10 MHz Filter for GPS Frequency Reference

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Many EME and microwave stations are improving their frequency accuracy and stability by linking to GPS. Surplus units like the HP Z3801 and Trimble Thunderbolt use high-quality disciplined oscillators, while simple portable units have a simple disciplined VCXO. The oscillator output frequency is usually 10 MHz.

Then the RF equipment frequency, for instance, a transverter local oscillator, is locked to the 10 MHz oscillator. One of the concerns is added phase noise generated by the frequency locking mechanisms, particularly PLLs. It has been observed that the cleanliness of the 10 MHz source can affect the phase noise of the final output signal.

Many of the 10 MHz sources, particularly the simple ones, generate a square-wave output rather than a pure sine wave. Some hams find that filtering the square wave into a sine wave improves phase noise. Several have resorted to a 10 MHz crystal filter – an expensive and unnecessary solution.

We know from Fourier analysis that a square wave consists only of a fundamental frequency, a sine wave, and the odd harmonics of that frequency – each harmonic is a sine wave at the harmonic frequency. If we remove the harmonics, we are left with only the fundamental frequency, a pure sine wave. Since the odd harmonics start at three times the fundamental frequency, they are well separated in frequency and easy to filter out. A sharp crystal filter is not necessary – a simple low-pass filter can do a fine job.

My latest 10 GHz transverter uses an N5AC A-32 synthesizer locked to the 10 MHz output of a simple 10 MHz GPS-lock unit designed by G3RUH. The 10 MHz output is a square wave, so I built a simple low-pass filter which cleans it up. Phase noise is still evident on my signal, but the filter does make a discernable difference. And I know my frequency.

Low-pass Filter design

A low-pass filter passes all frequencies below the design frequency and attenuates all higher frequencies. Only capacitors and inductors are required, and at 10 MHz, nothing fancy is required. Design equations and tables of component values can be found in numerous reference books including the ARRL Handbook, but I took the lazy way and let the computer do the work. I used free Ansoft Designer SV (www.ansys.com) software which includes a Filter Wizard – better than Harry Potter! Select the type of filter you want, the frequency, and fiddle with the parameters until you get the performance you like. I found that a 5-element (3 capacitors and 2 inductors) gave adequate performance, and selected a "Chebyshev Type-3" filter design, which adds a small inductor in series with the middle capacitor to improve the attenuation slope. A

schematic is shown in Figure 1. My starting design frequency was 11 MHz, to provide a margin for error, and the results were pretty good, but the calculated values had lots of decimal places.
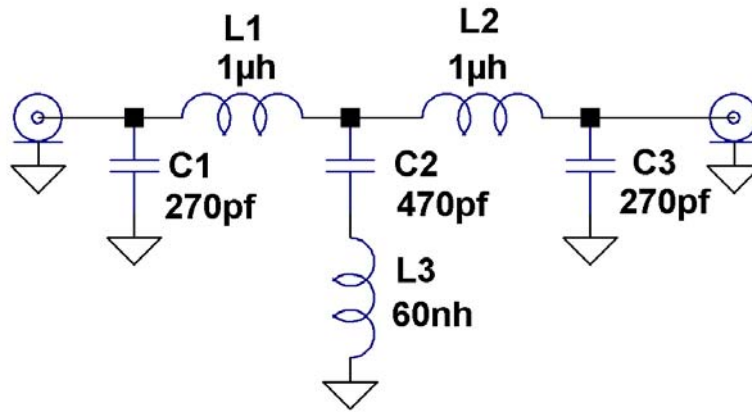

