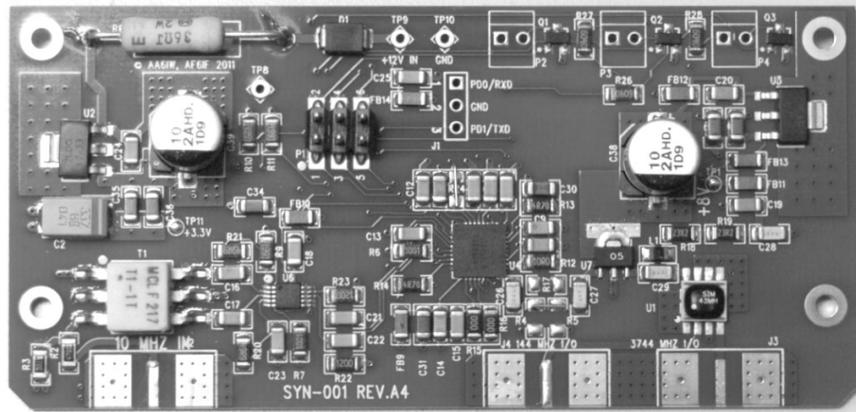


A 3600 MHz Synthesizer / Mixer / Amplifier boards

Rex Allers, KK6MK and Lars Karlsson, AA6IW



Many junk boxes may contain surplus P-Com up and down converters (Figure 1) usable for the 24 GHz Ham band, and the initial purpose of this project was to implement the difficult to obtain components that are required to realize a functioning 10/24 GHz radio. A few years after the P-Com modules became available, Al Ward W5LUA wrote a paper characterizing their use on ham frequencies [1]. Even if the P-Com modules are not available, it is likely that whatever 24 GHz hardware is being created or adapted, can use the same frequency conversion (3744 MHz to 144 MHz) provided by this boards. The boards are designed by AA6IW and AF6IF.

P-Com Converter Modules
Usable at 24 GHz



Down Converter



Up Converter

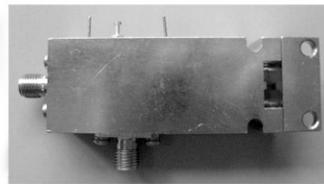
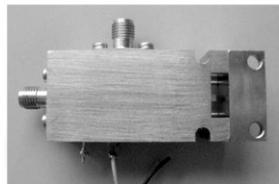


Figure 1 – P-Com Converter Modules

The block diagram (Figure 2) shows a complete dual band radio utilizing a single feed horn.

