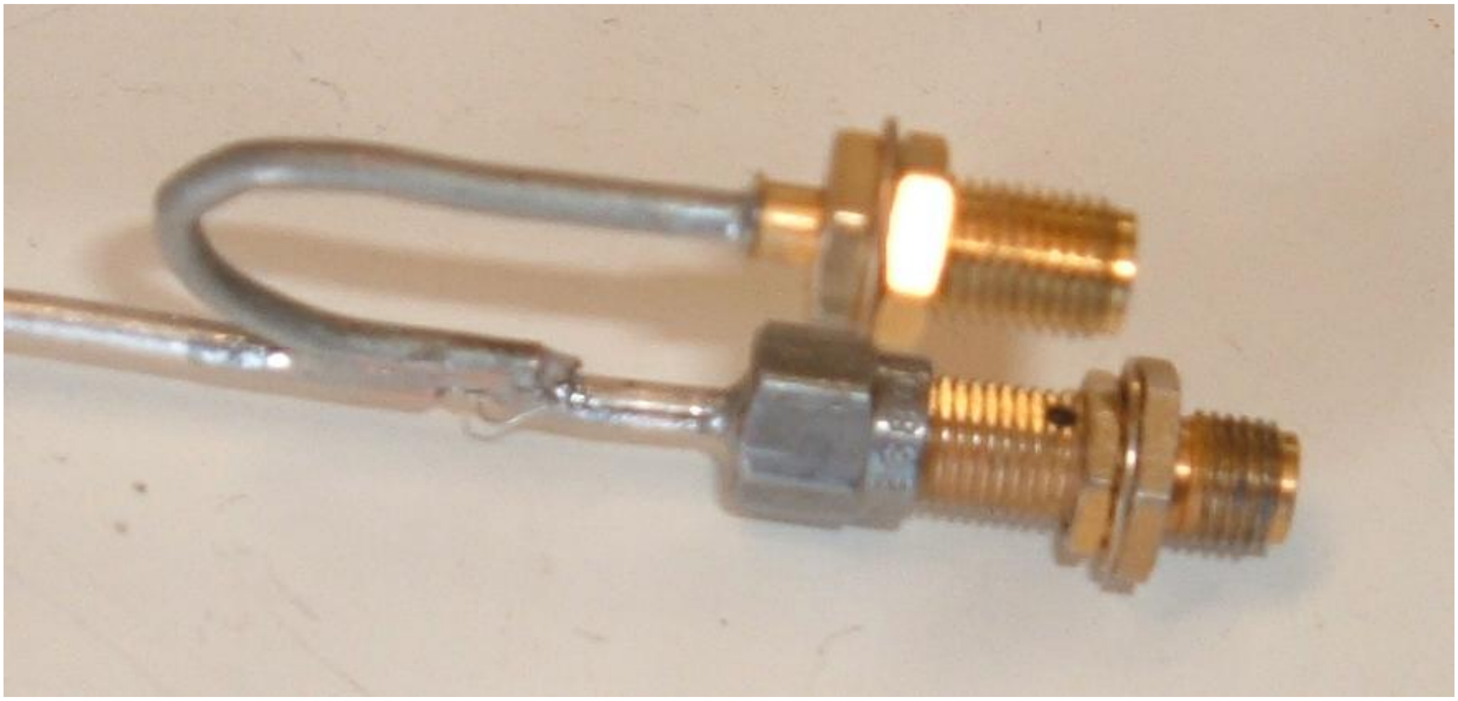
Fitting the IF Port.

Adding the IF Port is a fairly straightforward process but it is a little fiddly.
Fabricate (shape) the IF Port cable from a smaller piece of .085 hardline including cutting back the shield to expose the inner for the IF connection point.

I recommend these .085 hardline cables be soldered together first and then cut the access hole with a Dremel or similar because if the hole is cut in this main OSC line before soldering, the heat distorts the inner dielectric and the hole can fill with solder flux which could degrade the RF path. This access hole exposes the inner conductor of the main .085 hardline for the IF/RFC connection. It’s important the placement of the access hole be such that the soldered IF cable laps both sides of this access hole to give the now weakened main cable some physical strength. Do NOT make the access hole too large. RF leakage of the OSC signal will occur, causing performance degradation.



To form the IF Port connection, fit a very thin wire 5-6 mm long (coiled turns are not really necessary) from the inner conductor of the main OSC cable to the inner of the IF cable. See below this very thin RFC connection.

