Frequency Modulation and Demodulation Technique using Anadigm Designer2 and FPAA QUAD APEX V2 BOARD

Soumyashree Mangaraj
Dr. Aruna Tripathy
Dept. of IEE, College of Engineering & Technology, Bhubaneswar,Odisha, India

Abstract:

Abstract– Frequency modulation and demodulation (MODEM) has been implemented by numerous techniques over the past couple of decades. This paper focuses on the implementation on a recently available platform called FPAA (Field Programmable Analogue Arrays). For a sinusoidal carrier signal the frequency modulation (FM) is performed by the indirect method and subsequent demodulation is achieved by envelope detector. The functional blocks of the MODEM are implemented by employing available configurable analogue modules (CAMs) of the FPAAs AN231E04 from Anadigm Designer2. The proposed FM MODEM consists of different CAM modules like multiplier, differentiator, a sine-wave carrier oscillator, signal generator, gain limiter, rectifier filter, LPF and inverted gain stage components. The FPAA board can operate with supply voltage of +3V and +5V. The contribution of the paper is the hardware realization of an NBFM MODEM on an FPAA board which is a simulation as well as hardware platform. The similarity of simulation and experimental results using FPAA QUAD APEX V2 BOARD, DSO 70MHz shows a good match with the theoretical results.

Keywords:

Frequency modulation, Anadigm Designer2, FPAA AN231E04, FPAA QUAD APEX V2.

I. INTRODUCTION

Edwin Howard Armstrong (1890–1954) was an American electrical engineer who invented wideband frequency modulation radio. FM MODEM has been implemented by numerous techniques over the past couple of decades. This paper is an attempt to realize an FM MODEM on a recently available platform called FPAA, which is a simulation as well as hardware platform. The FPAA integrated circuits (ICs) are flexible, economical and fast prototyping solutions for the design of complex analogue systems [1], [2].

The proposed FM MODEM is implemented using FPAA AN231E04 is discussed in Section III. Results obtained on the hardware platform are illustrated in Section IV, followed by conclusion in Section V.

II. SYSTEM MODEL

The NBFM using Armstrong's Indirect Method is analyzed in this section, which establishes the various functional blocks to be implemented on the FPAA platform.

Angle modulation is obtained by varying the frequency or phase of the carrier signal in accordance with the modulating signal.

The carrier's instantaneous frequency deviation varies in proportion to the instantaneous amplitude of the modulating signal in FM.

To generate a frequency modulated signal, the frequency of the radio carrier is changed in line with the amplitude of the incoming audio signal.

Frequency deviation is an important criterion in frequency modulation technique; it is the amount by which the radio frequency carrier signal moves up and down with the audio signal. It is normally quoted as the number of kilohertz deviation.

It is narrow band FM (NBFM) that is typically used for two-way radio communication applications.

We have implemented a NBFM MODEM using FPAA QUAD APEX V2 BOARD is represented as,

$$S_{FM}(t) = A_c \sin(\omega_c t + \beta cos\omega_m t)$$
$$= A_c \sin[2\pi f_c t + \beta\cos(2\pi f_m t)] \quad (1)$$

where,
$S_{FM}(t)$ = instantaneous voltage of the FM wave
A_c = peak amplitude of the carrier
f_c = frequency of the carrier
f_m = frequency of the modulating signal
β = FM modulation index

Modulation Index: The modulation index for an FM signal is defined as the ratio of the maximum frequency deviation to the modulating signal frequency.

$$\beta = \frac{\delta}{f_m} \quad (2)$$

Where β = modulation index of FM
δ = maximum frequency deviation of the carrier caused by the amplitude of the modulating signal
f_m = frequency of the modulating signal

The FM wave given by Eq. (1) is expanded as,

$$S_{FM}(t) = A_c \sin\left[\omega_c t + \beta\int_0^t m(\lambda)d\lambda\right]$$
$$= A_c \sin[2\pi f_c t + \beta\cos(2\pi f_m t)] \quad (3)$$

for a sinusoidal modulating signal.

For NBFM expressed in Eq. (1), the modulation index (β) must be small compared to one radian.
Further expansion of Eq. (1) gives,

$$S_{FM}(t) = A_c \sin(2\pi f_c t)\cos[\beta\cos(2\pi f_m t)] + A_c \cos(2\pi f_c t) sin[\beta\cos(2\pi f_m t)] \quad (4)$$

Then under the condition that the modulation index (β) is small compared to one radian, we may use the following two approximations for all times t,
$\cos[\beta\cos(2\pi f_m t)] \approx 1$
and
$sin[\beta\cos(2\pi f_m t)] \approx \beta\cos(2\pi f_m t) \quad (5)$

Accordingly, Eq. (4) simplifies to

$$S_{FM}(t) = A_c \sin(2\pi f_c t) + \beta A_c \cos(2\pi f_c t)\cos(2\pi f_m t) \quad (6)$$

The NBFM using Armstrong's Indirect Method is analyzed in this section, which establishes the various fundamental blocks to be implemented on the FPAA platform.