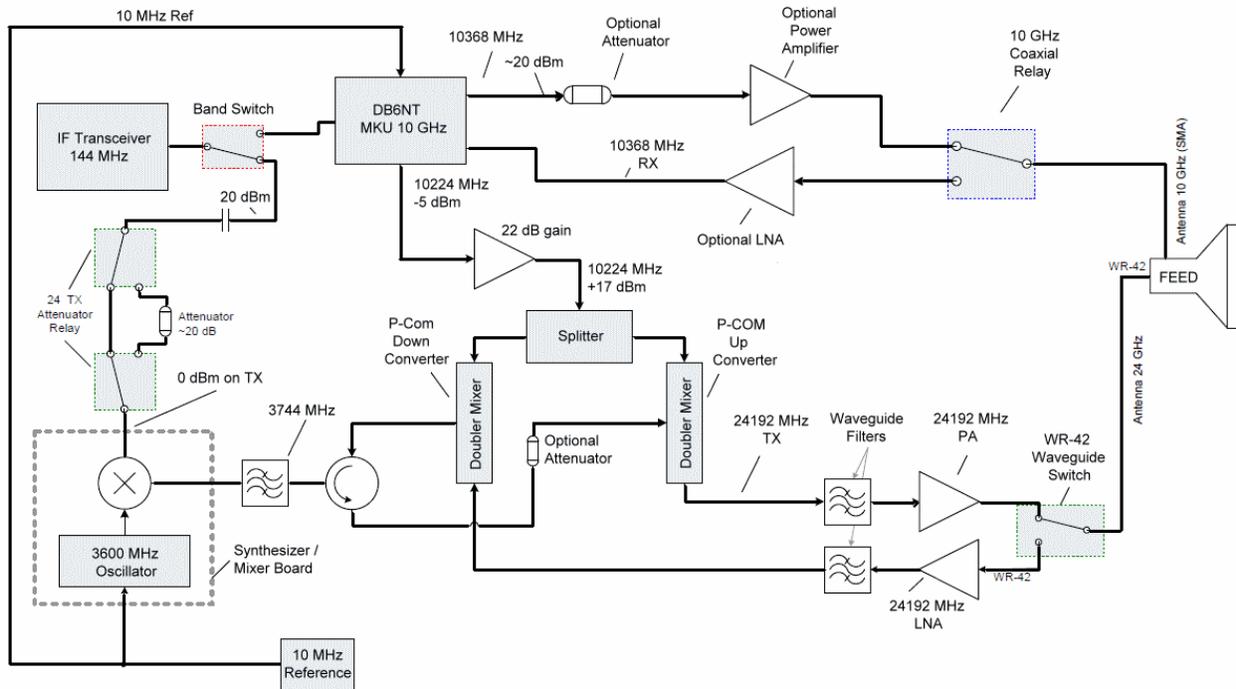


Figure 2 – Example of Dual Band 10/24 GHz Radio using the amplifier and mixer boards

The feed horn (Figure 3) was described in the 2001 Microwave update proceedings [2]. In the block diagram, the 10224 MHz oscillator signal for the P-Com converters is obtained from a DB6NT 10 GHz transverter by tapping a small sample. An SMA connector was added to the DB6NT converter near the 10224 signal path with a short loop from the center pin to ground (Figure 4). Sufficient leakage (about -5 to -7 dBm) of the 10224 MHz signal is obtained. The 10224 MHz signal is then boosted by a new 22 dB gain amplifier (described below) and then split to feed the LO ports of the P-Com converters.

Inside the P-Com converters the 10224 MHz signal is doubled to 20448 MHz. This is the LO for the 24192 MHz ham band. The difference, as these frequencies are mixed, is 3744 MHz into an up converter or out of a down converter. The new board, which is the subject of this paper, contains a phase locked 3600 MHz oscillator and a mixer. The IF rig's 144 MHz TX output is fed to the new board's up/down converter mixer via a switched attenuator in order to limit the power feed to the mixer. To obtain best noise figure the attenuator should be bypassed during receive. The mixer is a level 13 mixer and the input power should be limited to +3 dBm in order to achieve minimum distortion. Feeding too much power into the 144 MHz port of the up/down converter may also upset the locking of the 3600 MHz oscillator.