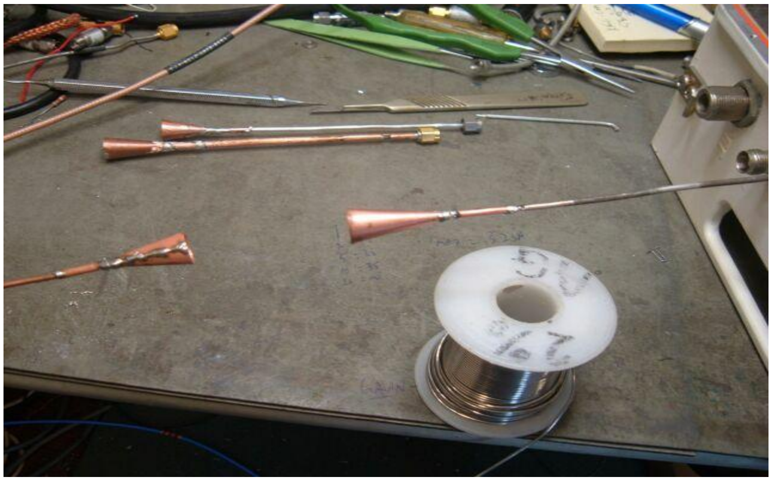


This RFC/IF connection forms a Diplexer. It will be vulnerable to damage so a small protective cover as per the first Photo in this article will need to be soldered in place to protect this Diplexer connection.
A piece of 2mm wire soldered between the sides of the IF loop in the first Photo provides additional rigidity.
There should be minimal degradation when converting any 2 Port Mixer to a 3 Port Mixer.

Optimising 2 Port or 3 Port homebrew Harmonic Mixers.

You will need to generate a known upper Microwave Harmonic signal source. So.. 47/76 GHz or 134 GHz. The absolute frequency is not critical - whatever you can generate reliably from say the 3rd, 5th, 7th or 9th Harmonics. I suggest if you make two coaxial Harmonic Mixers, then you can use one non optimised unit to generate some weak harmonics for the other unit to detect.
I chose to optimise several Feeds on 134 GHz because that is/was my frequency of interest. I'm unsure if the optimising process is frequency specific but all of my optimised Horns worked very well broadband.

I suggest mount your homebrew Mixer in a vice. Slide the Feed Horn over the Diodes almost to maximum distance. Aim this Horn at your Microwave Harmonic source. The distance/spacing may have to be quite close initially. Refer the photo below.

