

Ultra Narrow Band Analog Voice Transmission

Harold. R. Walker
Pegasus Data Systems
pegasusdat@aol.com

Key Words: Voice Transmission; UNB; Ultra Narrow Band; Analog Transmission; Audio.

Abstract:

Ultra Narrow Band modulation can be used to transmit analog voice or other information in an analog format at rates up to several hundred kilohertz with an RF transmission bandwidth of 1 Hz. No audio Codec is required. The performance of UNB for voice transmission has been shown to be superior to AM or narrow band FM. The method has a much better perceptible audio signal to noise ratio at low received SNR levels than any competing voice transmission method, despite the very narrow transmission bandwidth. Noise free audio is obtained with the SNR as low as 3.5 dB, and intelligible audio as low as 1.5 dB.

The method offers near instant change from digital to audio mode. Schematics are given to enable others wishing to duplicate these tests with minimum effort.

Ultra Narrow Band modulation is an unusual modulation method that appears to violate all of the commonly accepted rules of radio communications, without actually doing so, since it has; 1) A very broad 'Nyquist bandwidth', which is much greater than, and is not related to, the data rate, 2) A 'Transmission Bandwidth' 1 Hz wide, which is not related to bit rate, and 3) A receiver 'Noise Bandwidth', which is not related to either the 'Nyquist', or the 'Transmission' bandwidth. Despite the 1 Hz transmission bandwidth, it does meet the requirements of Shannon's channel capacity theorem, since the Nyquist bandwidth is not the transmission bandwidth, but is equal to the IF and is much larger than the bit period.

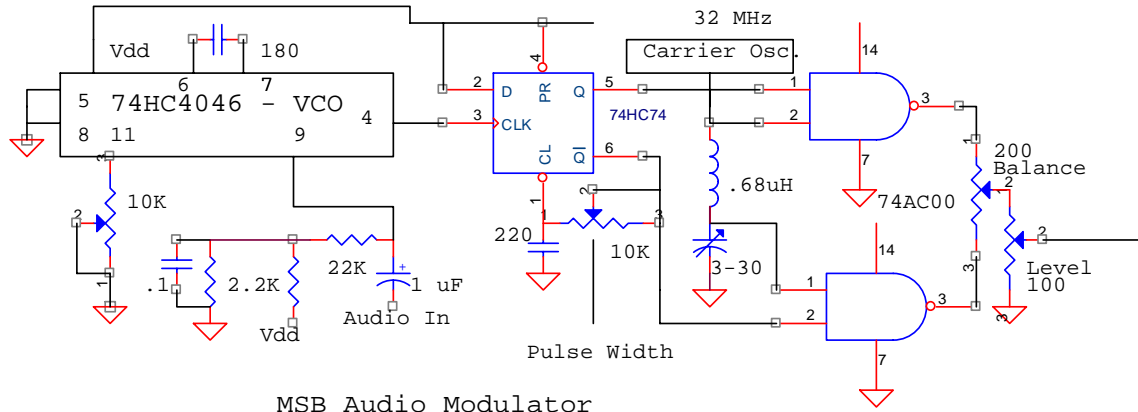
In the past, UNB has been used exclusively for digital data transmission in a 1 Hz 'transmission bandwidth'. Digital data rates as high as 10 Mb/s have been achieved using a 60 MHz IF. By transmitting a 0101010101

pattern at a varying data rate, the varying data rate can be detected as an analog signal. For example, a sine wave, at frequencies over 200 kHz, or a voice transmission.

Figure 1 shows the schematic of the UNB analog modulator. In Figure 1, the 74HC4046 VCO generates a square wave with the frequency varied by the audio input level. Approximately 1 Volt audio peak to peak is used. The square wave rising leading edge driving a 74HC74 causes a one shot pulse to be generated, which has a variable width. The time on each phase varies, having as little as 2 percent of the modulation cycle period on the shortest phase switched time, up to about 50% of the square wave period. The positive and negative outputs switch the carrier phase by 120 degrees (3PSK modulation, Ref. 2). The amount of the phase shift is variable with the .68 microHenry inductor and trimmer capacitor. The gates switch the carrier phases to transmit only one phase or the other. Other circuitry can be found in Ref. 2.

The highest audio frequency using this circuit with the components shown is far above normal voice requirements. The values and frequencies used here were those using existing RF boards, used to avoid building completely new transmitter and receiver hardware to obtain the necessary information. The original hardware was for digital data. A redesign should be tailored to the intended application.