III. PROPOSED MODEL FOR NBFM MODEM USING FPAA

The proposed block for an FM modulator's schematic corresponding to Eq. (6) is shown in Fig.1.

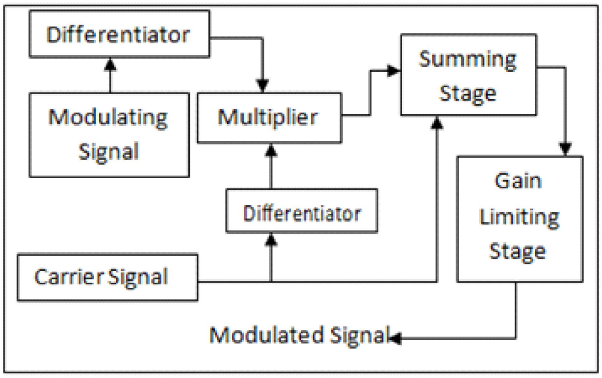

Fig.1. Proposed Structure for generation of NBFM signal according to Eq. (6)

In the proposed structure both the modulating signal $\mathbf{m(t)} = \boldsymbol{A_m \sin(2\pi f_m t)}$ and carrier signal $\mathbf{c(t)} = \mathbf{A_c \sin(2\pi f_c t)}$ are differentiated and fed to the multiplier. The multiplier output and the carrier signal are fed to the summing stage. The output voltage of the summing stage is limited to 2V peak-to-peak by using a gain limiting stage.

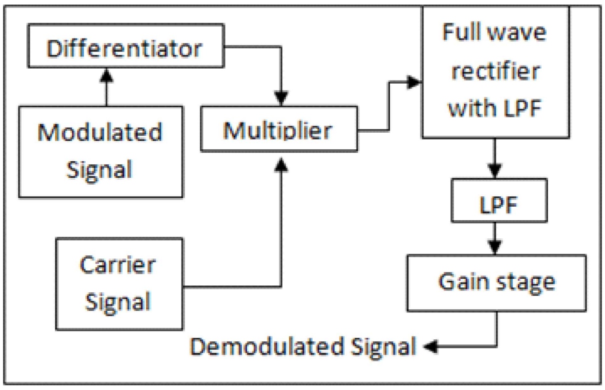

Fig.2. Proposed Structure for demodulation of NBFM signal

The Proposed demodulation of the NBFM signal is achieved by passing through a differentiator and its output along with the carrier signal is passed to a multiplier. The multiplier output is fed to a full-wave rectifier with LPF module which performs the envelope detection.

The following illustrates the demodulation operation,

$$\frac{d}{dt}S_{FM}(t) = \frac{d}{dt}\left[A_c \sin(\omega_c t + \beta \int_0^t m(\lambda)d\lambda)\right]$$

$$= A_c \cos[\omega_c t + \beta \int_0^t m(\lambda)d\lambda] \,.\, [\omega_c + \beta m(t)]$$

$$=A_c\, [\cos \omega_c t . \cos\left(\beta \textstyle\int_0^t m(\lambda)d\lambda\right) -$$

$$\sin \omega_c t . \sin\,(\beta \textstyle\int_0^t m(\lambda)d\lambda)].[\omega_c + \beta m(t)] \quad (7)$$

Use of Eq. (5) for small values of β reduces Eq. (7) to,

$$\frac{d}{dt}S_{FM}(t) =$$

$$A_c\, [\cos \omega_c t - \sin \omega_c t . \beta \textstyle\int_0^t m(\lambda)d\lambda)] \,.\, [\omega_c + \beta m(t)] \quad (8)$$

Multiplying Eq. (8) by the carrier itself, we obtain

$$A_c\,[\cos \omega_c t - \sin \omega_c t . \beta \int_0^t m(\lambda)d\lambda)][\omega_c + \beta m(t)] \cos \omega_c t$$

$$= A_c\,[\cos^2 \omega_c t - \sin \omega_c t . \cos \omega_c t\;\; \beta \int_0^t m(\lambda)d\lambda)]\,[\omega_c + \beta m(t)]$$

$$= A_c \omega_c \cos^2 \omega_c t + \beta m(t) A_c \cos^2 \omega_c t -$$

$$\omega_c\,(\sin 2\omega_c t)\; \beta \textstyle\int_0^t m(\lambda)d\lambda -$$

$$\beta^2 m(t)(\sin 2\omega_c t) \textstyle\int_0^t m(\lambda)d\lambda \quad (9)$$

We immediately note from Eq. (9) that, the use of an LPF having a cut off frequency of f_m which is equal to the maximum frequency content of the message signal, will remove all double frequency terms as well as the carrier frequency term. The output of this filter, hence becomes proportional to (the second term of $\beta m(t) A_c \cos^2 \omega_c t$), $\beta \frac{A_c}{2} m(t)$.

