Using Surplus 23 GHz Modules At 24192 MHz By Al Ward W5LUA

Introduction

The California surplus market seems to be a hot bed of 23 and 39 GHz transmit and receive modules. Thanks to Will Jensby, W0EOM, many of these modules have been made available to the hams. These modules are part of various 23 GHz data transmission radios originally manufactured by Digital Microwave Co. and P-COM, Inc. With Will Jensby's (W0EOM) and Ted Buell's (WB5TBL) help, I was able to have access to various different units. This paper summarizes the performance of these various up and down converter modules in the 24 GHz amateur band.

Discussion

Both the up-converters and down-converters are waveguide input and SMA for the IF and LO ports. The waveguide flange on most modules is very similar to WR-42. 2 of the 4 holes on the waveguide flange will mount directly to a piece of WR-42. The remaining 2 holes will have to be repositioned or not used. Some units come with an isolator attached to a diplexer unit. The diplexer is not usable as-is at 24 GHz. The isolators , however, can be used effectively at 24 GHz. The test results shown in this paper are without an isolator attached.

Reviewing the data that came with one of the P-COM units indicates a receive frequency in the 22.4 to 23.1 GHz with high side LO/2 injection between 12.4 and 12.8 GHz. The resultant IF is 2443 MHz. On the transmit side, the same LO scheme is used with a 3675 MHz IF with resultant RF output between 21.2 and 21.9 GHz. The high side LO injection and the relatively high IF were probably used to develop some measure of image rejection with simple filtering.

The first order of business was to find out how the modules work with various convenient IFs such as 1296, 2304, and 3456 MHz. The initial results of the up-converter tests are shown in Table I.

Unit	IF Input	LO Input	2 X LO Output	LSB Output	USB Output
	2.304 GHz	**10.944 GHz**	**21.888 GHz**	**19.584 GHz**	**24.192 GHz**
CTR-60703 R	+10 dBm	+14 dBm	+19 dBm	+13.7 dBm	+7.7 dBm
		+9 dBm@ 12.1 GHz	+7 dBm @ 24.2 GHz		
CTR-958195	+10 dBm	+10 dBm	+16 dBm	+8 dBm	+14 dBm
		+6dBm@ 12.1 GHz	+17 dBm @ 24.2 GHz		
	1.296 GHz	**11.448GHz**	**22.896 GHz**	**21.6 GHz**	**24.192 GHz**
CTR-60703 R	+10 dBm	+10 dBm	+4 dBm	Nil	-5 dBm
CTR-958195	+10 dBm	+10 dBm	+10.7 dBm	Nil	+5.7 dBm
	3.456 GHz	**10.368 GHz**	**20.736 GHz**	**17.28 GHz**	**24.192 GHz**
CTR-60703 R	+10 dBm	+13 dBm	+9.8 dBm	-5.3 dBm	+10 dBm
CTR-958195	+10 dBm	+13 dBm	+5 dBm	-17.7 dBm	+16 dBm

Table 1. Initial 23 GHz Up-Converter Module Test Results with various IFs

All modules were tested at an IF input level of +10 dBm which is where maximum power output normally occurs with these modules. For the purist, this level is past the 1 dB gain compression point, but we are more concerned with raw power at 24 GHz than splatter on SSB. The modules are all designed to be fed with the LO at half frequency. Therefore the LO is calculated by the following equation. LO input = (RF – IF) / 2. The LO is varied for each test to find the optimum level for each module. The RF output of the module is viewed on an HP8563E spectrum analyzer. Several signals were of interest. The primary desired signal is 2 X LO plus IF which is 24192 MHz. This will be called the upper sideband or USB output. In addition there is also a signal at 2 X LO minus IF which is the undesired lower sideband or LSB output. The 2 X LO output signal level is also recorded.

A choice of a 1296 MHz IF is clearly worse than the use of 2304 MHz and 3456 MHz as shown by lower power output, i.e. +5.7 dBm on one unit and only –5dBm on another. The optimum choice of IF is 3456 MHz. The two test modules provided a couple of dB greater power output when using a 3456 MHz IF versus a 2304 MHz IF. In addition, the use of a 3456 MHz IF provides some image rejection so very little if any filtering is required at the output of the up-converter module. In comparing the level of the USB output versus the LSB output, one finds 33 dB of image rejection on one unit and 15 dB on another. The greatest concern with either of the units would be the level of LO coming through at the RF port. An LO level of +5 to +10 dBm is sure to drive any sort of power amplifier into compression. When using a power amplifier be sure to use some sort of filtering to reduce LO leakage and to further reduce the image frequency. However, using the module “bare-bones” as a start on 24 GHz is fine with a 3456 MHz IF.