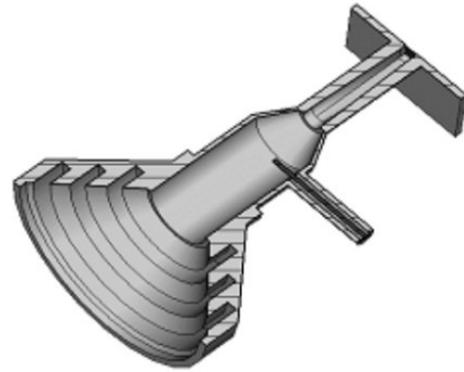


Figure 3 – AA61W 10/24 GHz Dual Band Feed

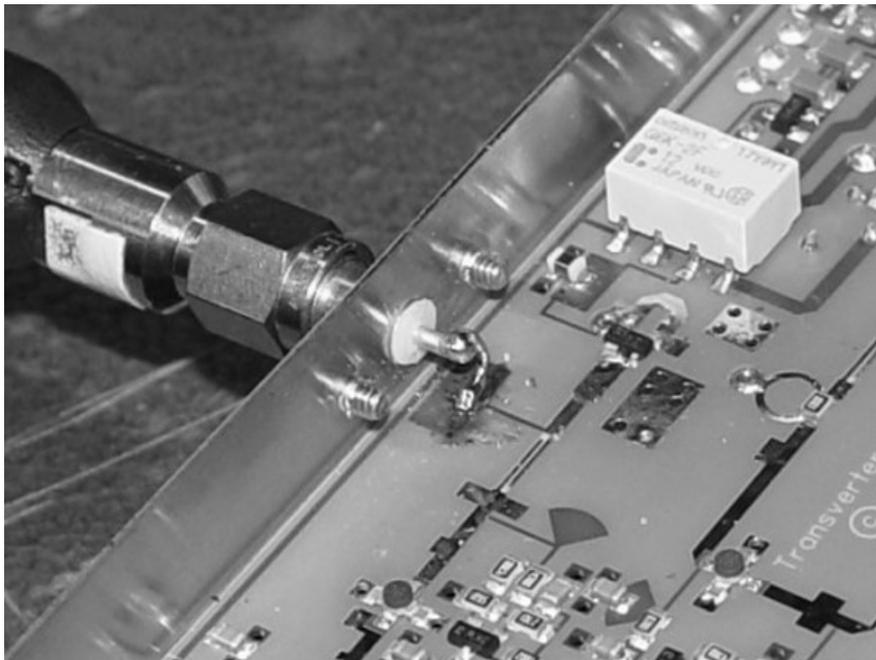


Figure 4 – Tapping some 10224 MHz from a DB6NT converter

Frequencies

To summarize, the frequency scheme for 24 GHz conversion to 144 MHz is:

$$\begin{aligned} 10224 \times 2 &= 20488 \text{ (Doubled in P-Com module)} \\ 24192 - 20448 &= 3744 \text{ (IF input/output for P-Com modules)} \\ 3744 - 3600 &= 144 \text{ (Intermediate LO of 3600 converts to 144 MHz)} \end{aligned}$$

The 24 GHz P-Com modules' IF is 3744 MHz. The new Synthesizer / Mixer board contains a locked oscillator at 3600 MHz. The board also has a mixer to convert 3744 MHz to or from 144 MHz for the ham IF radio.

Synthesizer / Mixer Board Technology

A block diagram of the board is shown in Figure 5. The Synth/Mixer board is based on the TI LMX2541 chip family [3]. Specifically, the 3740 version of the chip is used, which is capable of generating the 3600 MHz frequency we need. TI (ex. National Semiconductor) has a free design-software program for selecting chips and creating designs for many of their clock chips including the LMX2541 family [4]. The tool is compatible with designs like this board for the P-Com application with a 3600 MHz LO.