A carrier (or IF) as low as 4 MHz would probably yield acceptable voice communications comparable to telephone quality audio. The RF components would have to be scaled as required for different frequencies.



MSB Audio Modulator

Figure 1. Schematic of the UNB analog audio modulator using 3PSK. (90/120 degree phase change).

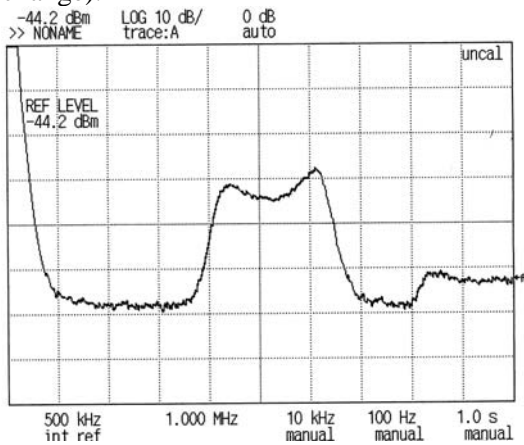


Figure 2. The output of the 74HC4046 VCO responding to a sine wave input. (Pins 3, 4). Approximately 500 kHz center frequency deviated +/-100 kHz.

A simple monostable pulse generator will detect the varying frequency from the modulator. The circuit of Figure 3 attached to pin 5 of the 74HC74 monostable chip, or the detector output, has the detected linearity shown in Fig. 4.

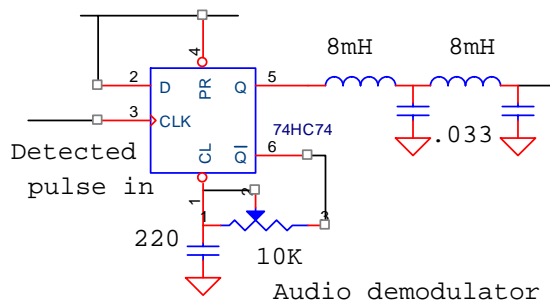


Figure 3. Audio demodulator.

The monostable multivibrator frequency to voltage conversion circuit creates pulses from the detected RF signal. These pulses are integrated in the low pass filter to create a low frequency voice output.

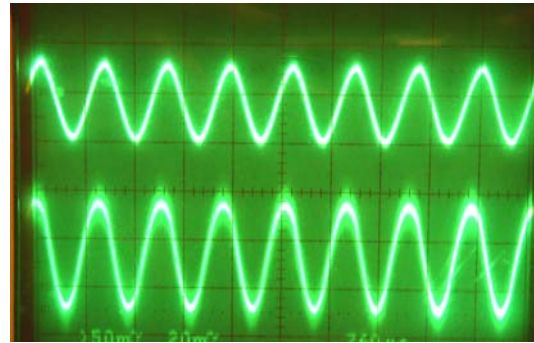


Figure 4. The 4046 modulator input is the top trace. The demodulator output is the lower trace.

Figure 2 shows the spectrum of the square wave modulation signal after being frequency modulated +/-100 kHz. The square wave is then passed to a one shot multivibrator to reduce the pulse width. This pulse width reduction reduces the sidebands prior to filtering. The sidebands can be reduced 20 dB or more by this means. Prior to being transmitted, 1 or 2 stages of zero group delay filtering should be used to meet regulatory requirements regarding out of band radiation.

Regulatory agencies may also require a separate voice identifier. The carrier can be amplitude modulated up to 85% without affecting the 3PSK phase shifted UNB carrier. (Refs. 3, 4).

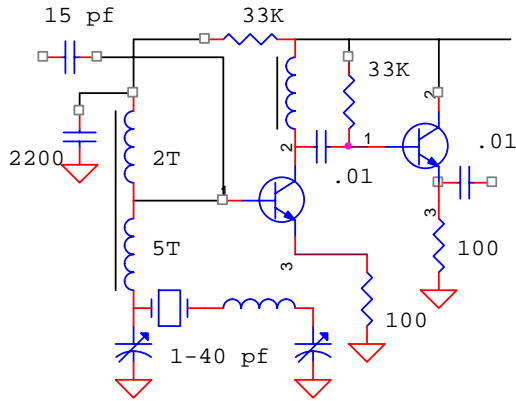


Figure 5. TRS 3rd overtone filter.