The modules also work fine as frequency doublers. I took the CTR-958195 unit and drove the LO input at 12.1 GHz at a +6 dBm power level. The output level at 24.2 GHz was a surprising +17 dBm. Not bad for a “weak” signal source or beacon.

After my initial testing of these modules, I came across some additional 23 GHz modules and decided to take a closer look at what would happen if one were to apply a lower harmonic of the desired LO frequency. The data in Table 2 shows the performance achieved with a 3456 MHz IF and LO frequencies of LO/2, LO/3, and LO/4. I use "I/O" in the table to indicate that the performance is at a level so low as to render the modules not useful for amateur applications.

I tried to include all the model number, serial number, and date code information in the table to help out in classifying the modules. When reviewing the data in the table, the first important item to note is that not all units with the same apparent model number and slightly different date codes work the same. We are using units "out-of-band" with regards to their original intended design frequency so beware. Some units are definitely higher power, i.e. +15 to +20 dBm and some are lower power in the +7 dBm range or less. As one can see, one of the modules works fairly well at LO/3. The real surprise is that all modules have some measure of performance at LO/4. Finding a 5 to 6 GHz LO may be easier and cheaper than finding a 10 to 11 GHz LO.

I also included a harmonic mixer that WA5TKU bought at Dayton in 2000 and it appears to like the higher IFs as well. It is a simple harmonic mixer with no RF amplification.

Table 3 shows the performance of most of the same units when used with a 2304 MHz IF and the same lower harmonic LO frequencies.

24192 MHz up-converter w/3456 MHz IF @ +10 dBm	10368 MHz LO LO/2		6912 MHz LO LO/3		5184 MHz LO LO/4	
Model	LO PWR (dBm)	Power out (dBm) @ 24192MHz	LO PWR (dBm)	Power out (dBm) @ 24192MHz	LO PWR (dBm)	Power out (dBm) @ 24192MHz
CTR-958195 15081-001 96111 9522	+13	+16	+17	+15.5	+17	+12.5
CTR-960699R 16051 1R4 20060	+16	+7	+17	+6	+17	0
CTR-958195 15081-001 18744 9552	+13	+2.7	+17	+4	+14	+1
CTR-958196 15081-002 96289 9524	+13	+20	I/O	I/O	+16	+19.3
Marki Microwave Harmonic Mixer M97143-1 1312	+17	-11 with +2 dBm IF drive				

Table 2. 23 GHz Up-Converter Module Test Results with LO input of LO/2, LO/3, and LO/4 with a 3456 MHz IF.

24192 MHz up-converter w/2304 MHz IF @ +10 dBm	10944 MHz LO LO/2		7296 MHz LO LO/3		5472 MHz LO LO/4	
Model	LO PWR (dBm)	Power out (dBm) @ 24192MHz	LO PWR (dBm)	Power out (dBm) @ 24192MHz	LO PWR (dBm)	Power out (dBm) @ 24192MHz
CTR-958195 15081-001 9611 9522	+13	+13.5	I/O	I/O	+16	+13.3
CTR-960699R 16051 1R4 20060	+13	+6	I/O	I/O	+17	+5
CTR-958195 15081-001 18744 9552	+10	+2.7	I/O	I/O	+14	+3.3
CTR-958196 15081-002 96289 9524	+16	+19.3	I/O	I/O	+18	+15.3

Table 3. 23 GHz Up-Converter Module Test Results with LO input of LO/2, LO/3, and LO/4 with a 2304 MHz IF.

I then set out to measure the 23 GHz down-converter modules at 24192 MHz. Knowing that these modules were designed for frequencies somewhat below the 24192 MHz band, led me to believe that these modules will have very little image rejection. I initially made some double side-band noise figure measurements but then decided that the data would be more useful if it were a single side-band noise figure measurement. Since the conversion gain/loss of the modules is probably different for both the desired frequency and the image, a DSB measurement could be misleading.

The noise figure and gain measurements shown in Table 4 were obtained by using an HP346C noise source rated to 26 GHz. A 24192 MHz band pass filter with a measured 1 dB loss was attached to the output of the noise source. I corrected the measurements to take into account the loss of the filter.

I again tested the units at various sub-harmonic levels. The results were not very encouraging at the sub-harmonic frequencies.