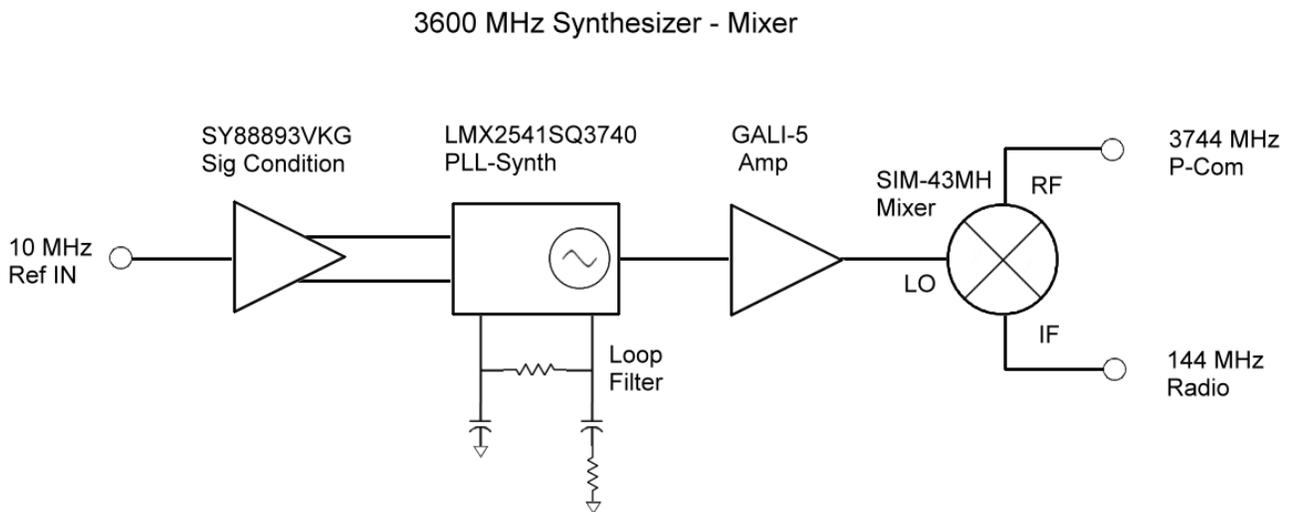


Figure 5 – Block Diagram of the Synth/Mixer Board

The board has a signal conditioning SY88893VKG chip for the 10 MHz reference input. The 10 MHz standard reference frequency is at the low end of what can lock the PLL chip so the conditioning chip helps ensure reliable operation. The board works well with a Ref at +5 to +15 dBm and reference port can be connected in parallel with the DB6NT 10 MHz ref input port.

The board also has a Mini-Circuits GALI-5 amp for driving the LO signal out of the synthesizer. This drives a Mini-Circuits SIM-43MH+ mixer for converting the 3744 MHz from a P-Com module down to 144 MHz. The LMX2541 is loaded with operational parameters from a small AVR ATINY microprocessor on the bottom side of the board.

Figure 6 is a picture of the board mounted in a Hammond 1550B box.

