A Flip-Switch 10/24 GHz Dual Band Radio

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Introduction

I had a great time in my first 10 Ghz and up contest in 1999 even though I was only able to operate for a few hours on the second weekend. I used a homemade low power (50 mw) transverter based on the designs of W1VT and W1GHZ [1,2]. After that first time I decided to build a better radio for the contest in 2000. The result is described in this paper.

Having minimal experience operating on the microwave bands I leaned heavily on discussions with AA6IW, W0EOM and KK6MK to define this radio. I started collecting components for the radio at Microwave Update 1999 and luckily by July 2000 had everything I needed to start construction. Starting construction in July proved to be a bit of a problem, I finished the radio in a frenzied burst of activity just hours before the first contest weekend in August.

The photo at the right shows the 4’ offset dish with microwave electronics mounted below the feedhorn.

Goals

I started by making a list of goals for the new radio, not in any particular order of importance:

- Dual band 10 and 24 GHz
- Use a 4' offset dish I had acquired
- Change bands at the flip of a switch
- Dual band feed for the dish
- Use a 10 watt 10 GHz amplifier that was acquired
- Use Celeritek up/down converters for 24 GHz
- Run everything off 12 volts using dc-dc converters
- Lock all local oscillators to a Rubidium standard
- Use the same IF for 10 & 24 GHz (144 MHz)
- Locate the microwave electronics near the feed to minimize loss

Several of the goals are intended to work together to make 24 GHz contacts much easier and faster. The local wisdom about 24 GHz contacts was that many are not completed due to antenna misalignment and frequency errors. Using the same dish for both bands with a dual band feed takes care of the alignment issue, the dish is peaked up on 10 GHz where signal levels are stronger then the switch to 24 GHz is made. To solve the frequency error problems all of the local oscillators are locked to a Rubidium source and a common IF radio is used on both bands. Once a contact is made on 10 GHz and the antenna is peaked up with a flip of a switch the radio is ready to go on 24 GHz without retuning the IF radio or repeaking the dish.

Local Oscillator Scheme

Like others, I've discovered that much of the work of building a microwave radio is in the local oscillator(s). My plan was to minimize the number of oscillators that I would need to lock to the Rb source. Some bench checks of the Celeritek up/down converters indicated that they perform well with a 3+ GHz IF frequency (for a thorough analysis see [3]). I chose a first IF of 3.744 GHz for the 24 GHz section allowing a 10.224 GHz oscillator to be used for both the first conversion on 24 GHz as well as the local oscillator on 10 GHz. The second conversion for 24 GHz then uses a 3.6 GHz oscillator to convert the 3.744 GHz first IF down to 144 MHz. The full local oscillator scheme is shown in Table 1.

Band	First LO	First IF	Second LO	Second IF
10.368 GHz	10.224 GHz	144 MHz	-------------	-------------
24.192 GHz	10.224 GHz (x2 = 20.448 GHz)	3.744 GHz	3.6 GHz	144 MHz

Table 1 - Local Oscillator Scheme

A benefit of running a high IF frequency on the Celeritek up/down converters is that the image and LO frequencies are 7.488 and 3.744 GHz away respectively and the rejection of the built-in filters is acceptable (> 25 db).

The 10.224 GHz and 3.6 GHz oscillators are both "bricks". The 10.224 GHz brick uses an internal ovenized 106.5 MHz crystal while the 3.6 GHz brick is driven from an external 100 MHz ovenized crystal oscillator. Both crystals are locked to the Rb reference using varactors to "pull" the crystal frequency. A pair of Fujitsu MB1502 PLL chips taken out of synthesizers from Pcom radios [4] are used to lock the crystals. The programming of the MB1502 synthesizers is done with a PIC processor.

A set of bicolor LEDs is used to monitor the various lock conditions:

- 10.224 GHz Brick
- 3.6 GHz Brick
- 106.5 MHz crystal
- 100 MHz crystal
- Rubidium standard

A red LED indicates the corresponding loop is out of lock while a green LED indicates a locked condition. It takes about 4 minutes for the Rb standard to lock up and by that time all of the other loops have locked onto the Rb. The Rubidium standard is an Efratom STPB-100 with a 5 MHz output. A disadvantage of using this Rb is that it draws a little over 1 ampere at 24 volts during warm-up. Figure 1. is a block diagram of the local oscillator section.