According to Will Jensby, all of the down-converters that he has opened up and examined have an LNA in front of the mixer. The higher measured noise figure of some of the units at 24 GHz may be due in part to roll-off of the band pass filter that precedes the mixer. Will has been working on methods of re-tuning the front-end filters.

The same units were tested at a 2304 MHz IF. The results of which are shown in Table 5.

24192 MHz RF w/3456 MHz IF	10368 MHz LO LO/2			6912 MHz LO LO/3			5184 MHz LO LO/4		
Model	Gain (dB)	SSB NF (dB)	LO PWR (dBm)	Gain (dB)	SSB NF (dB)	LO PWR (dBm)	Gain (dB)	SSB NF (dB)	LO PWR (dBm)
OS5POS94-46602 22.2 – 23.6 GHz 9530 10134d	16.9	11.4	+13	15.1	11.5	+10	9.1	19	+11
CTR-958259 15628-001 10501 9552	19.9	5.2	+13	I/O	I/O	I/O	7	9	+18
OS5PO S94-46592 DN CONVERTER 21.2 – 22.6 GHz 9527 11461	14.3	7.4	+16	13.6	7.8	+13	8.6	13.1	+17
OS5PO S94-46592 DN CONVERTER 21.2 – 22.6 GHz 9527 10557	7.1	11.3	+14	7.8	10.6	+13	I/O	I/O	I/O
OS5PO S94-46592 DN CONVERTER 21.2 – 22.6 GHz 9520 9576	8.2	13.2	+17	8.7	12.5	+17	I/O	I/O	I/O
CTR960701R 15628-1R4 21058	19.4	9.5	+16	18.5	5.7	+10	17.1	11.9	+16
CTR960701R 15628-1R4 20591	15.9	6.9	+17	N/A	N/A	N/A	N/A	N/A	N/A
Marki Microwave Harmonic Mixer M97143-1 1312	-6.6	6.7	+17	I/O	I/O	I/O	-15.8	16.2	+13
Avantek SMW86-1323 D/C 9249 S/N 6011	-1.2	6.9 DSB	+10	0	11 DSB	+17	I/O	I/O	I/O

Table 4. 23 GHz Down-Converter Module Tests with LO input of LO/2, LO/3, and LO/4 with a 3456 MHz IF.

24192 MHz RF w/2304 MHz IF	10944 MHz LO LO/2			7296 MHz LO LO/3			5472 MHz LO LO/4		
Model	Gain (dB)	SSB NF (dB)	LO PWR (dBm)	Gain (dB)	SSB NF (dB)	LO PWR (dBm)	Gain (dB)	SSB NF (dB)	LO PWR (dBm)
OS5POS94-46602 22.2 – 23.6 GHz 9530 10134d	0	9.5	+10	-.7	9	+13	I/O	I/O	I/O
CTR-958259 15628-001 10501 9552	8.5	4.5	+17	I/O	I/O	I/O	I/O	I/O	I/O
OS5PO S94-46592 DN CONVERTER 21.2 – 22.6 GHz 9527 11461	-9.8	10	+16	-11.5	11.2	+13	I/O	I/O	I/O
OS5PO S94-46592 DN CONVERTER 21.2 – 22.6 GHz 9527 10557	I/O	I/O	I/O	I/O	I/O	I/O	I/O	I/O	I/O
OS5PO S94-46592 DN CONVERTER 21.2 – 22.6 GHz 9520 9576	-12.5	8.2	+7	I/O	I/O	I/O	I/O	I/O	I/O
CTR960701R 15628-1R4 21058	-6.5	10.2	+7	I/O	I/O	I/O	I/O	I/O	I/O
CTR960701R 15628-1R4 20591	11.2	5.8	+15	N/A	N/A	N/A	N/A	N/A	N/A

Table 5. 23 GHz Down-Converter Module Tests with LO input of LO/2, LO/3, and LO/4 with a 2304 MHz IF.

Additional Information

After Will reviewed my original test results, he had the suggestion of trying the high side LO injection to see if results were any better. The only information I had about any of the modules was the data sheet for the P-COM unit CTR-960699R. As indicated earlier, this transmit module is designed for a 3675 MHz IF, a half LO of 12.784 GHz and an RF frequency of 21.894 GHz. I decided to verify this information on the CTR-960699R unit and to also test high and low side LO injection for 1296, 2304, and 3456 MHz IFs. I also evaluated another unit, the CTR-958195. The results are shown in Table 6. The CTR-960699R certainly did meet the data sheet power output of +20 dBm at 21.894 GHz but was only producing +8.5 dBm at 24.192 GHz with a 1296 MHz IF and high side LO injection. Surprisingly, the CTR-958195 produced +9.8 dBm at 24.192 GHz with a 1296 MHz IF and high side LO injection.

