SUBHARMONIC IF RECEIVERS

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This paper discusses a class of receivers that use a harmonic of the BFO as the local oscillator in a single conversion superhet receiver. Subharmonic IF receivers retain many of the advantages of direct conversion: reduced internally generated spurious responses; simple CW transmit capability; absolute frequency readout; and a single LO to stabilize. They overcome some of the inherent problems of direct conversion by having a band limited IF amplifier with gain, and no local oscillators operating on the received "zero-beat" frequency. Subharmonic IF receivers are particularly attractive for multi-band recievers in which the desired operating bands have a common submultiple, and for high performance CW radar or transponder applications.

INTRODUCTION

Figure 1 is the block diagram of a single conversion superheterodyne receiver with a linear "product detector" for demodulation of the received signals. The product detector is normally associated with SSB and CW signals, but with appropriate signal processing and in-phase and quadrature mixers, it can demodulate any band-limited modulation. The only variation of figure 1 from conventional superhet receivers is that the local oscillator signal is obtained by frequency multiplying the BFO signal.

If F_{if} is the frequency of the BFO signal, N is the multiple, and F_{rf} is the desired signal frequency, then

$$F_{rf} = F_{if}(N \pm 1)$$

The + and - signs give the desired signal and image frequencies. Either the + or - signal may be used, with a few caveats to be discussed later.

As in conventional single conversion superhets, the image is separated from the desired signal by twice the IF. It is relatively easy to remove the image by filtering, for values of N up to about 10. With more care, acceptable image rejection may be achieved with N much greater than 10.

As an example, a Subharmonic IF receiver for 28 MHz is shown in figure 2. The IF is 7 MHz, and N is 3, for an LO frequency of 21 MHz. The image frequency is 14 MHz. As the BFO tunes from 7.0 to 7.1 MHz, the LO tunes from 21.0 to 21.3 MHz, the desired input signal tunes from 28.0 to 28.4 MHz, and the image tunes from 14.0

to 14.2 MHz. Since the 21 MHz LO is subtracted from the 28 MHz RF signal, a USB signal at 28 MHz appears as a USB signal at the 7 MHz IF. The 14 MHz signal is subtracted from the 21 MHz LO, so a 14 MHz USB signal in inverted, and becomes a 7 MHz LSB signal.

Figure 3 is a four band receiver covering 7, 14, 21 and 28 MHz. The only additions to the basic 7 MHz direct conversion receiver are X2 and X3 multipliers, a mixer, and RF filter-preamps for the 14, 21 and 28 MHz bands.

Until recently, a disadvantage of the "direct conversion" tunable IF was the lack of opposite sideband rejection. With modern components and engineering, it is now entirely practical to build single sideband direct conversion IF receivers with excellent performance [1,2,3]. For many applications, however, the extra complication of an image reject IF is not needed. The stark simplicity of a receiver consisting of a pair of mixers, a narrow band IF amplifier, an audio amplifier, a single LO and a frequency multiplier is most attractive--especially to a microwave enthusiast with a well stocked junk box.

One of the reasons that bad superhet receivers work surprisingly well is that none of the internally generated signals are on the received signal frequency. Direct conversion receivers must be carefully engineered to work well, since the LO is on the received "zero beat" frequency. Subharmonic IF receivers do not intentionally have any internally generated signals on the received signal frequency, but the undesired N+1 or N-1 harmonic is on the signal frequency. Direct conversion type problems may be avoided by carefully shielding the BFO and IF, and using a clean frequency multiplier with good rejection of the undesired signal frequency harmonic.

There are two modes that should be avoided in designing a Subharmonic IF receiver: the $F_{rf} = F_{if}$ case with N=2, and the $F_{rf} = 2F_{if}$ case with N=1. The only problem with the $F_{rf} = F_{if}$ case is that subtracting the RF signal from the doubled signal inverts the RF signal at the same frequency IF. In other words, a 7 MHz LSB signal at the RF port becomes a 7 MHz USB signal at the IF. If an image reject IF is used, the opposite sideband suppression is limited by the RF to IF isolation of the mixer, since signals leaking through the mixer will not be inverted. This is not a problem at low frequencies, where mixer isolation is easy to obtain, but at higher frequencies, mixer leakage may limit the opposite sideband suppression to 20 dB or less. For the $F_{rf} = F_{if}$ case, it is much easier to dispense with the first mixer entirely, and just use the IF as a direct conversion receiver.