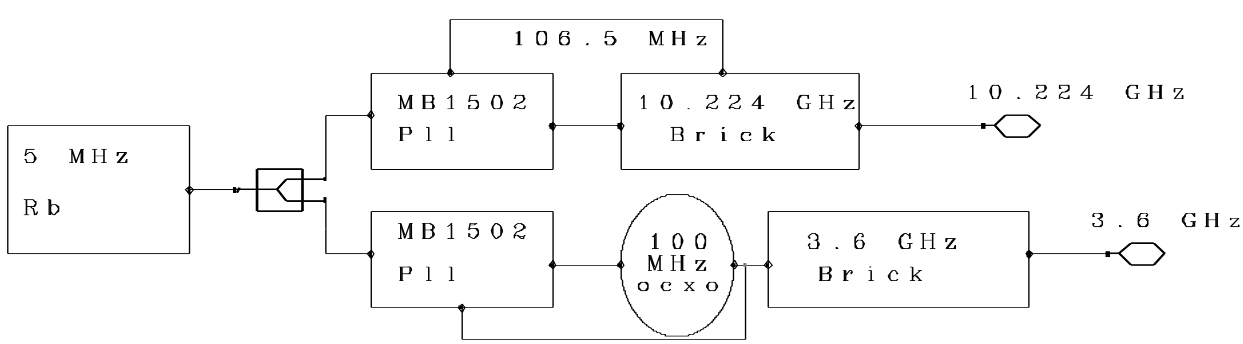


Figure 1 - Local Oscillators and PLLs Block Diagram

10 GHz RF section

The 10 GHz RF section is quite simple consisting of only eight components. Unlike my first 10 GHz radio which used separate mixers for transmit and receive this radio shares a single mixer and filter between the transmit and receive paths. A W1VT designed filter [5] is used to suppress the LO and image frequencies and provides very low insertion loss (< 1 db) in the process. On receive two low noise amplifier gain stages using Agilent ATF-36077 PHEMTs are used ahead of the mixer/filter providing a total gain of over 28 db. On transmit the mixer/filter is switched to two stages of amplification resulting in over 40 db of gain and 10 watts of power output. Figure 2 is a block diagram of the 10 GHz RF section.

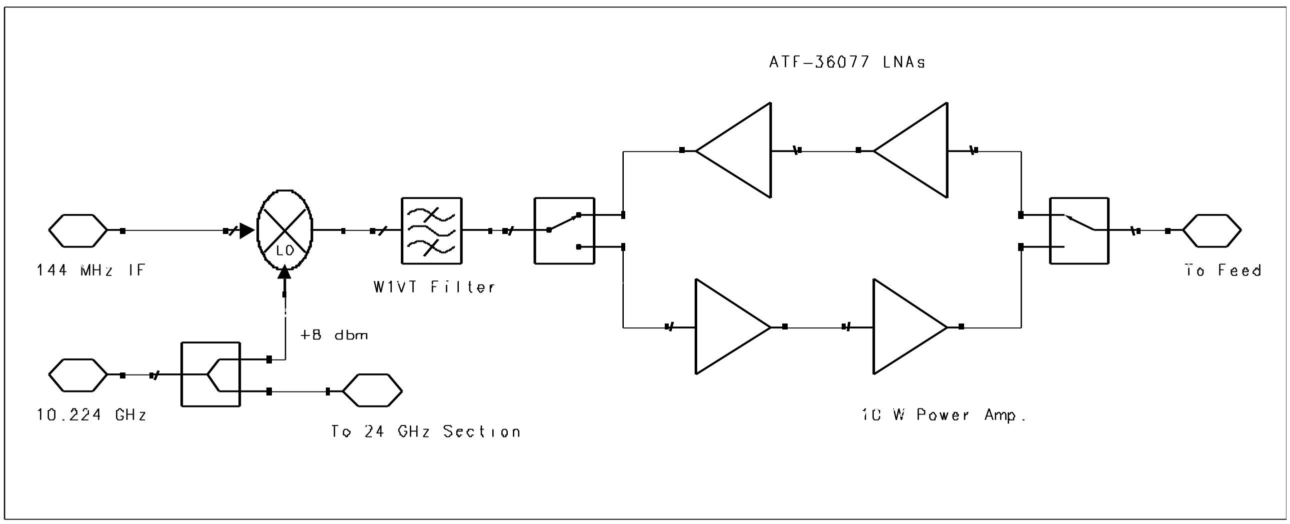


Figure 2 - 10 GHz RF Block Diagram

24 GHz RF section

On 24 GHz a pair of surplus Celeritek [3] up and down converters do most of the work. The 24 GHz down converter is bolted directly to a waveguide switch. On the IF path a 3.7 GHz LNA is used after the downconverter to drive the circulator that splits the transmit and receive paths. The 3.744 GHz up/downconverter is just a connectorized mixer and a surplus K&L bandpass filter.

