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A New Digital Modulation Technique: Two Messages in One Carrier

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A new digital modulation concept and technique have been proposed in this paper. Two entirely separate digital messages shall modulate one carrier unlike traditional Digital Modulation or even unlike QAM or APSK which might open the numerous possibilities of various future applications in channel modeling or in data communication. All Simulation models are being designed over Simulink ™.

Keywords: New Digital Modulation, Two messages in one carrier, Level shifted ASK, QPSK, Combine modulation

Introduction

First digital message modulating the carrier using any of the established PSK (Phase Shift Keying) scheme. Then the Second digital message of relatively higher frequency than the first message shall modulate the carrier and first message combined using level shifted ASK (Amplitude Shift Keying). In the receiver, process shall be reversed, i.e. second message shall be recovered first then the first message. Using this unique dual modulation we can communicate two different messages in same time using one carrier (Refer Figure. 1a and Figure. 1b).

Modulation

Stage 1: Relatively lower frequency message signal (100Hz Binary Pulse for example) i.e. 'm_1' shall modulate the carrier using BPSK(or QPSK) modulation(see [1], [2]). Hence the resultant signal after first (BPSK) modulation is $M_1C=M_1(t)\cos(\omega_c t)$. $m_1(t)$ has been converted into a bipolar signal of +1v (for binary '0' level) and -1v (for binary '1' level) before BPSK modulation as usual i.e $M_1(t)$. Where ω_c is the carrier frequency and assuming carrier signal's peak magnitude is equal to 1v. (Refer Figure. 1c)

Stage 2: Then relatively higher frequency message signal (200Hz binary pulse for example) i.e. '$m_2(t)$' shall be converted into '$M_2(t)$' where $M_2(t) = m_2(t)+1$. Hence a binary level '0' will be represented as 1v level and binary level '1' shall be represented as 2v. (Refer Fig.1c)

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Stage 3: Then $M_2(t)$ shall be multiplied with M_1C which constitutes the Signal to be Transmitted (T_x) (Refer Figure 2a).

Hence $T_x= (M_1C)\ M_2(t) = M_2(t)\ M_1(t)\cos(\omega_c t)$. (Refer Fig.1a and Fig.1c)

Demodulation

Stage 1: T_x will be multiplied by the locally generated carrier in the receiver (Fig. 1b).

$$T_x\cos(\omega_c t) = M_2(t)\ M_1(t)\cos^2(\omega_c t)$$
$$=M_2(t)\ M_1(t)\ [0.5\cos(2\ \omega_c t)+0.5]$$
$$=0.5M_2(t)\ M_1(t)\ \cos(2\ \omega_c t)+\underline{0.5\ M_2(t)\ M_1(t)}$$

Stage 2: The low pass filter (LPF for m_2, refer Fig.1b) which has a higher cut off frequency just above the sum of the maximum frequencies of $m_1(t)$ and $m_2(t)$ but much less than carrier frequency, shall select the second (underlined) term of above i.e $0.5M_2(t)\ M_1(t)$. Now, as $M_1(t)$ having +1v and -1v amplitude level, squaring the LPF output (i.e $0.5\ M_2(t)\ M_1(t)$) will results simply $0.25M_2^2(t)$ which has now amplitude level of 0.25v(for binary '0' level) and 1v(for binary '1' level).

Stage 3: Now the comparator 1 (Fig.1b) or the decision making circuit shall provide the decision between binary '1' or '0' level if the amplitude of $0.25M_2^2(t)$ is greater than or less than 0.5v respectively and thus recovering the second message(Dm_2) signal accurately in the receiver (refer Fig.1b and Fig.1d).

Stage 4: Once the second message has been demodulated/recovered (Dm_2) in the receiver, performing $T_x/(Dm_2+1)$ shall recover the first