The ultra narrow band IF filters are extremely narrow in bandwidth, having a usable phase shift region of only 200-300 Hz. They are therefore subject to thermal drift and AFC means must be included in any system to compensate for this. The 3 dB noise bandwidth is approximately 500 Hz.

Reference 2 should be consulted regarding the detector circuits, filter overload, and other factors. The circuits using the NE602 as a phase detector were used for this experiment. Additional receiver filter stages were used to prevent filter BW overload (Ref 2, Ch 5) while making the SNR measurements. The SA636 limiter was used.



Figure 6, Recovered information spikes with no modulation deviation. Taken from the IF detector output after multiple stages of UNB zero group delay filtering. The spikes in Figure 6 are demodulated with the frequency to voltage

converter of Fig.3 to produce the sine wave seen in Figure 4.

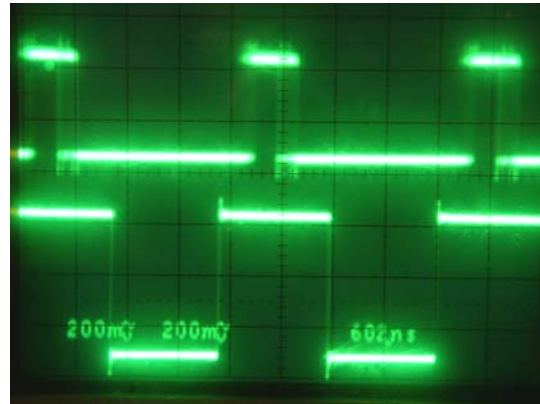


Figure 7. Signal out to audio detector after clipping with 1 dB SNR using a CW interference source.

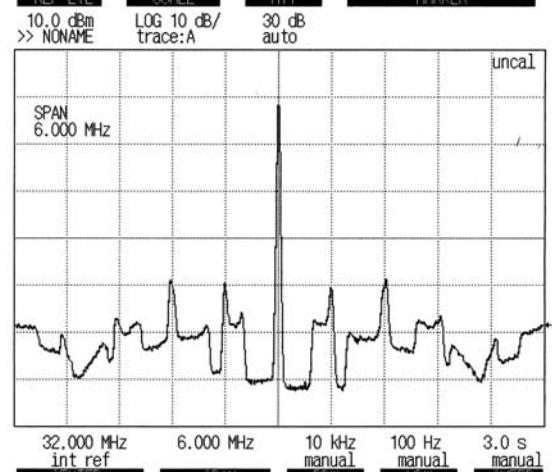


Figure 8. RF Spectrum after 3PSK modulation prior to any bandpass filtering to reduce sidebands.

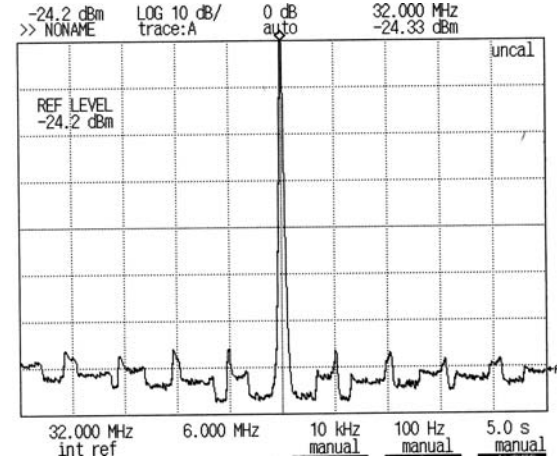


Figure 9 shows the transmission spectrum after 2 stages of 3rd overtone TRS filtering. This is adequate for most regulatory requirements. With

a 3 dB RBW on the analyzer, the sidebands would measure 10 dB lower.

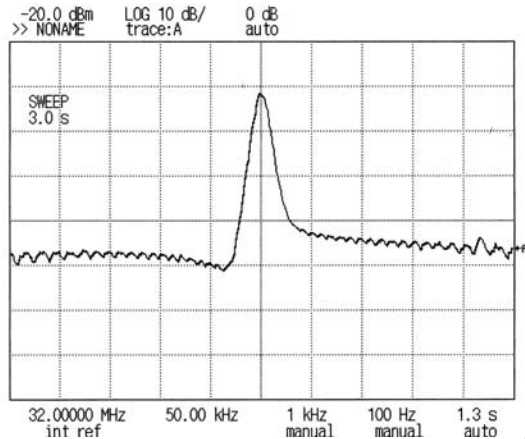


Figure 10. Swept bandpass of the TRS 3rd overtone UNB filter in the receiver. The 3dB noise BW is 500 Hz.

