Design and Implementation of Frequency Down Converter for 40-m Amateur Bands

Chaw Myat Nwe

Abstract— This research paper presents a frequency down conversion for 7 MHz 40-m receiver. The designed and tested results of present research work are added and illustrated. MC 1496 balanced modulators/ demodulators IC is used as a main of the down converter design. The crystal ladder filer is used to pass the desired band. And the two frequency oscillators are designed and implemented. Down conversion can be accomplished the 7MHz RF range to baseband audio range. The overall receiver performance is satisfied with the sensitivity of 2.5 μV, the selectivity of 7.00224 MHz to 7.00364 MHz range and the dynamic range of the receiver is 32.2 dB with a distortion of less than 50.2 μV.

Key words **– Down converter, Filter, VFO, BFO, IF amplifier.**

1) INTRODUCTION

The amateur radio service (amateur service and amateur-satellite service) is established by the International Telecommunication Union (ITU) through the Radio Regulations. Radio amateurs use a variety of voice, text, image, and data communications modes and have access to frequency allocations throughout the RF spectrum. This enables communication across a city, region, country, continent, the world, or even into space.

When cell phones, regular phones, the internet and other systems are down or overloaded, Amateur Radio still gets the message through. Radio amateurs, often called "hams," enjoy radio technology as a hobby. But it's also a service –a vital service that has saved lives when regular communication systems failed. [3]

40 meters (7.0–7.3 MHz) band is considered the most reliable all-season DX band. Popular for DX at night, 40 meters is also reliable for medium distance (1500 km) contacts during the day. Much of this band was shared with broadcasters, and in most countries the bottom 100 kHz or 200 kHz are available to amateurs. However, due to the high cost of running high power commercial broadcasting facilities; decreased listener-ship and increasing competition from net based international broadcast services, many "short wave" services are being shut down leaving the 40 meter band free of other users for amateur radio use. [6]

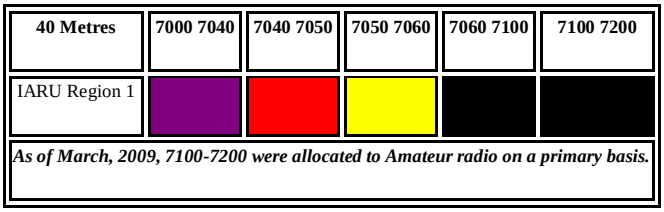

Fig.1. Frequency spectrum of 40 Meters Amateur Band for Region I

The system converts 7MHz RF signal to an IF signal in the range of 4.43 MHz, and then converts to baseband signal range. The system was designed and test under the construction of mixer, oscillator and filter design.

2) DOWN CONVERTER DESIGN

Fig.2. shows the overall block diagram of the receiver. The shaded portion is the interested areas for this research paper of down conversion.

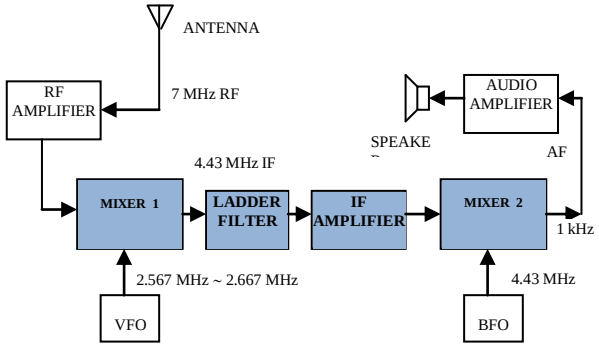

Fig.2. Block Diagram of the Two Stages Downconverter Receiver

The two MC 1496s are used as two stage downconverter mixers. The most common mode of operation of the MC 1496 consists of applying a high level input signal to the dual differential amplifiers, and a low level input signal to the lower differential amplifier. The saturated switching operation is carried out with dual differential amplifiers and linear operation of the modulating differential amplifier.

The resulting output signal contains only the sum and difference frequency components and amplitude information of the modulating signal. Saturated operation of the carrier input dual differential amplifiers also generates harmonics.