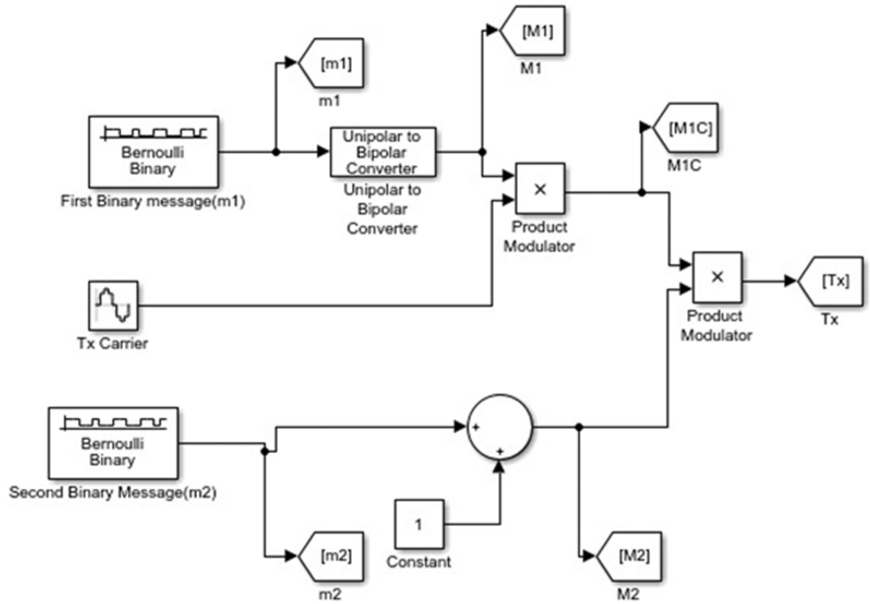

Fig. 1(a) — Schematic diagram of Two messages on One Carrier BPSK Modulator

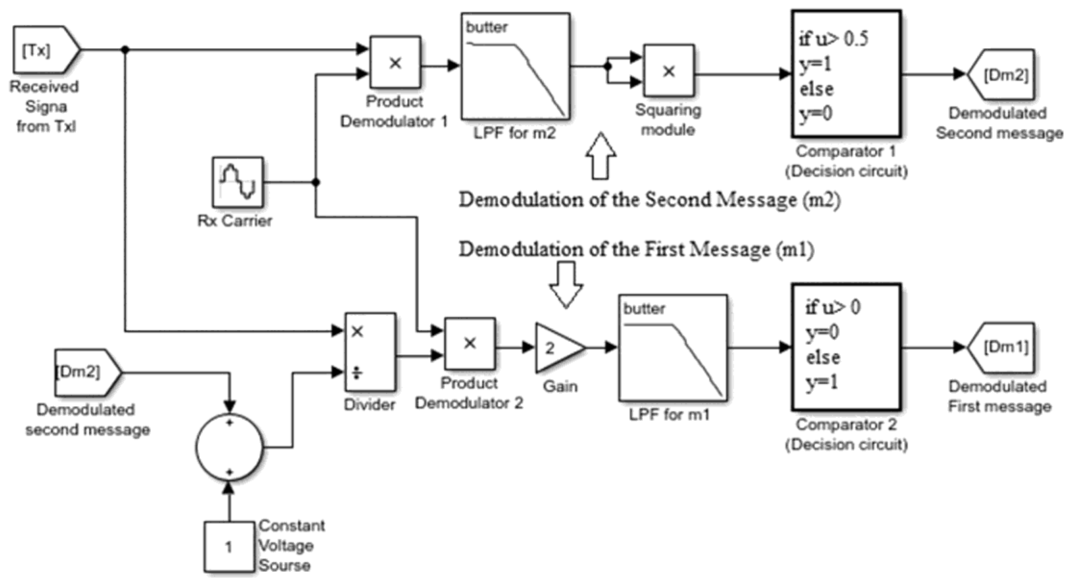

Fig. 1(b) — Schematic diagram of Two messages on One Carrier BPSK Demodulator

message signal (labelled as 'T_x/Dm_2' block in the Fig.1b) accurately as $Dm_2+1 = m_2(t)+1= M_2(t)$ (refer Fig. 1b).

Step1: $T_x/(Dm_2+1) = T_x/M_2(t)= M_1(t)\cos(\omega_c t)$

Step2: $T_x/(Dm_2+1)$ shall be multiplied with the locally generated carrier again –

$$[T_x/(Dm_2+1)]\ \cos(\omega_c t)= M_1(t)\cos^2(\omega_c t)=0.5\ M_1(t)+ 0.5\cos(2\omega_c t)$$

Now a LPF with a higher cut off frequency slightly greater than the maximum frequency of $m_1(t)$ shall select the $0.5M_1(t)$ which is having peak amplitudes of -0.5v and +0.5v for binary '1' and '0' level respectively. Finally, another comparator or decision making (Comparator 2 in Fig. 1b) circuit, which will take the decision with reference to 0v level fetch out the binary version of demodulated first message, i.e. Dm_1 which is exactly matching the transmitted first message signal $m_1(t)$ (refer Fig.1d).