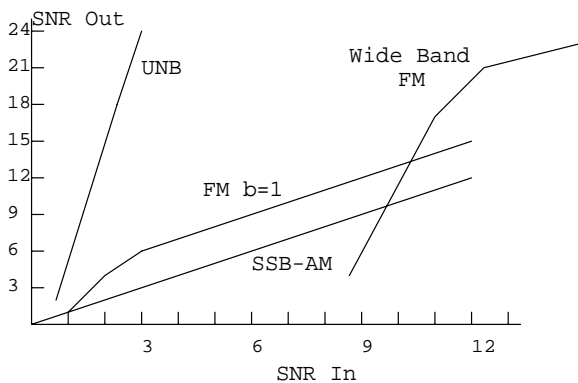


Figure 11 shows the approximate SNR required to obtain a 1/1 SNR and the noise reduction when the SNR exceeds 0 dB. The curves show the measured SNR improvement compared to that for normal SSB-AM and Narrow Band FM.

The signal output of Figure 1 is added to an AWGN noise generator to obtain the SNR measurements. The swept bandpass of the receiver IF filter is seen in Figure 10. Any noise or sidebands outside this narrow bandpass has no effect. Only low frequency noise - below 1 kHz, or long burst periods, can pass the UNB filter (Ref. 6, Sect 7.5).

Signal and noise power measurements were made with an HP3403C True RMS Meter and with an Analog Devices AD8306 Unit, which is accurate to ½ dB. A NoiseCom AWGN source was used. The procedure used is described in Ref. 2, Chapter 14. An LSI 812A equivalent to HP 4934A/4935A was also available.

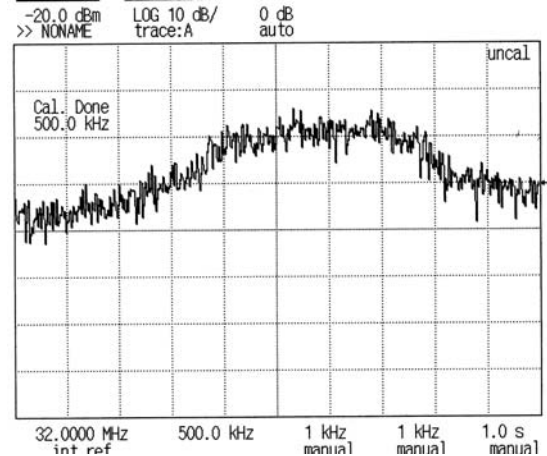


Figure 12. Signal plus white Gaussian noise when the SNR is 1 dB. The audio is still acceptable. The noise level is far above the sidebands of Figure 9.

Summary: A Nyquist bandwidth of 32 MHz, a transmission bandwidth of 1 Hz and a receiver noise bandwidth of 500 Hz have been demonstrated. Because of the very low SNR required and the very narrow noise BW, the method offers a considerable improvement in range for a given signal power. The performance of UNB for voice transmission has been shown to be far superior to AM or narrow band FM.

References:

- (1) US Pat. 7,424,065 H.R. Walker, "Apparatus and Method for an Ultra Narrow Band Wireless Communications Method". 9/9/2008.
- (2) "Ultra Narrow Band Textbook", which is available for free download from www.VMSK.org. (Over 75 UNB references are included in the 210 page text).
- (3) Chenhao Qi and Lenan Wu, "Hybrid Modulation for AM Broadcasting". The 3rd International Conference on Natural Computation (ICNC'07). Hainan, China. August 2007.
- (4) J.C. Pliatsikas, C.S. Koukourlis, J.N. Sahalos, "On the Combining of Amplitude and Phase Modulation in the same Signal". IEEE Transactions on Broadcasting, June 2005.
- (6) Taub and Schilling, "Principles of Communications Systems", McGraw Hill. 1986. (Sects. 7.5, 10.1).
- (7) Chenhao Qi and Lenan Wu. Comments on "On the combining of the amplitude and phase modulation in the same signal". IEEE Transactions on Broadcasting, vol. 54, no.3, Sept. 2008, p.489