Figure 1

I adjusted the calculated values to common standard values, which I happened to have in the junk box, and found that the response was still good. Finally, I adjusted the value of L3, the additional inductor in series with C2, to move the notch to 30 MHz, the undesired third harmonic. Final calculated response is shown in Figure 2 – all harmonic frequencies are many dB down.
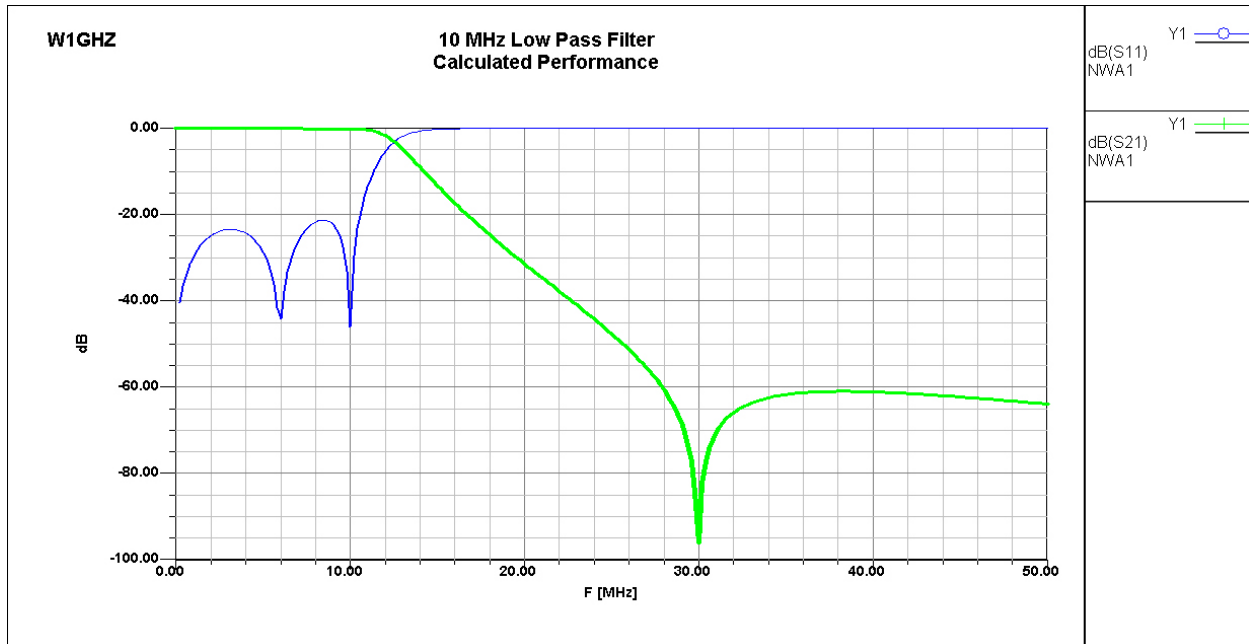

Figure 2

Now to build it. A further search of the junk box yielded a hamfest find – a small Pomona box with a BNC connector at each end and some components inside which were easily removed.

The filter components are common disc capacitors and ordinary RF chokes for the inductors, which fit nicely in the box. L3 is made by winding the capacitor leads into coils around a Q-tip; for 60 nh, about 3 inches of wire is needed – the leads aren't that long, but probably close enough. The completed filter is shown in Figure 3.
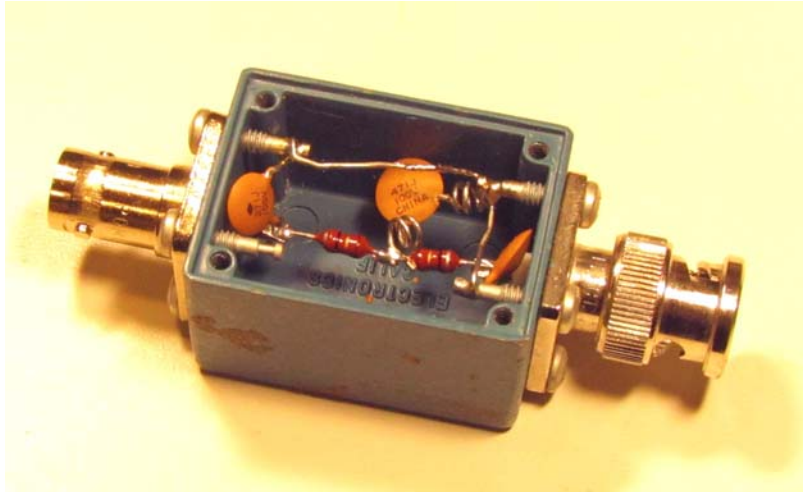

Figure 3

Testing

The first test is to see if the frequency response is similar to the calculated response in Figure 2. I don't have a fancy Network Analyzer with computer output, so Figure 4 is a digital camera shot of the screen, with some numbers added. Pretty close, but the attenuation at 30 MHz is not as good – with the smaller L3 due to shorter leads, the notch is closer to 50 MHz. This filter should still do a good job of attenuating harmonics.
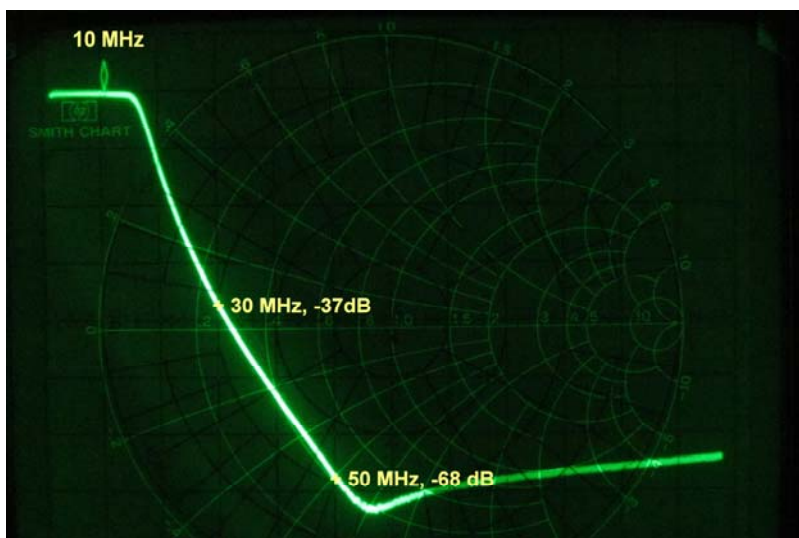