QPSK-Level Shifted ASK:

Two messages in one carrier modulation: The BPSK-level shifted ASK based modulation can be extended for QPSK also, and then it will provide

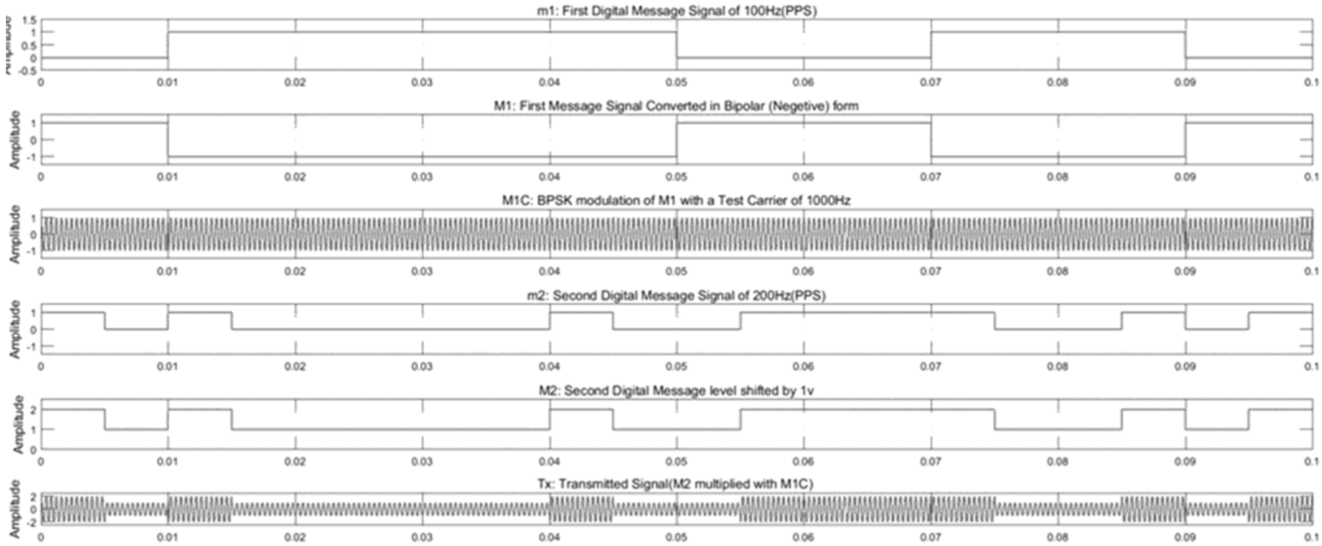

Fig. 1(c) — Waveforms of First message signal $m_1(t)$ and it's bipolar version $M_1(t)$, BPSK modulation of first message signal(M1)with carrier i.e M1C, Second message signal $m_2(t)$ and it's level shifted version $M_2(t)$ where $M_2(t)= m_2(t)+1$ and Final Transmitted signal (M2 multiplied with M1C) that is Two messages modulated over one carrier