The 24 GHz transmit path consists of a Celeritek upconverter followed by a .5 watt power amplifier. The power output of the Celeritek upconverter was reduced to the proper level to drive the PA by reducing the voltage on the +5V terminal of the upconverter with a series string of diodes. This power reduction also allows the upconverter to run much cooler.

To get a good drive level for the up/down converters the incoming 10.224 GHz local oscillator signal is amplified to a +16 dbm level before being split to drive the converters. Figure 3 shows the block diagram of the 24 GHz RF section.

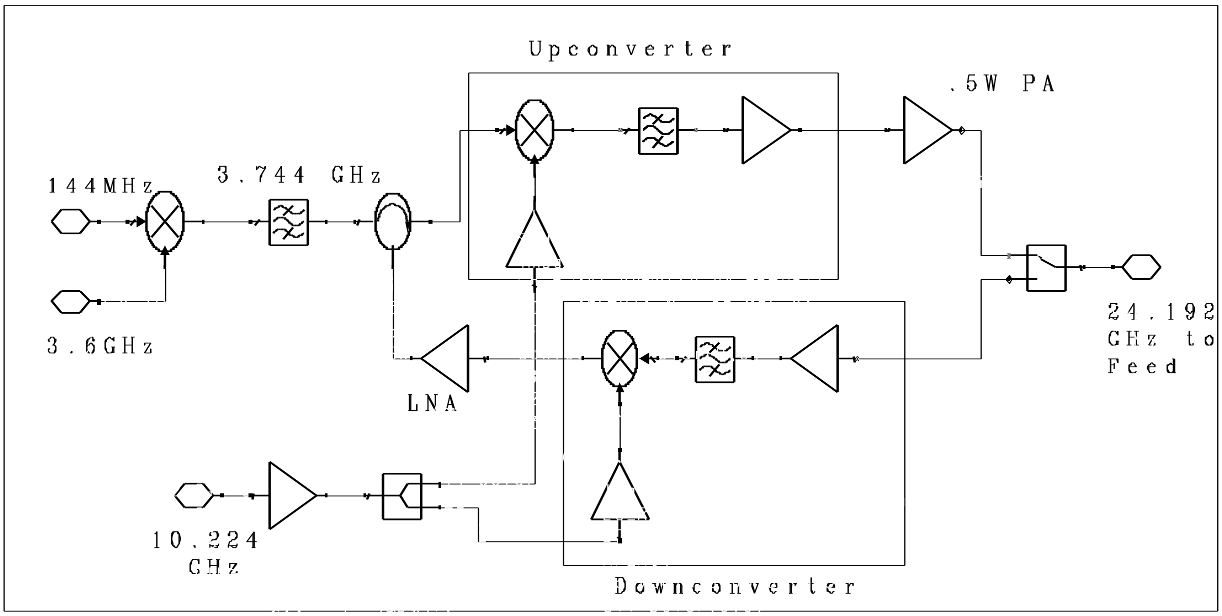
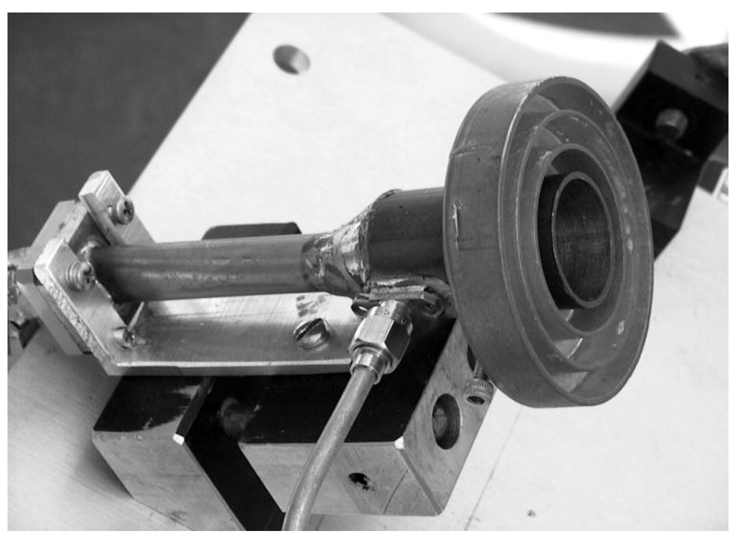


Figure 3 – 24 GHz RF section

Dual Band Feed

I first tried using the dual band feed described by W5ZN [6]. The ZN feed is a better match for dishes with f/d ratios of around .4. Not being happy with the Sun noise measurements I decided to try some other configurations of dual band feeds. The picture at the right shows the feed that I used last year. It's a W2IMU dual mode on 24 GHz cut for .7 f/d and a Chaparral "11 GHz Superfeed" on 10 GHz. This feed shows considerably better G/T numbers in Sun noise measurements on my .7 f/d dish than the original ZN feed measured.