Figure 4

But does it really change a square wave into a pure sine wave? Figure 5 shows the before and after – a square wave from a signal generator going in on top, and a nice sine wave coming out on the bottom. The sine wave is inverted from the square wave because the time delay of the filter is roughly ½ cycle.
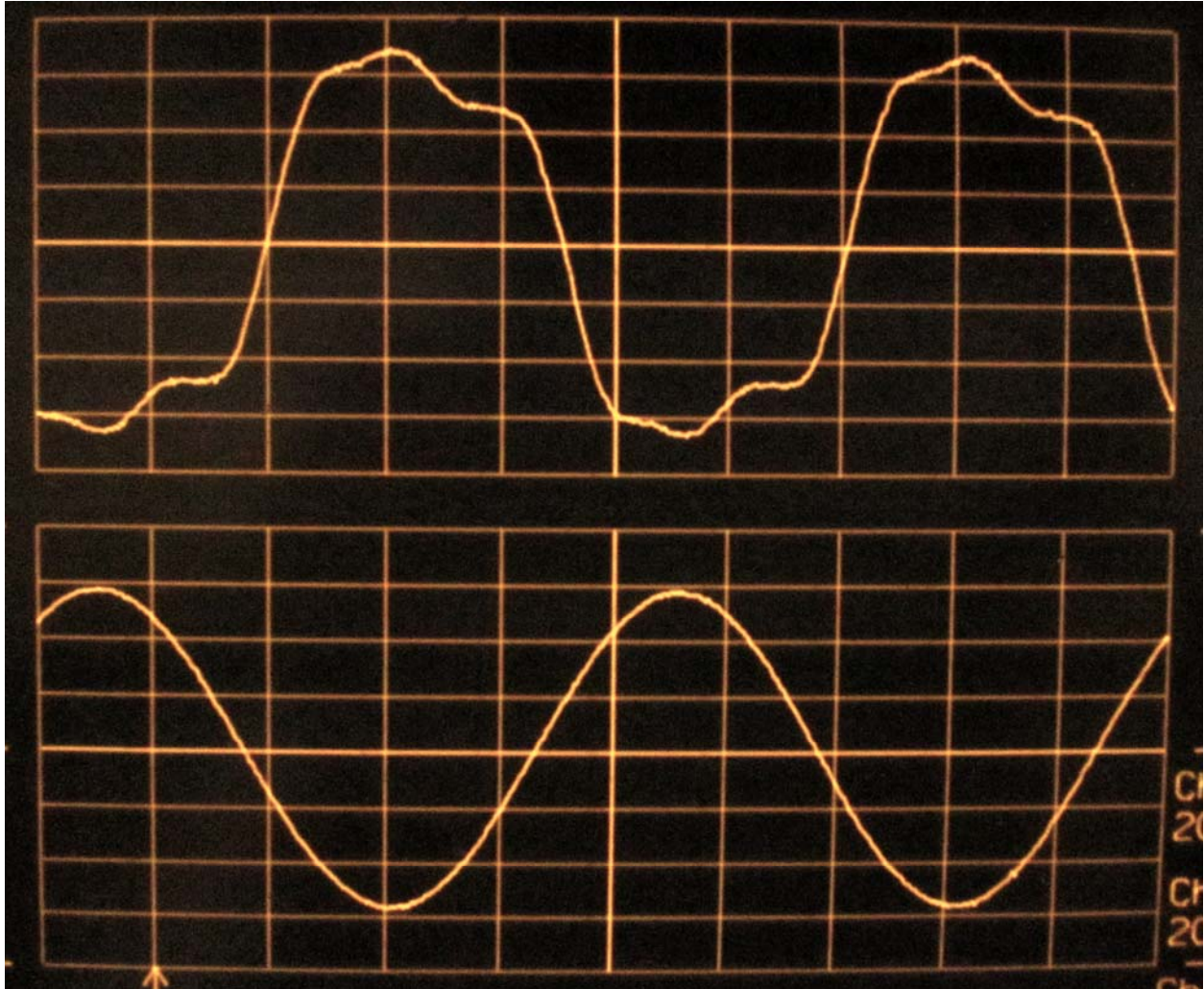

Figure 5

Summary

A simple low-pass filter is an easy and cheap way to clean up your 10 MHz GPS reference. And it is something that anyone capable of putting together a microwave system can build.

K1IIG reports that one of these filters has cleaned up close-in noise on his 432 MHz beacon.