The tests shown in Table 7 show the performance of both units when used as LO multipliers. In this case the waveguide is the output port and the LO port the input port. The IF port is left open circuited. The interesting results are that both units work well as a doubler to 22.392 GHz which can then be used to pump a harmonic mixer at 47.088 GHz with a 2304 MHz IF. The units also provide a healthy signal at 23.544 GHz which can be used to drive a multiplier to 47.088 GHz.

LO Frequency Level = +16 dBm	IF Frequency	RF Frequency	Unit A RF Power Output	Unit B RF Power Output
12.784 GHz (hi-side)	3.675 GHz	21.893 GHz	+20 dBm	+7.7 dBm
12.744 GHz (hi-side)	1.296 GHz	24.192 GHz	+8.5 dBm	+9.8 dBm
10.944 GHz(low-side)	2.304 GHz	24.192 GHz	+5 dBm	+2 dBm
13.248 GHz(hi-side)	2.304 GHz	24.192 GHz	+6.3 dBm	+6.7 dBm
10.368 GHz(low-side)	3.456 GHz	24.192 GHz	+6.3 dBm	+3 dBm
13.824 GHz(hi-side)	3.456 GHz	24.192 GHz	+5.7 dBm	+7.5 dBm

Unit A CTR-960699R 16051 1R4 20060
Unit B CTR-958195 18744 9552

Table 6 Up-Converter Modules tested for various high and low side LO injection

Unit	Input Frequency	Input Power Level	Output Frequency	Output Power Level	Application
CTR-960699R 16051 1R4 20060	12.096 GHz	+10 dBm	24.192 GHz	+6 dBm	Beacon/weak signal source
	11.772 GHz	+10 dBm	23.544 GHz	+14.3 dBm	X2 = 47.088 GHz
	11.196 GHz	+16 dBm	22.392 GHz	+18 dBm	X2 = 44.784 GHz LO + 2.304 GHz IF = 47.088 GHz
CTR-958195 18744 9552	12.096 GHz	+10 dBm	24.192 GHz	+10 dBm	Beacon/weak signal source
	11.772 GHz	+10 dBm	23.544 GHz	+21.5 dBm	X2 = 47.088 GHz
	11.196 GHz	+7 dBm	22.392 GHz	+23 dBm	X2 = 44.784 GHz LO + 2.304 GHz IF = 47.088 GHz

Table 7 Up-Converter Modules tested as multipliers

The last test was to take one of the units and analyze its’ performance with very low IFs’ The data shown in

Table 8 shows that even with a 144 MHz IF and 12.024 GHz LO, the output at 24.192 GHz is +7 dBm. With a 432 MHz IF and a 11.880 GHz LO, the 24.192 MHz signal is only +1 dBm. Also note that the lower sideband or undesired sideband is 10 to 20 dB higher than the desired 24.192 GHz signal. The disadvantage of a low IF is that the LO and image frequency are very difficult to filter.

relays is rated to 26.5 GHz. Loss should be less than 1.5 dB at 24 GHz. Another option is the popular SMA transfer relays that are fairly common on the surplus market. Even though they are usually only rated to 18 GHz because of their SMA connectors, I have measured losses between 1.5 to 2 dB and greater than 30 dB of isolation at 24 GHz.

Another option is the use of a circulator which works well with transmit powers below +20 dBm. The output from the up-converter is routed through the circulator to the antenna. Received signal from the antenna is routed through the circulator to the down-converter. All works well as long as the antenna is well matched, i.e. low VSWR or good return loss. In addition to a receive signal being routed to the down-converter, any transmitted signal that is reflected from the antenna will also be routed to the down-converter. Besides having a well matched antenna, be sure to keep all objects away from the feed. Any object brought in close to the antenna could change the VSWR of the antenna and cause more power to be reflected.