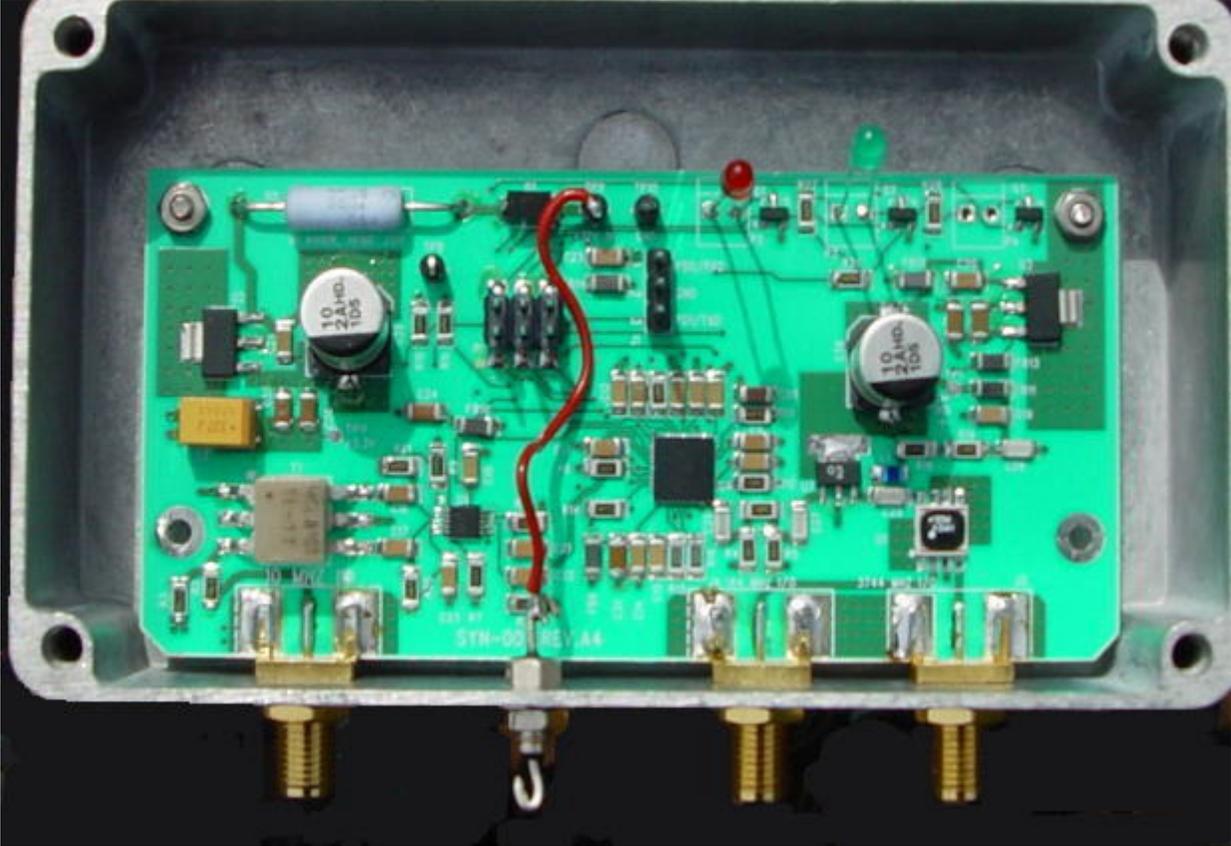


Figure 6 – Synthesizer / Mixer Board mounted in a Hammond box

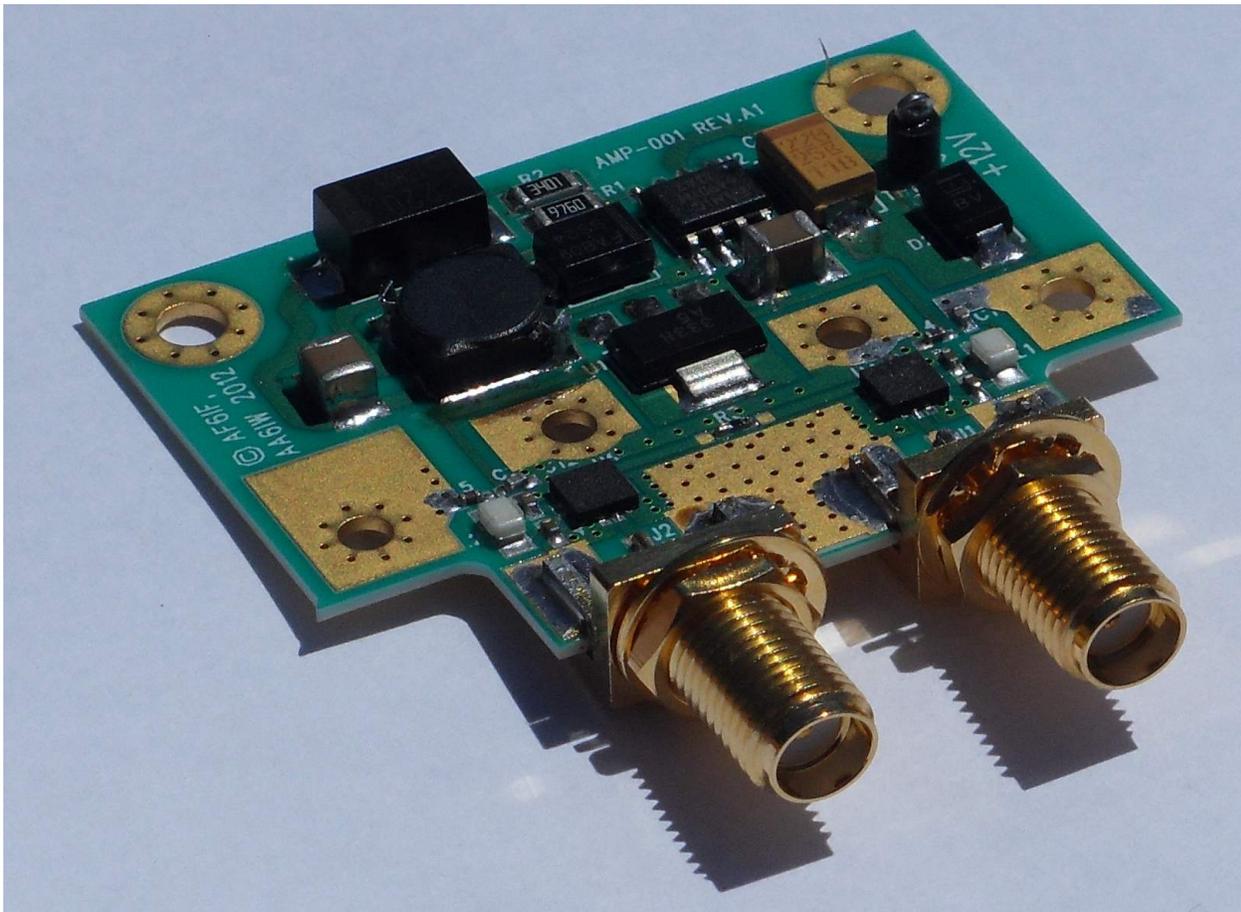


Figure 7 – 5 to 18 GHz Amplifier Board

Amplifier data:

Frequency range: 5 GHz to 18 GHz

Gain: 22 dB

Noise figure @ 10 GHz: 4.5 dB

Output power at 1 dB compression: +19 dBm typ.

DC power: +8V to +20V

DC current: 166 mA at +12V DC, 144 mA at +13.8V DC

Performance

AA6IW and AF6IF have built “flip switch” 10/24 GHz radios using these boards in their radios during the ARRL 10 GHz and Up contest with good results. Rex KK6MK has made some measurements to get a ballpark assessment of the phase noise performance of the PLL local oscillator on the board.