A more serious problem occurs when $F_{rf} = 2F_{if}$, with N=1. Signals at the RF frequency are converted to the IF "right-side-up" by subtracting the LO frequency, and converted to the same IF inverted by subtracting the RF frequency from 3 times the LO frequency. The 3LO frequency is generated inside the mixer, and the inverted signals from typical mixers will only be about 13 dB below the desired right-side-up signals. A subharmonic IF receiver with $F_{rf} = 2F_{if}$, N=1, and an image reject IF, will only have about 13 dB of opposite sideband rejection. This problem may be avoided by building the receiver for $F_{rf} = 2F_{if}$ with N=3 instead of 1.

The receivers in figures 2 and 3 were built and tested to explore the possibilities and peculiarities of Subharmonic IF receivers. The motivation for studying this class of receivers was not to built a new HF receiver. Figure 4 shows a microwave Subharmonic IF receiver and CW transmitter, with multiplier numbers for all of the amateur bands from 2304 through 24192 MHz. Note that a single LO provides all of the frequencies needed for receiving and transmitting on all of the bands and that all of the circuitry to the left of the dotted line is the same for all bands. Figure 5 shows a complete modular 2304 through 24192 MHz CW transceiver, with various blocks assembled in different combinations to operate on the different bands. Note the extensive re-use of the X2, X3 and X5 multiplier blocks on the various bands. Reconfiguring the system is easy if each block has SMA input and output connectors, and a standard DC connector.

This is the microwave radio version of LEGOs. Unlike many other simple schemes for putting a signal on the higher bands, this one is EME capable, by using the appropriate preamp, power amp, and antenna. The single LO simplifies frequency stability engineering, and eliminates the multiple LO birdies that plague typical multiband microwave stations.

Subharmonic IF receivers are also particularly suitable for CW Doppler radar and transponder telemetry systems. The transmit frequency multiplier chain, amplifiers, and antenna may all be separate and isolated from the corresponding receiver components, while still maintaining coherence.

The Subharmonic IF receiver is a promising hybrid topology, offering many of the advantages of superhet and direct conversion techniques.