This completes the demodulation process. The LPF is implemented as an envelope detector.

A. FPAA configurations for Frequency Modulation in ANADIGM DESIGNER2

This section is focused on the key qualities and elements of FPAA device that will be used for frequency modulation.

The functional circuits of voltage-mode frequency modulator based on FPAA AN231E04 are presented.

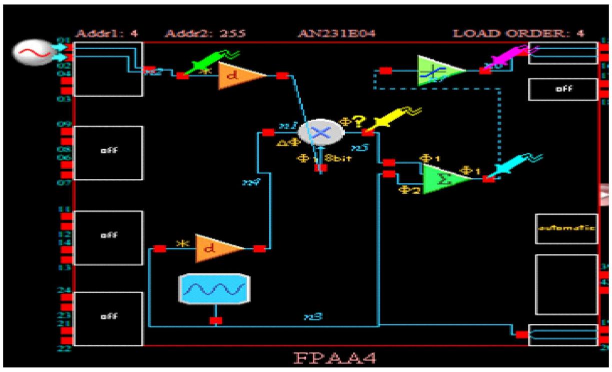

Fig.3. FPAA configuration for frequency modulator using indirect method for generating a NBFM wave

FPAA configuration of frequency modulator using indirect method: Armstrong modulator based on AN231E04 is shown in Fig.3. The differential input signal is connected to the FPAA3 input cell 1 (pins 01 and 02). In input mode, the input signal is routed directly through the cell. The modulated carrier signal is obtained from the output cell 5(pins 15 and 16) of FPAA4. The carrier sinusoidal signal is generated by internal oscillator, whose output is connected to node *n4,* the multiplier CAM. The oscillator is realized by using *Oscillator Sine* CAM. The oscillating frequency is taken as 250kHz and the amplitude is equal to 1*V*. A Gain Limiter CAM with gain value 2V is used at the summer output to limit the amplitude to ±1V.

B. FPAA configurations for Frequency Demodulation in ANADIGM DESIGNER2

Frequency demodulator circuit is made in Anadigm with FPAA AN231E04 is shown in Fig.4.

Fig.4. FPAA configuration for frequency demodulator (input is given from modulator circuit)

The bypass mode output of FPAA4 is connected to the FPAA3 input cell 1 (pins 01 and 02). In input mode, the input signal is routed directly through the cell. The modulated carrier signal is passed through a differentiator CAM with differentiation constant of 0.4. Output of the differentiator is passed through a multiplier CAM with another input the carrier signal from input cell 2 (pins 08 and 09). The multiplier output is sent to the full wave rectifier filter with cutoff frequency 50kHz. The rectified output is again passed through a low pass filter with cutoff frequency 50 kHz, quality factor 10 and gain 0.707. The filtered output is passed through the gain stage and output is taken from cell 5(pins 15 and 16) of FPAA3.

IV. EXPERIMENTAL RESULTS

The simulated input, carrier, modulated and demodulated output waveforms of the FPAA configuration *AnadigmDesigner2 simulator* are shown in Fig.5(a), (b) and (c) at a modulating frequency 50kHz and carrier frequency 250kHz.

The experimental setup for frequency modulation and demodulation with FPAA QUAD APEX V2.0 configuration on AN231E04 is shown in Fig. 7(a) and (b).

The differential input modulating signal is connected to the FPAA3 input cell 1 (pins 01 and 02) and the output modulated signal is obtained by output cell 5 (pins 15 and 16) of FPAA3. The multiplier output is connected to the *Gain Limiter* CAM which is chosen as 2. The output voltage is limited to 1V here.

The demodulator module is built in FPAA3. The input to FPAA3 is fed at IO cell1 with the output from FPAA4 IO cell5 and the demodulated output is collected from IO cell5 of FPAA3 which is connected with an inverted gain stage of gain 4.