Jeffrey WA6KBL agreed to make the first measurements of phase noise with his 8563E spectrum analyzer equipped with PN measurement software. The HP 80511 OCXO in the SA was used as the 10 MHz reference for the test board. The DUT board was made with no mixer chip installed to allow bringing the 3600 MHz out to an SMA connector. Figure 8 shows the result of this measurement. The PN is below -80 dBc at 100 Hz and drops to about -93 dBc at 1 kHz.

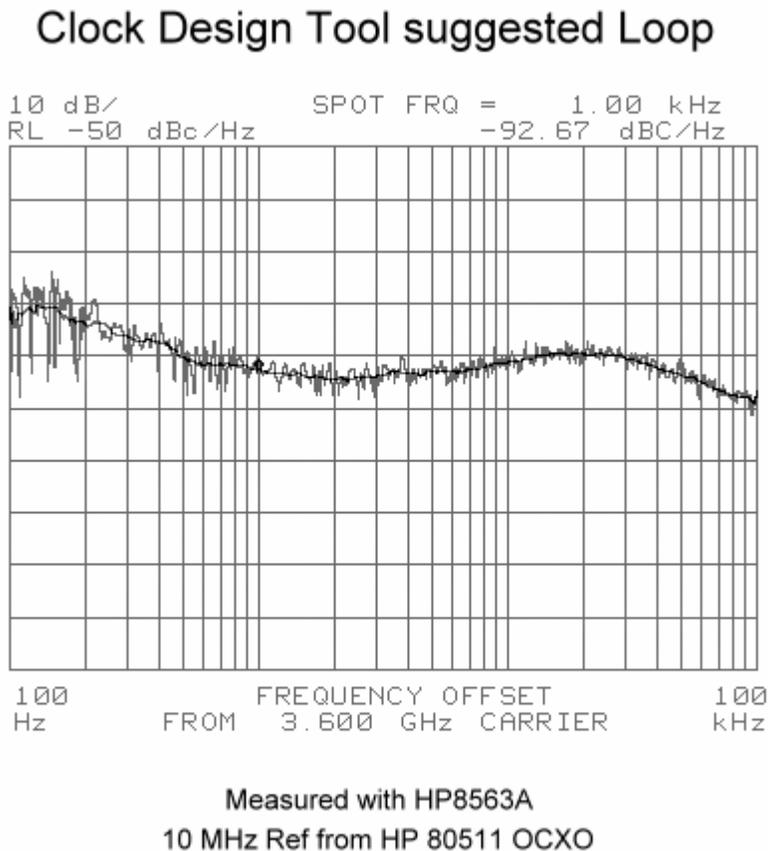


Figure 8 – First Phase Noise measurement

When Rex KK6MK returned home, I made more measurements with my 8566B spectrum analyzer. The PN measurements were driven and recorded by John Miles’ KE5FX GPIB PN software [5]. These are in the same general PN levels but look a little different across the measured PN bandwidth. I’m not sure why the shape is different; the quality of the reference