REFERENCES

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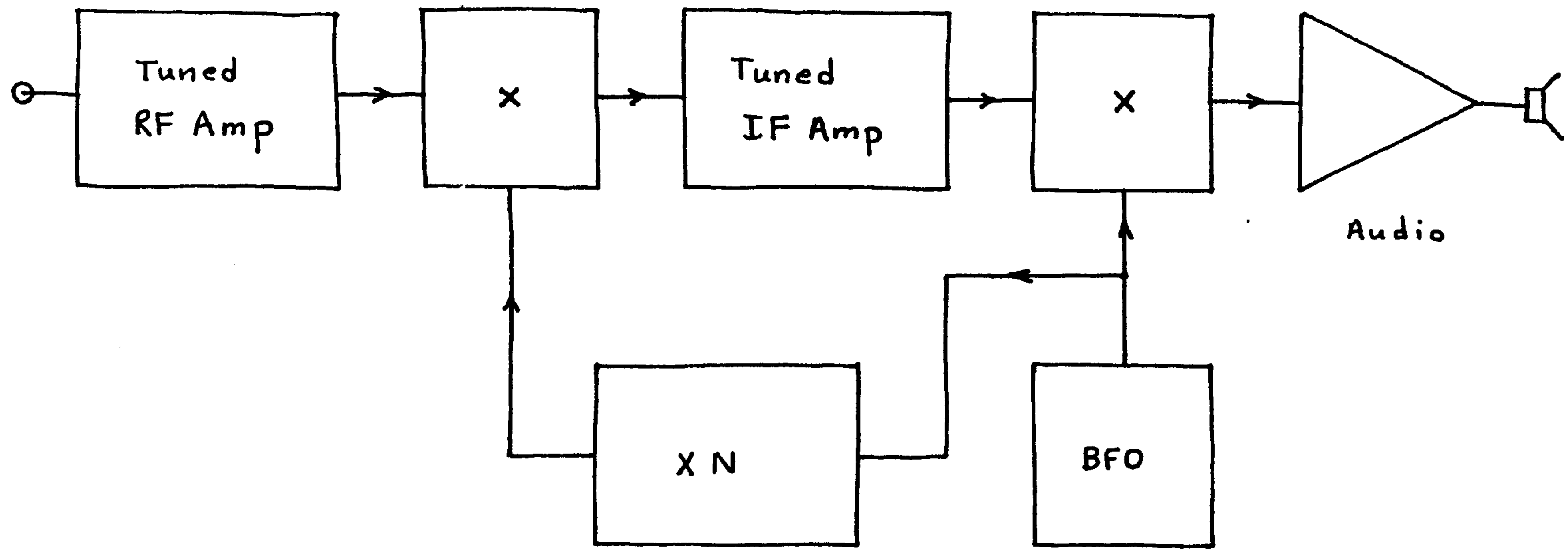
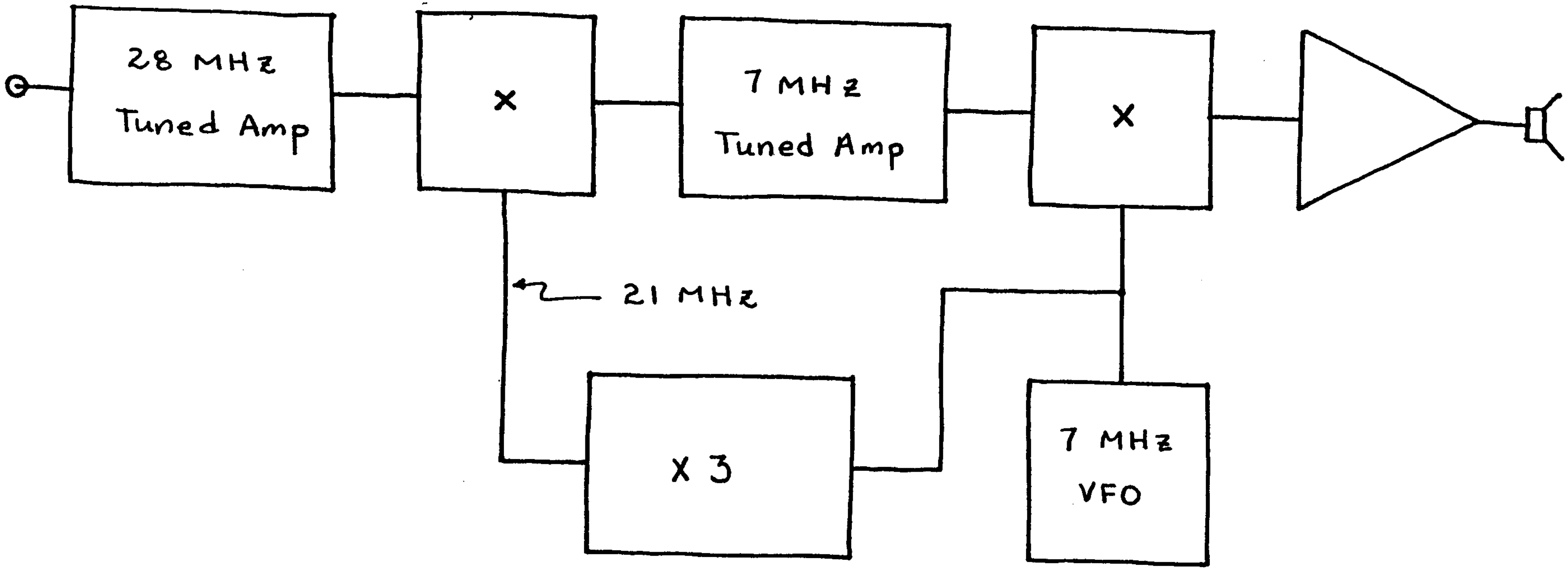