The workability of the proposed frequency modulator of Fig. 3 and 4 is presented by the simulation results using the simulator built in *AnadigmDesigner2* and also through the experimental results from the circuit configured on prototype board. The experimental test that has been used for validating the FPAA configuration is shown in Fig. 6. The experiment is carried out using Function Generator, DSO, FPAA Quad Apex v2.0 Development Board and Anadigm software.

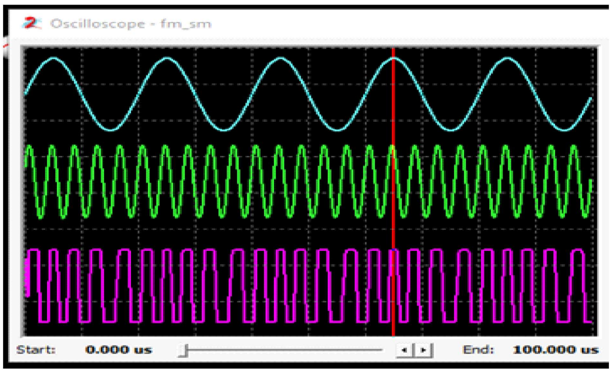

Fig.5(a). Simulated input, carrier and modulated output waveforms *in AnadigmDesigner2 simulator*

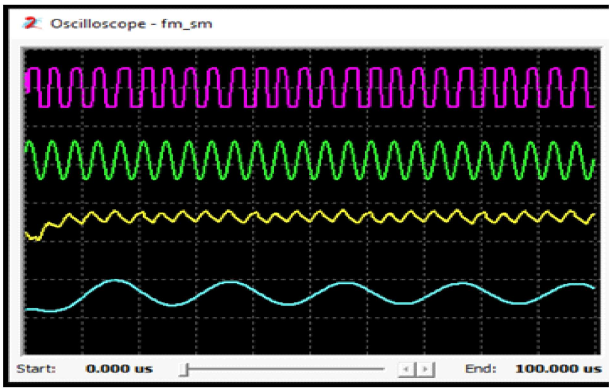

Fig.5(b). Simulated modulated carrier, carrier, rectifier output (without LPF) and demodulated output waveforms in AnadigmDesigner2 simulator

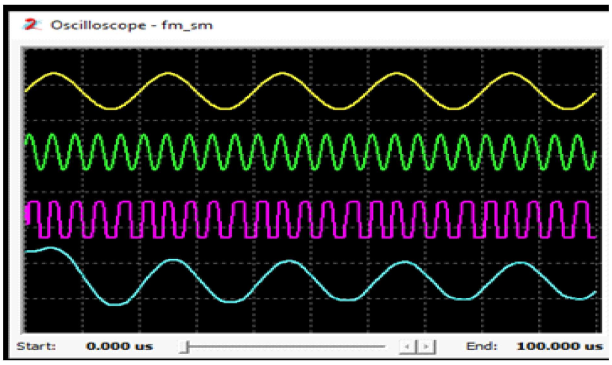

Fig.5(c). Simulated input, carrier, modulated and demodulated output waveforms *in AnadigmDesigner2 simulator*

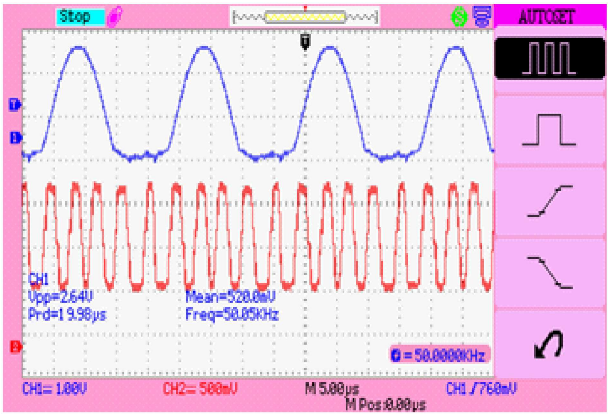

Fig.6(a). Modulated carrier signal – CH2 (pin 15 & 16 on FPAA4 AN231E04) with modulating wave – CH1 (pins 01 and 02 on FPAA4 AN231E04).

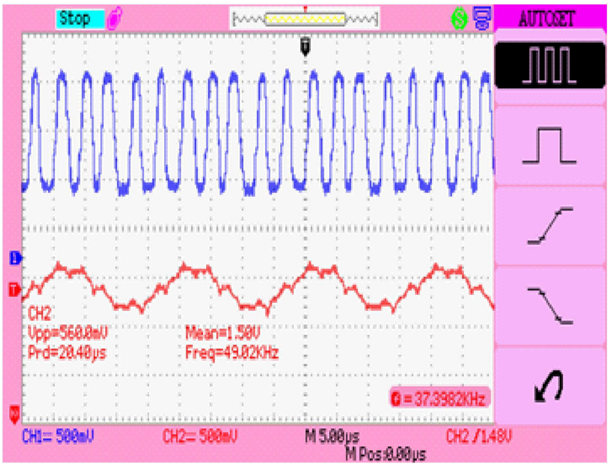

Fig.6(b). Modulated carrier signal – CH1 (pin 15 & 16 on FPAA4 AN231E04) with demodulated wave – CH2 (pins 05 and 06 on FPAA3 AN231E04).