LO source probably has something to do with it. Figure 9 shows three PN measurements made with the 8566B. Three different 10 MHz reference sources were used on the three plots.

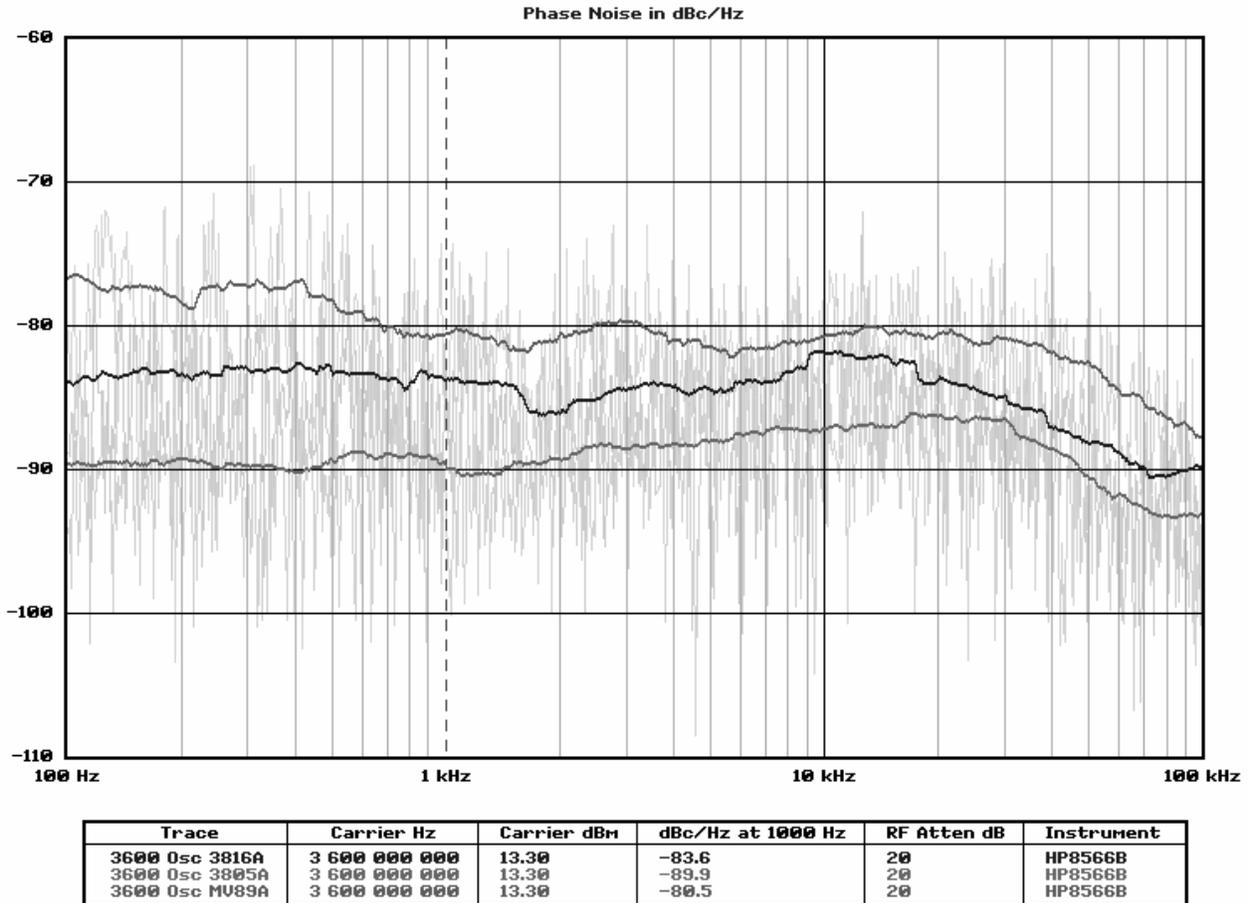


Figure 9 – PN Measurements with 3 10 MHz references

The loop filter for the board’s PLL is wide – on the order of 11 kHz, so the quality of the PN at 3600 MHz will be largely determined by the quality of the 10 MHz reference locking the board. In Figure 9, the effects of three different references can be seen. The oscillators used, in order from best to worst PN were: An HP 3805A GPSDO, an HP 3816A GPSDO, and an eBay Morion MV89A OCXO.

Other Uses

The board is great for its intended purpose, but it probably can be used for other interesting ham functions. The oscillator in the LMX2541 PLL chips can generate frequencies in the 2 to 4 GHz range, but different versions of the chip are required to cover portions of that range. The 3740 version of the chip used in this design is specified to cover 3480 to 4000 MHz.

Additionally, the PLL chip can be programmed to divide down the oscillator frequency so it should be possible to produce frequencies down to 10’s of MHz.

Of first interest to me (KK6MK) is to investigate producing 3456 MHz or 3408 MHz. This is because $3456 * 3 = 10368$ (for a beacon) and $3408 * 3 = 10224$ (for a 10 GHz LO). Unfortunately these frequencies are below the specified range for the 3740 version of the chip. I plan to make a test board with a 3320 version of the chip and no mixer installed to test these options. The board, now used as an LO, could then be followed with a tripler like W1GHZ described for his 10 GHz beacon [6].