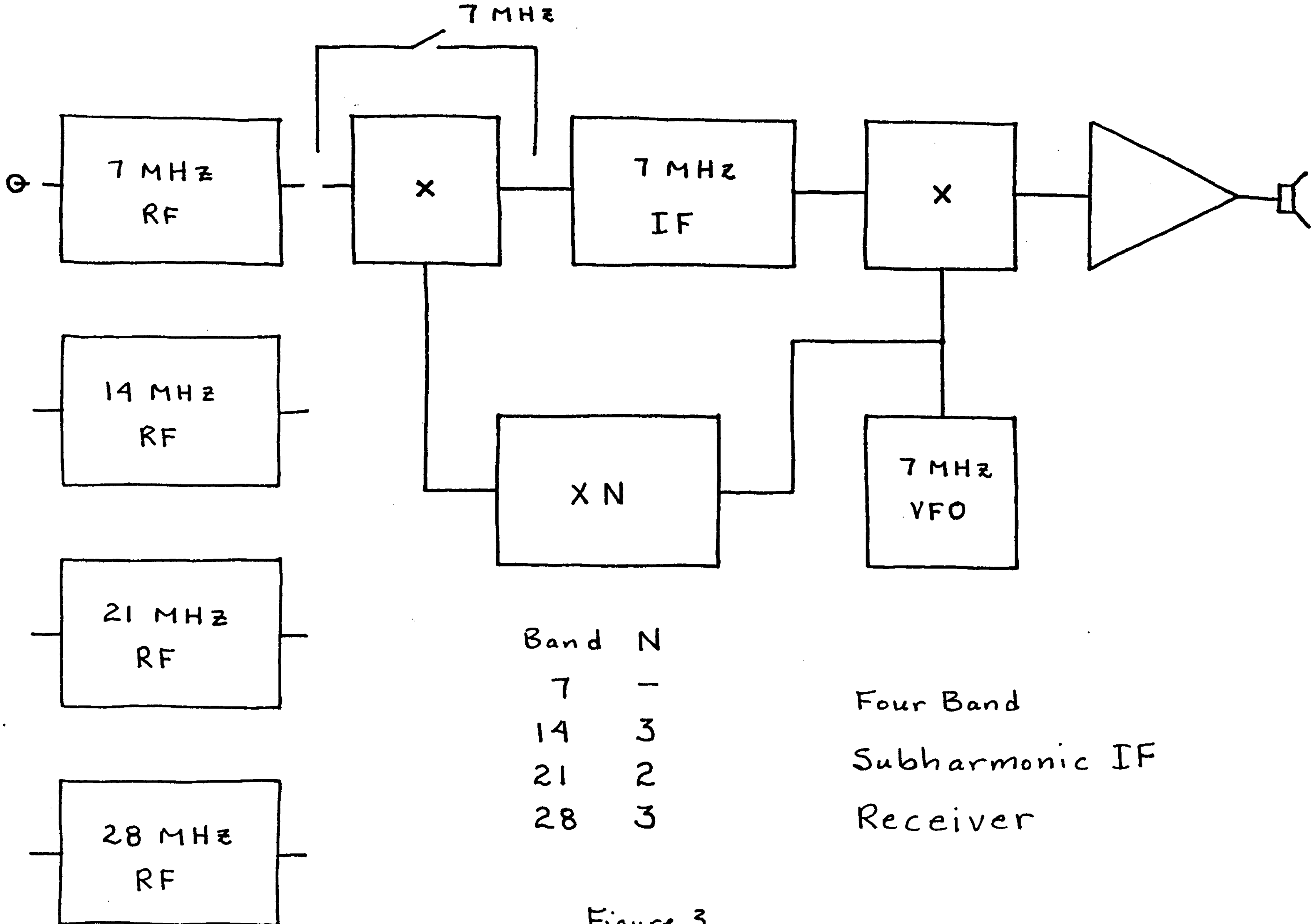
Subharmonic IF Receiver

Figure 1



28 MHz Subharmonic IF Receiver

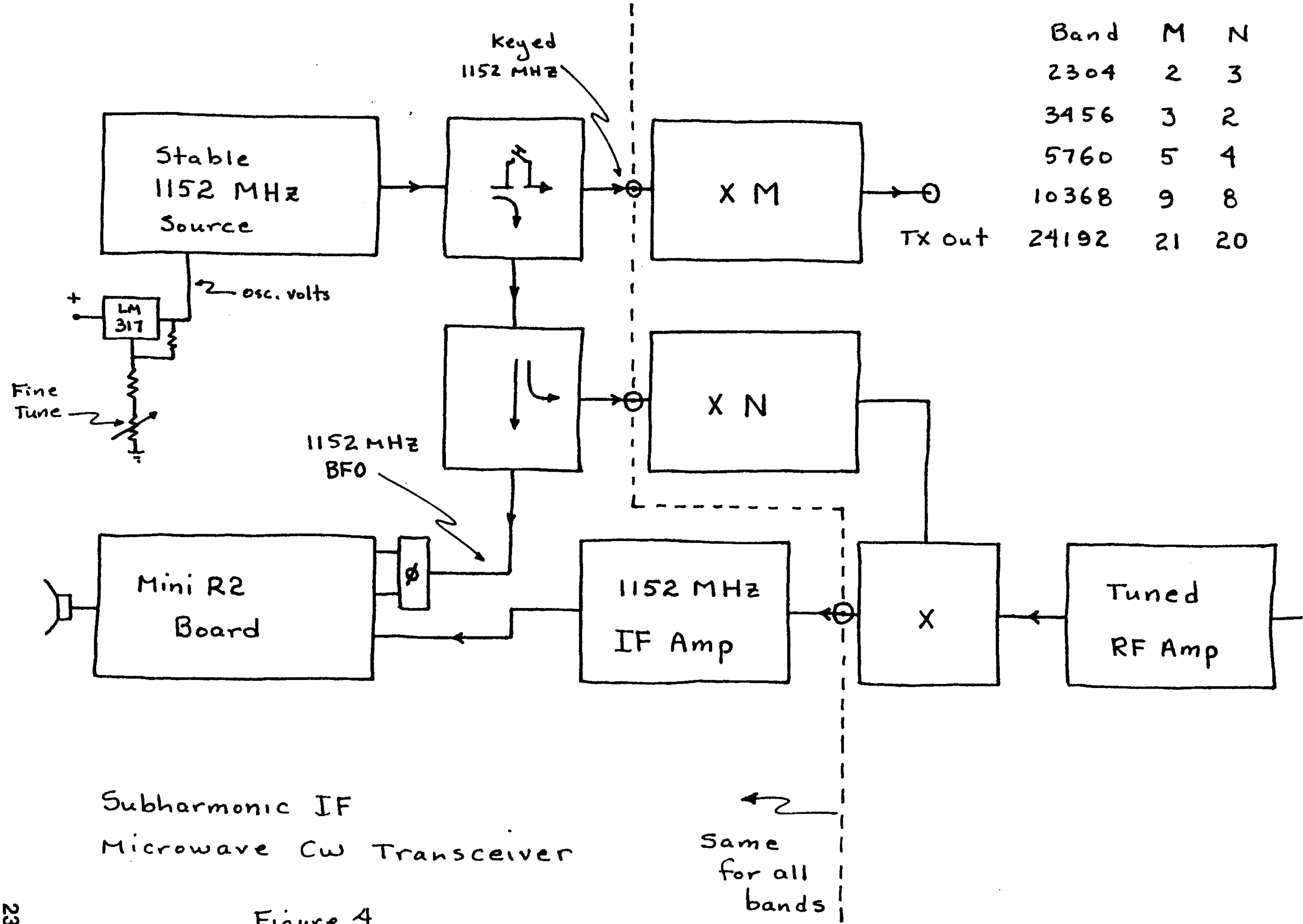
Figure 2



Band	N
7	—