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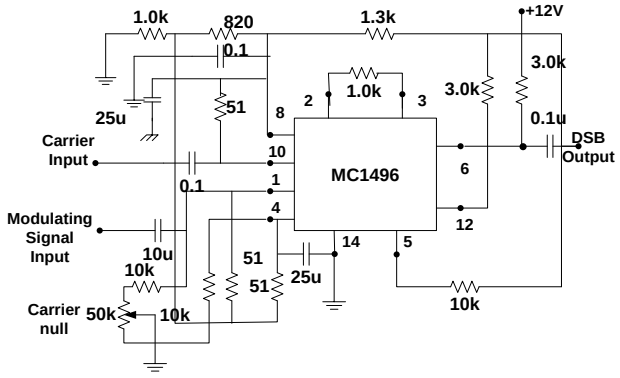
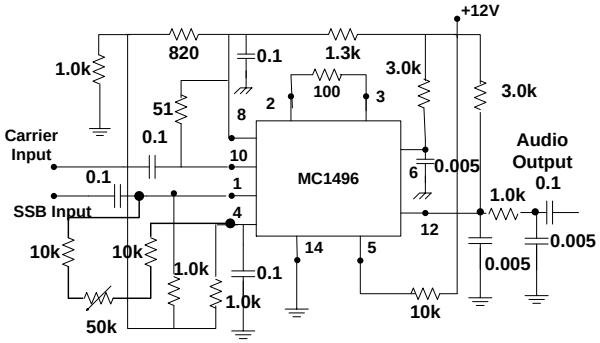
Reducing the carrier input amplitude to its linear range greatly reduces these harmonics in the output signal. However, it has the disadvantages of reducing device gain, causing the output signal to contain carrier signal amplitude variations. Fig.3 (a) and (b) shows the schematic diagram of double stage down converter.



(a)



(b)

Fig.3.Schematic diagram of (a) mixer 1 and (b) mixer 2

Variable frequency oscillator is designed to get the resonance frequency of 2.567 MHz. For the inductance of $L = 30.3455\mu H$, consider FT-50 of 61-mix ferrite toroid, The number of turns

$$N = 1000\sqrt{\frac{30.3455\times10^{-3}\,\text{mH}}{68}} = 21 \text{ Turns.}$$ The schematic diagram of VFO is shown in Fig.4.

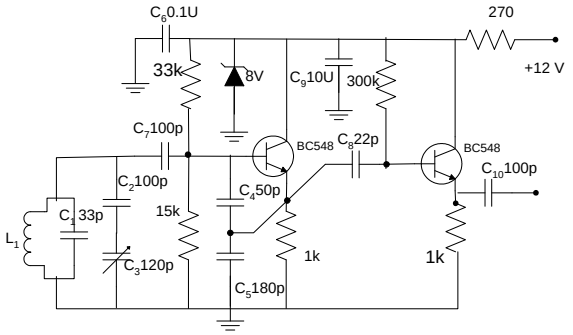


Fig.4. Schematic Diagram of Variable Frequency Oscillator (VFO)

The beat frequency oscillator is also Clapp oscillators. The amplifier is a buffer amplifier that drives the mixer and shown in Fig.5. It use 4.43MHz crystal with motional inductance L_m = 0.13826 H and motional capacitance $C_m = 9.355\times10^{-15}\text{F}$.

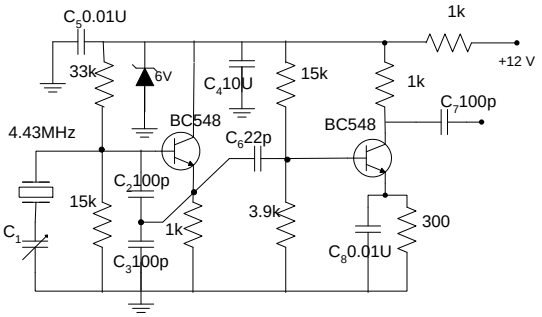


Fig.5. Schematic Diagram of Beat Frequency Oscillator

After mixing procedure of incoming RF signal and VFO signal, it is fed to crystal ladder filter to reduce unwanted sidebands frequency. It use 4 numbers of crystals and it is needed to design 9th order Chebyshev bandpass filter. All crystals of same make and with same serial number need to be collected for the same electrical characteristics. The schematic diagram of bandpass filter with four numbers of crystals is shown in Fig.6.