Changing frequencies also requires different PLL chip parameters, so a custom version of the microprocessor software will be required. Some changes to the component values of the loop filter might also be needed. The TI Clock Design tool [4] can be used to investigate the feasibility of a particular frequency and get reasonable parameters and loop configurations.

Characteristics

To close, we will list some of the characteristics of the 3600 MHz Synthesizer/Mixer board.

- Designed to convert bi-directionally between 3744 MHz and 144 MHz
- Uses +10 to +15 V DC power at ~ 300 mA
- Takes a 10 MHz reference @ 5 to 15 dBm to lock the internal 3600 MHz osc.
- Has three LEDs that indicate the state of Ref-In and Lock
- Measured phase noise in the vicinity of -80 dBc/Hz
- The board is 3.8 x 1.8 inches
- There may be an option to use a custom design for other frequencies or functions
- A small number of these boards will be made available to hams. Expected cost in the range of \$80 - \$100

KK6MK has put up a web page for this project [7]. Current information should be available there.

References

[1] Al Ward, W5LUA, "Using Surplus 23 GHz Modules at 24192 MHz", Proceedings of Microwave Update, 2000. Also available at <http://kl7uw.com/24modules2.pdf>

[2] Gary Lauterbach AD6FP and Lars Karlsson AA6IW, "Dual-Band 10/24 GHz Feedhorns for Shallow Dishes", Proceedings of Microwave Update, 2001

[3] Texas Instruments, Ultra-Low Noise PLLatinum Frequency Synthesizer with Integrated VCO, <http://www.ti.com/product/LMX2541>

[4] Texas Instruments, Clock Design Tool - Loop Filter & Device Configuration + Simulation, <http://www.ti.com/tool/clockdesigntool>

[5] John Miles, KE5FX, PN on the web page: "KE5FX GPIB Toolkit", <http://www.ke5fx.com/gpib/readme.htm>

[6] Paul Wade, W1GHZ, "A Personal Beacon for 10 GHz",
http://www.w1ghz.org/small_proj/Beacon_10GHz.zip

[7] Rex Allers, KK6MK, web page: "Synthesizer/Mixer Project",
http://www.xertech.net/Projects/Synth_proj.html