14	3
21	2
28	3

Four Band
Subharmonic IF
Receiver

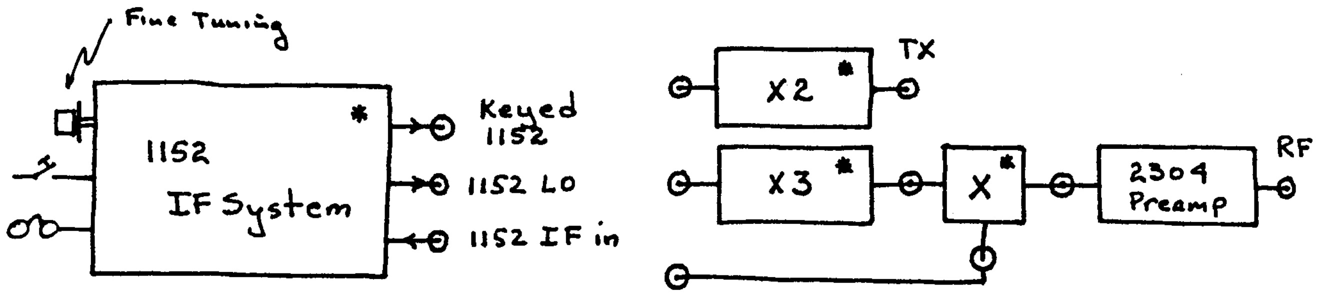
Figure 3



Band	M	N
2304	2	3
3456	3	2
5760	5	4
10368	9	8
24192	21	20

Subharmonic IF