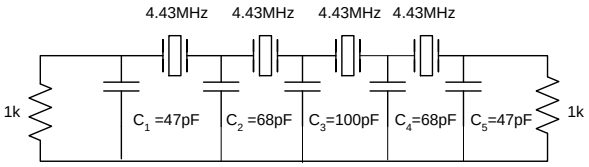


Fig.6. Schematic Diagram of Crystal Ladder Filter

Design IF transistor amplifier with center frequency of 4.43 MHz and bandwidth of 40 kHz. Use the transistor with h_{ie} =1.6kΩ and h_{oe} =18 μ mho. Use FT-23, 61-mix ferrite toroids and so, A_L = 24.8.

Number of turns of L_1,

$$N_1 = 1000\sqrt{\frac{L(\text{mH})}{24.8}} = 1000\sqrt{\frac{5.0185\times10^{-3}}{24.8}} = 14.225 \quad (15\text{Turns})$$

and

$$C = \frac{1}{\omega_0^2 L_1} = \frac{1}{(2\pi\times4.43\times10^6)^2\times5.0185\times10^{-6}} = 257.19\,\text{pF}$$

Choose 220pF of standard values. The schematic diagram is shown in Fig.7.

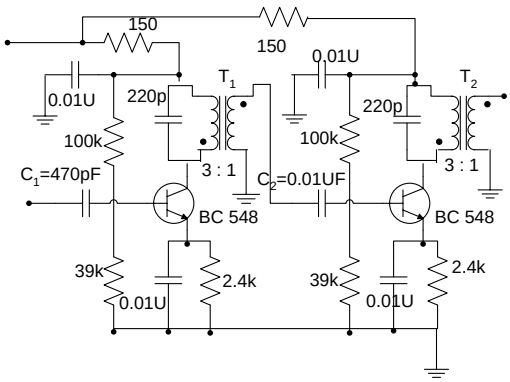


Fig.7. Schematic Diagram of IF Amplifier

3) TEST RESULTS

The output waveforms of 7MHz LC tuned circuit are shown in Fig.8.(a) and RF front end amplifier is shown in Fig.8(b).

(a) (b)

Fig.8.(a) The Output Waveform of LC Tuned Circuit. (b)The Output Waveform and Frequency Front End Amplifier

The output waveform and frequency of receive mixer 1 are shown in Fig.9. It gets IF frequency of 4.43MHz.

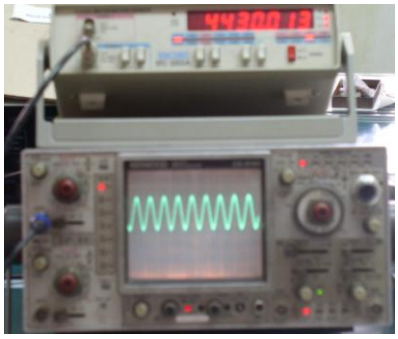


Fig.9. Output Waveforms of Receive Mixer

The output spectrum of crystal filter is shown in Fig.10.

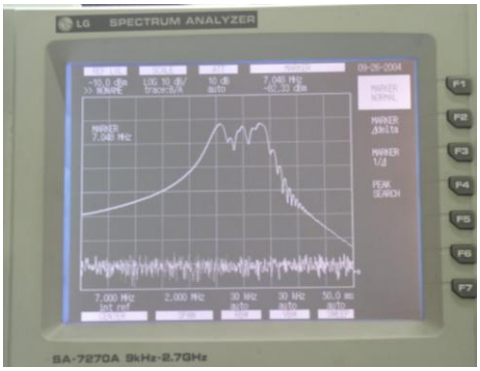


Fig.10. The Output Spectrum of Crystal Filter

The output waveforms and frequency of mixer 2 are shown in Fig.11. The output frequency is baseband audio frequency of 1kHz tone.