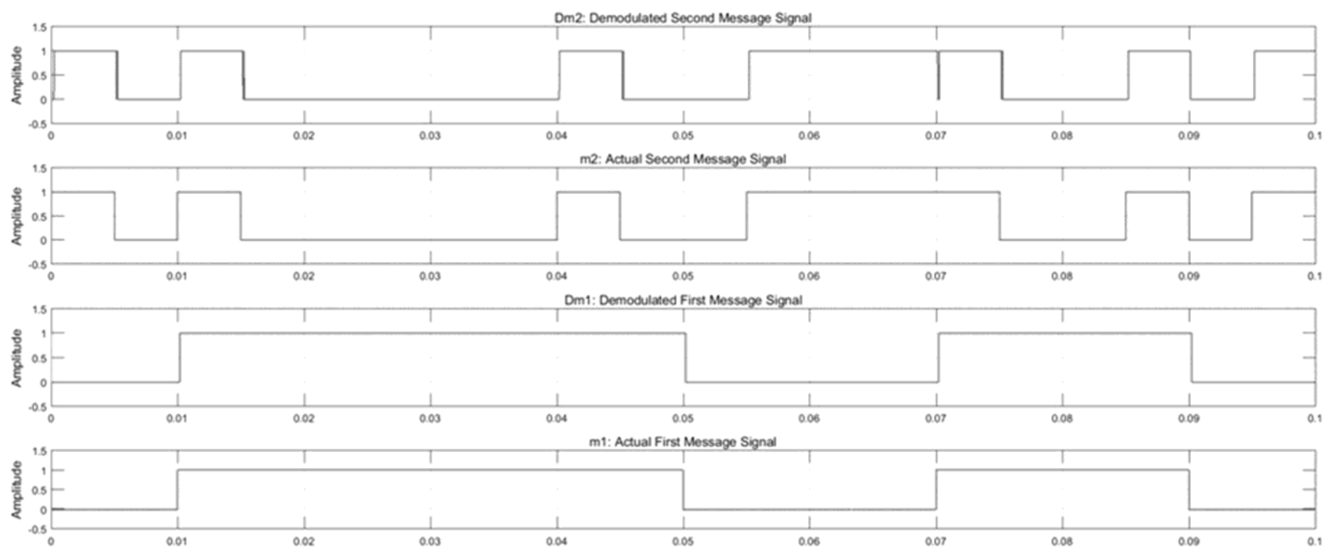

Fig. 1(d) — Comparison of Actual second message and first message with demodulated second and first message respectively

strong advantages over existing digital modulation techniques like ASK, FSK, QPSK, QAM or APSK in terms of simultaneously transferring two messages over one carrier signal.

Modulation

Stage 1: Just like the BPSK stage, relatively lower frequency message signal (100Hz Binary Pulse for example) i.e. 'm_1' shall modulate the carrier using QPSK modulation[1,2] (refer Fig. 2a and 2b), hence the resultant signal after first (QPSK) modulation is $Qm_1C=M1_e(t)\ \cos(\omega_c t)+\ M1_o(t)\ \sin(\omega_c t)$. $m_1(t)$ has been converted into a bipolar signal of +1v (for binary '1' level) and -1v (for binary '0' level) inside the QPSK Modulator (refer Fig. 2b) and the bipolar version of m1 is M1, and $M1_e$ and $M1_o$ = Even bits stream and Odd bits stream after bits splitting in the QPSK modulator respectively, where ω_c is the carrier frequency and assuming carrier signal's peak magnitude is equal to 1v. (Refer Figure. 2a, Figure. 2b and Figure. 3a)

Stage 2: Just like previously described BPSK based scheme, relatively higher frequency message signal (200Hz binary pulse for example) i.e. 'm_2' shall be converted into 'M_2' where $M_2 = m_2+1$. Hence a binary