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The feedhorn sits on top of the RF plate that extends from the dish out past and under the focal point. The RF plate is ¼" aluminum about 36" long and 8" wide and is supported at the back of the dish and by two struts that extend from each side of the dish. The feed horn is mounted to an adjustable bracket that allows the fine-tuning of the position of the feed to the focal point.

Since last year AA6IW and myself have been working on an improved dual band feedhorn for shallow offset feed reflectors. A separate paper in this proceedings describes our latest feedhorn and the design / simulation process that was used.

Power supplies and T/R switching

DC to DC power converters are used to supply the numerous different voltages required. All of the negative voltage supplies as well as positive voltages greater than 12 volts use the LT-1070 from Linear Technology. Table 4 summarizes the various power supplies.

Voltage	Uses
+24	Rubidium
+24	10 GHz brick and T/R relays
+5	PLL chips and PIC
-8	10 GHz PA bias
-20	3.6 GHz brick
+11	10 GHz PA

Table 4 - Power Supplies

The +11 volt supply for the 10 GHz PA uses a National LP2975 along with a 50 amp P-FET to make a very low drop-out (<300 mv) linear regulator. A nice feature of the LP2975 is an input that enables keying the power to the PA.

All T/R switching is keyed from a 12 volt signal applied to the IF line on transmit. On 24 GHz the PA is keyed from an auxiliary set of contacts on the waveguide relay. On 10 GHz a simple 300 ms delay is used to hold off keying the power to the PA until the T/R relay has switched.

Packaging, cooling and mechanical

With the large number of power hungry circuits cooling is a concern. For the first few minutes during warm-up the radio draws 8 amperes at 12 volts, slowly decreasing to 3.6

amperes after warm-up. 10 GHz key down transmit draws about 12 amperes. A muffin fan is included in the local oscillator box to remove the approximately 40 watts of heat. The RF electronics on the feed plate are convection cooled with the exception of the 24 GHz PA which uses an impingement fan (a fan intended to cool a PC processor chip) which is powered only during transmit.

The local oscillator box hangs on the back of the dish to partially offset the weight of the dish and balance the tripod. For portability the feed plate and the local oscillator box are attached with fittings to allow quick removal. The radio breaks down into four pieces:

- Dish, tripod head and elevation mechanism
- Tripod
- Local oscillator box
- RF and feed plate

Performance

So far I've been pleased with the performance of the radio. Numerous "flip-switch" QSOs have been made with AA6IW who has built a similar radio. Since both our radios are Rb locked and use a common IF radio for both bands we can peak up on 10 GHz, literally flip the switch, and without touching anything else continue the QSO on 24 GHz. With the microwave oscillators being locked most of the frequency error is in the IF radio (an IC-275) which drifts about 300 Hz during warm-up. The flip-switch features were also helpful in setting the North American 24 GHz distance record in last years contest [7]. Table 5 summarizes some of the measured performance numbers for the radio.

Parameter	**24 GHz**	**10 GHz**
System noise figure	3.7 db	1.4 db
Output Power	.5 watt	10 watts
Sun Noise[1]	6.7 db	7.3 db

Table 5 - Measured Performance Numbers

References

[1] "Home-Brewing a 10 GHz SSB/CW Transverter", Zack Lau W1VT, UHF/Microwave Projects Manual Vol. 2, ARRL, 1997

[1] Sun Noise was measured at 143 SFU

[2] “Building Blocks for a 10 GHz Transverter”, Paul Wade W1GHZ, UHF/Microwave Projects Manual Vol. 2, ARRL, 1997

[3] “Using Surplus 23 GHz Modules at 24192 MHz”, Al Ward W5LUA, Proceedings of Microwave Update 2000

[4] http://microwavepll.rfdude.com/

[5] “A High RF-Performance 10 GHz Band-Pass Filter”, Zack Lau W1VT, UHF/Microwave Projects Manual Vol. 2, ARRL, 1997

[6] “W5ZN Dual Band 10 GHz / 24 GHz Feedhorn”, Joel Harrison W5ZN, Proceedings of Microwave Update 1998, pp 189-190

[7] “2000 ARRL 10 GHz and Up Cumulative Contest Results”, QST Magazine, March 2001