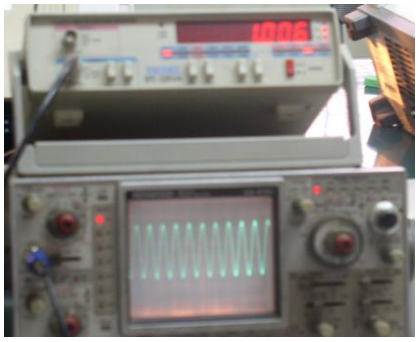


Fig.11. Output Waveforms of Product Detector

The ability of a receiver to reproduce weak signals and so measured under standardized conditions and expressed in terms of signal voltage (μV).The Fig.12 shows the constructed down converter under test.

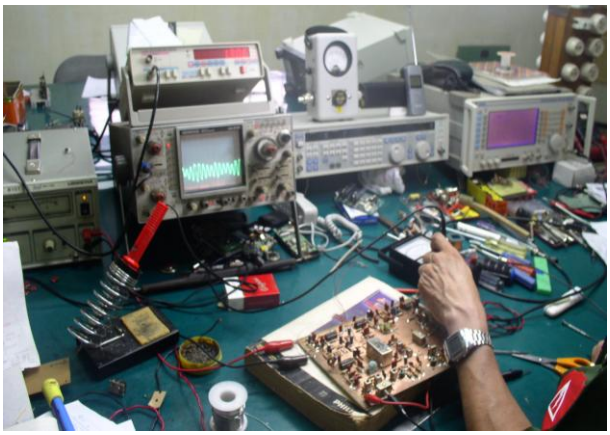


Fig.12. Receiver under Test

The technical specifications of down converter are described below:

(1) Sensitivity: 2.5 μV,
(2) Selectivity: 7.00224 MHz to 7.00364 MHz
(3) Dynamic range: 32.2 dB
(4) Distortion ≤ 50.2 μV
(5) Audio output: 0.78 W (2.5 V)

4) CONCLUSION

The design, construction and testing of radio circuits and system have been studied. The approach that has been taken is the progressive construction of a 7 MHz down converter receiver. It has designed for 7 MHz RF which is 40 meter amateur band, 4.43 MHz IF frequency and audio frequency of human voice range. In VFO, LC control resonator of clap oscillators was used with 2.567 MHz to 2.667 MHz range. And crystal control Clap oscillator was used as carrier reinsertion oscillator with 4.43 MHz frequency. Both the

mixer and product detector circuits have been constructed with IC based Gilbert cell design using MC 1496 balanced modulator / demodulator IC. The required inductor and RF transformer has been designed and built with locally available components.

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REFERENCES

[1] American Radio Relay Langue-1995- The ARRL Handbook for the Radio Amateur 1995 Seventy Two Edition

[2] American Radio Relay Langue-1996- The ARRL Handbook CD Version 1.0

[3] American Radio Relay Langue-2000- The ARRL Handbook CD Version 4.0

[4] Bowick, Chris -1982- RF Circuit Design 1st edition Fourth printing 1987

[5] Carr, Joseph J. -2001- Secrets of RF Circuit Design Third Edition McGraw-Hill

[6] Davis, W. Alan (University of Texas at Arlington), Krishna Agarwal (Raytheon Systems Company)-2001- Radio Frequency Circuit Design John Wiley & Sons, Inc.

[7] Everard, Jeremy (University of York, UK) -2001- Fundamentals of RF Circuit Design with Low Noise Oscillators John Wiley & Sons, Ltd.

[8] Ferris, Clifford D. (University of Wyoming) -1995- Elements of Electronic Design by West Publishing Company

[9] Frerking, Marvin E. -1978- Crystal Oscillator Design and Temperature Compensation by Litton Educational Publishing, Inc.

[10] Hejhall Roy, Applications Engineering- January,2002 – MC 1496 Balanced Modulator Publication Order Number: AN531/D

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