Microwave CW Transceiver

Figure 4



Subharmonic IF Microwave Transceive System.

* Blocks used on more than one band.

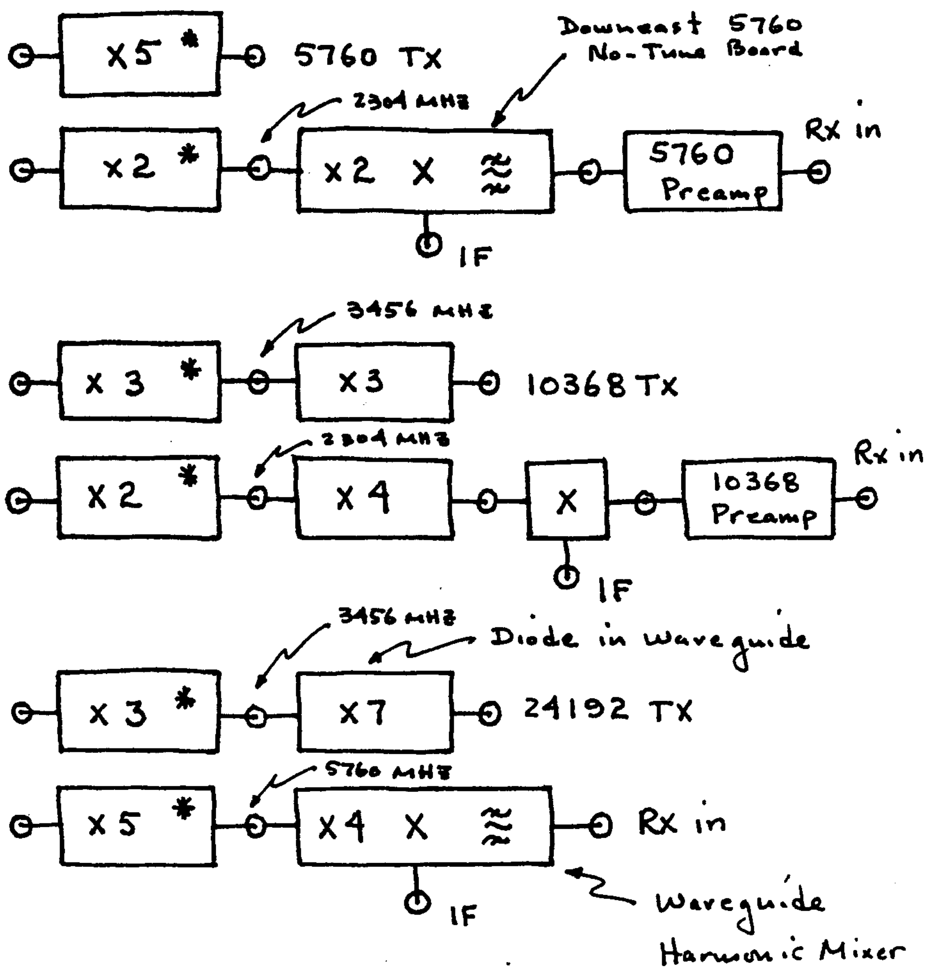


Figure 5