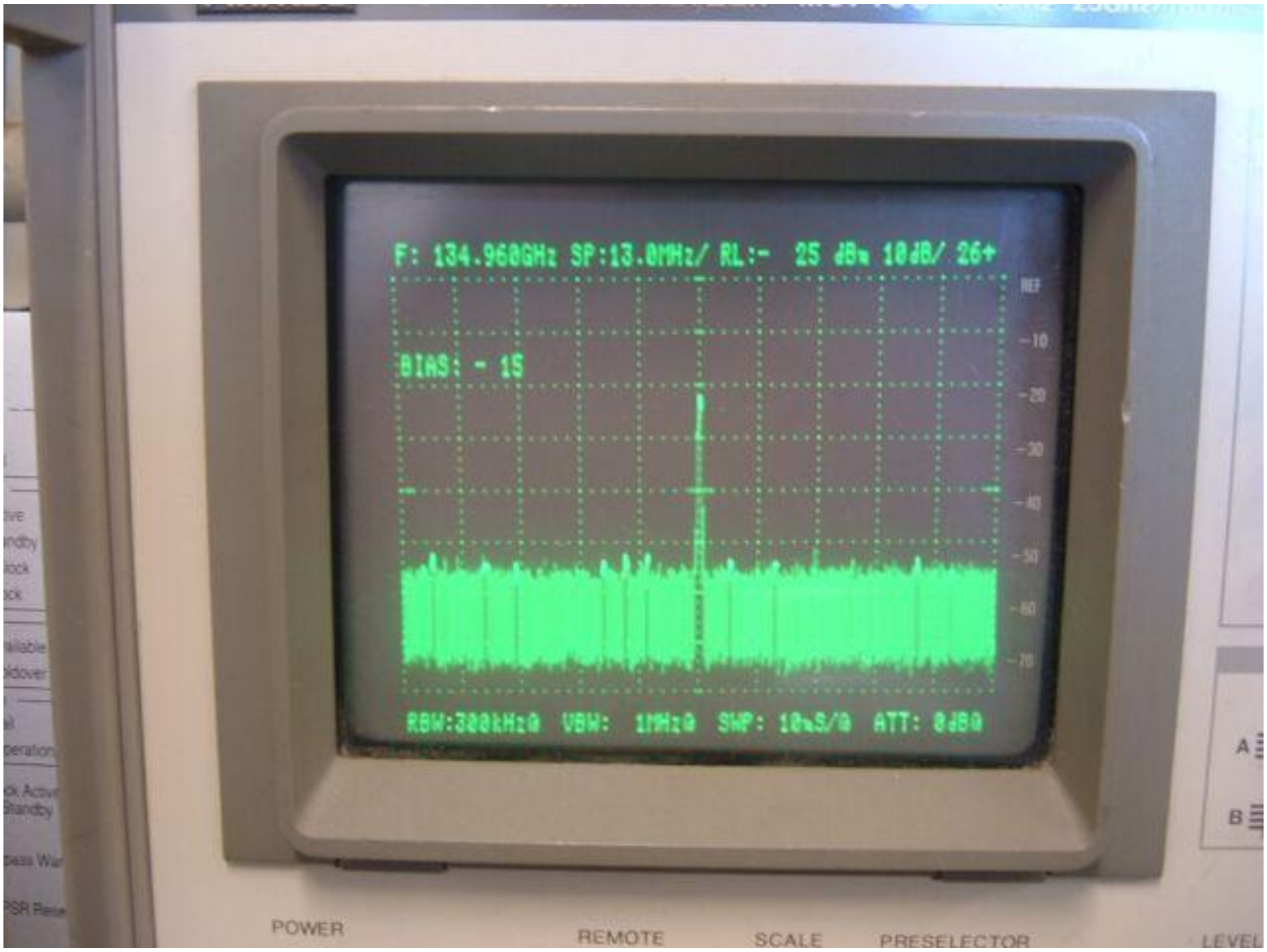


Connect your homebrew coaxial Mixer to the Spectrum Analyser with either one or two cables for 2 Port or 3 Port working. It does not matter which Mode so long as the Spectrum Analyser is set accordingly.
Select External Mixer mode and the desired Frequency/Band. Set the Mixer Conversion Loss to say 30 dB. This will give you good Sensitivity. Leave/set the Frequency "Span" as wide as possible initially.
With any luck you should now see lot's of signals (real and images) as the Analyser sweeps across the screen. If not, bring the Harmonic source closer to the Harmonic Mixer.
Once you see signals, set the Spectrum Analyser for the absolute Harmonic frequency you expect to view.
Set the Reference Level for -20 dBm or more. Now, set the Span to say 100 MHz or less. With any luck your desired Harmonic will be visible. Optimise its displayed level with the Mixer Bias function.
Verify the displayed signal is "real" by using the Signal Identifier function.

Now all you need do is carefully slide the Feed Horn position in and out along the axis of the .085 hardline. You will also need to rotate it radially around the hardline. The combination of these two actions will allow you to optimise the displayed level on the Spectrum Analyser. BOTH of these actions will cause the viewed signal level to change radically from being NOT visible at all, to a 20-30 dB improvement.

The final position of the Feed Horn relative to the diodes is VERY critical. It's a rather fiddly process.
We are talking fractions of a millimetre position adjustment for best optimisation. The diode body will be well down the conical Horn when fully the optimised. There may be multiple "sweetspots", so choose the one which gives you best performance. Once the optimum "sweetspot" is found, place a dob of solder the end of the sliding collar to lock it to the .085 hardline.
You will need to be careful during this soldering operation because the Feed Horn may move, detuning your Feed !

Here is an example of what an optimised 134 GHz signal over a 1 metre path looks like.



The absolute Conversion Loss of your un-calibrated Harmonic Mixer may be unknown - but who cares !!
It’s the ability to actually “see” and quantify these upper Microwave Frequencies that is of great importance.
And best of all, these 200+ GHz coaxial Harmonic Mixers only cost a few $$$ to make.

Cheers,

Alan – VK3XPD

1. Due for publication in DUBUS 4/2011 - Simple 78 GHz and 122 GHz Transverter design.

My Thank you’s.

Kerry Banke - N6IZW, San Diego Microwave Group for his Technical article -
A Simple Harmonic Mixer/Antenna Feed for 47 and 76 GHz Experiments.
For more information, check out this Website... http://www.ham-radio.com/sbms/sd