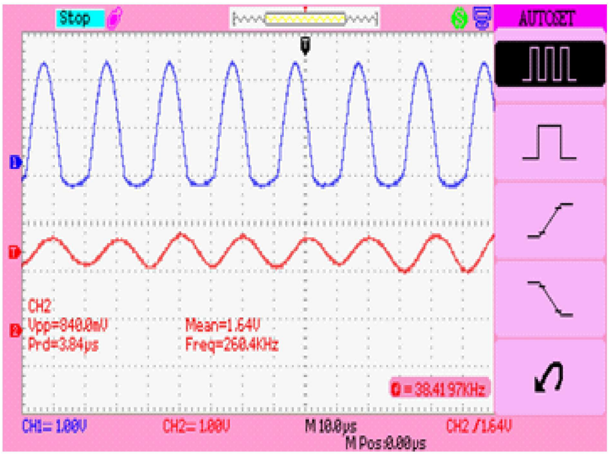

Fig.6(c). Modulating signal – CH1 (pin 01&02 on FPAA4 AN231E04) with demodulated wave – CH2 (pins 05 and 06 on FPAA3 AN231E04).

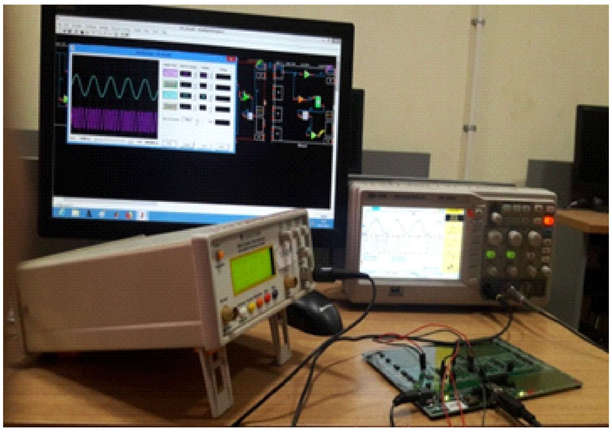

Fig.7(a). Experimental set-up for frequency modulator and demodulator

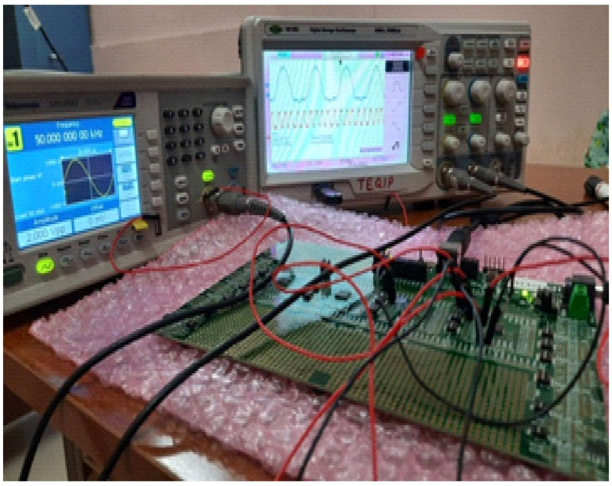

Fig.7(b). Experimental set-up for frequency modulator and demodulator

The modulating signal, modulated carrier signal and demodulated signal obtained in DSO are shown in Fig. 6. (a),(b) & (c). The original baseband signal has an amplitude of 1V (peak) and frequency of 50kHz. The carrier signal has an amplitude of 1V (peak) and frequency of 250kHz.

V. CONCLUSION

In this paper a frequency modulator using indirect method: Armstrong modulator and demodulator based on AN231E04 has been proposed. The FM MODEM module consists of multiplier, differentiator, sine-wave carrier oscillator, signal generator, gain limiter, rectifier filter and LPF and inverted gain stage components.

The Anadigm AN231E04 FPAAs has been selected for analogue signal processing. The FPAA QUAD APEX V2 board, DSO and function generator are used for hardware implementation.

The experimental and simulation waveforms, obtained at various stages of the FM-MODEM confirm the theoretical analysis.

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