When all is working well, there will still be some transmit power that shows up at the receive port. A typical circulator may only have 15 to 20 dB isolation. This means that when the up-converter is delivering +17 dBm into the antenna, the power delivered to the receive port will only be 15 to 20 dB below the +17 dBm. This means that the down-converter may see –3 to +2 dBm. As long as dc power is removed from the

IF Frequency	LO Frequency	LO Power	Upper Side Band	Lower Side Band
144 MHz	12.024 GHz	+16 dBm	+7 dBm @ 24.192 MHz	+17 dBm @ 23.904 MHz
432 MHz	11.880 GHz	+16 dBm	+1 dBm @ 24.192 MHz	+21 dBm @ 23.328 GHz

Table 8 Model CTR-958195 18744 9552 Up-Converter tested with 144 and 432 MHz IFs

The Next Step

What do we do with the modules? A block diagram showing a typical system is shown in Figure 1. To start with we need a low power 3456 MHz transverter to interface with the modules. Noise figure can be 3 to 5 dB and power output must be about +10 dBm. If the 3456 MHz transverter has a single output for both transmit and receive then some sort of SPDT switch or circulator must be used to provide separate receive and transmit ports to drive the IF ports of the 23 GHz modules. A power divider of the appropriate frequency range must be used to split the LO between the two modules.

Probably the biggest dilemma is how to switch the RF ports to a single antenna. Some amateurs have had luck using two separate antennas on the same mast hopefully aimed in the same direction. The nicest solution is a WR-42 or WR-28 waveguide switch. The next best solution would be a 3.5 mm coaxial SPDT switch. The HP33311C family of down-converter module while transmitting, the several milliwatts of transmit power at the RF port of the down-converter should not damage the unit. In fact, I would think the down-converter module could handle +7 dBm at the RF port without damage as long as dc power is removed. The best approach is to measure the power at the receive port before attaching the down-converter module. Inadequate isolation in a circulator can quite often be improved by attaching magnets to the body of the circulator and monitoring the power at the receive port. One might be able to find the right magnet position to improve isolation a few dB.

Conclusion

Hopefully the information presented in this paper will help amateurs use these units successfully in the 24 GHz amateur band. I would like to thank Will Jensby (W0EOM) and Ted Buell (WB5TBL) for making these units available to the amateur market.

73 de Al Ward W5LUA Sept 3,2000

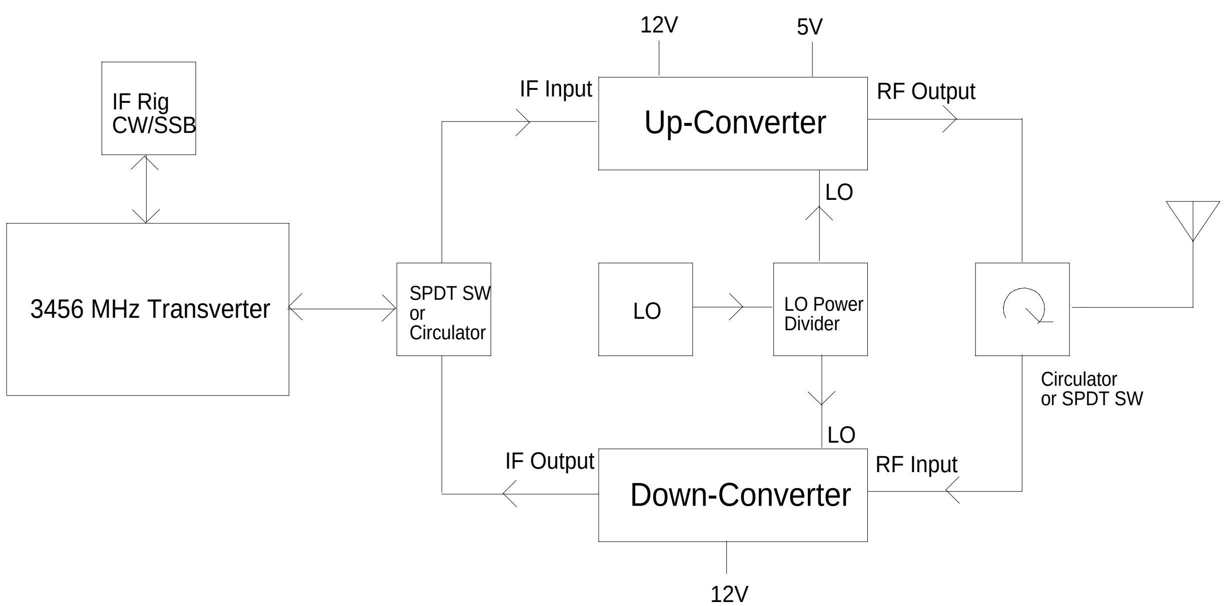

Figure 1. Block diagram showing a typical 24192 MHz transverter using the surplus modules