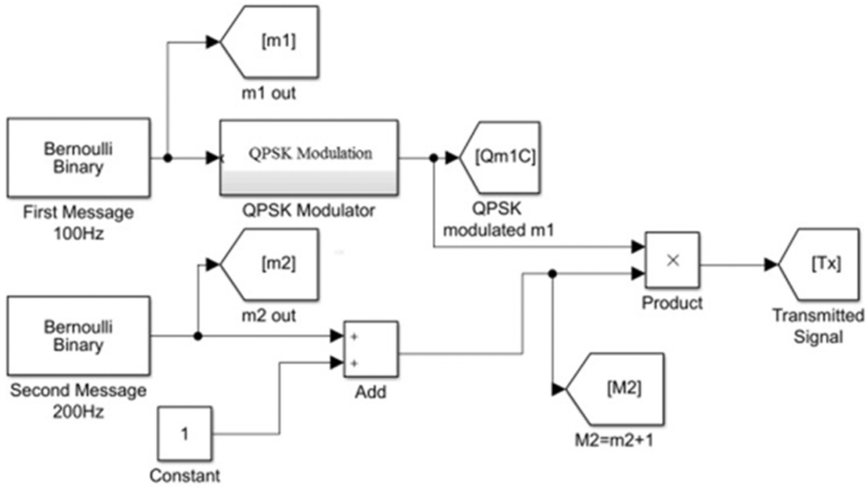

Fig. 2(a) — Schematic diagram of Two messages on One Carrier QPSK Modulator

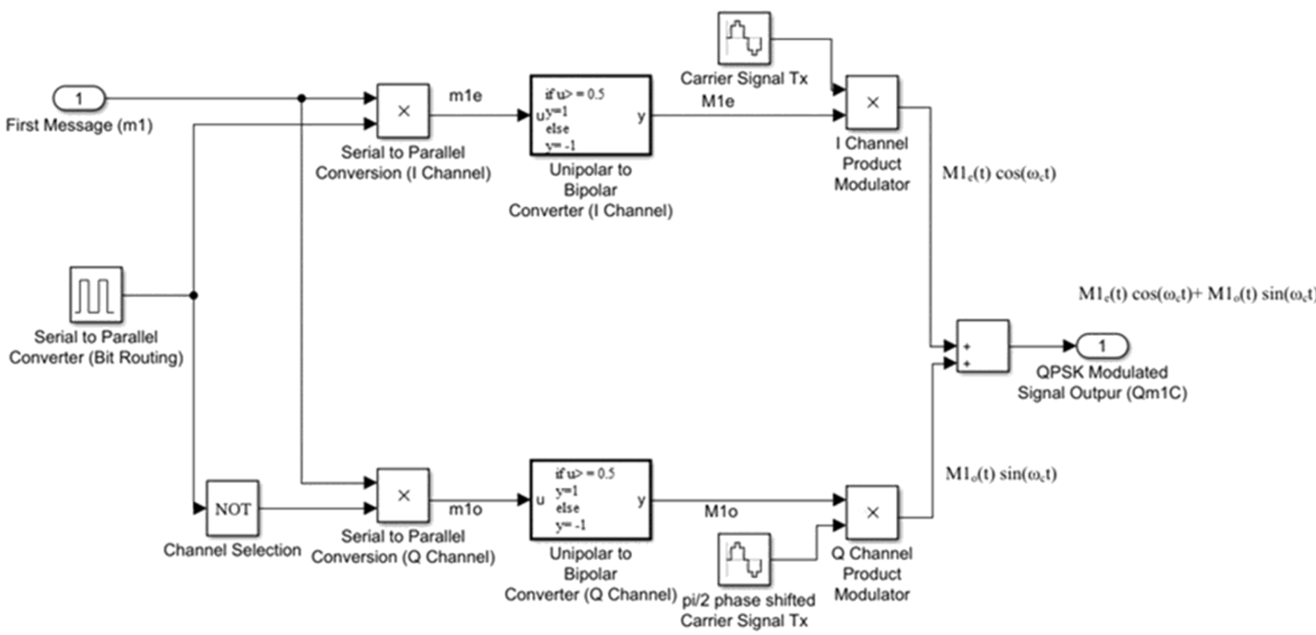

Fig. 2(b) — Schematic diagram of Two messages on One Carrier QPSK modulator block inside

level '0' will be represented as 1v level and binary level '1' shall be represented as 2v (Refer Fig.2a and Fig.3b), then final version of Transmitted Signal will be created by simply product modulating M_2 with Qm_1C . Hence final Transmitted message T_x will be - $T_x=M_2Qm_1C=M_2[M1_e(t)\ \cos(\omega_c t)+\ M1_o(t)\ \sin(\omega_c t)]$ (refer Figure. 2a and Figure. 3b).

Demodulation

Stage 1: Recovery of Second Message - T_x shall be multiplied with the locally generated carrier (or by recovered carrier in case of homodyne detection using Costa's loop). (refer Fig. 2c)

So we get, $T_x\cos(\omega_c t)$

$= M_2[M1_e\cos^2(\omega_c t)+ M1_o\sin(\omega_c t)\cos(\omega_c t)]$

$=\underline{0.5M_2M1_e} + 0.5\ M_2M1_e\cos(2\ \omega_c t) + 0.5M1_o\sin(2\omega_c t)$

The subsequent Butterworth and Bessel filters (refer Fig. 2c) both having lower cut off frequency of 4000Hz in this case (just above of the addition of 13th harmonics of m1 and m2) shall select the underlined term of above derivation i.e. $0.5M_2M1_e$ which will be fed into the squaring circuit resulting $v=0.25M_2^2$ (cause as $M1_e=\pm1$, $M1_e^2=1$).Now as M_2= 1 or 2, v=0.25 or 1 corresponding to binary 0 and 1 level of m_2 respectively. Now a

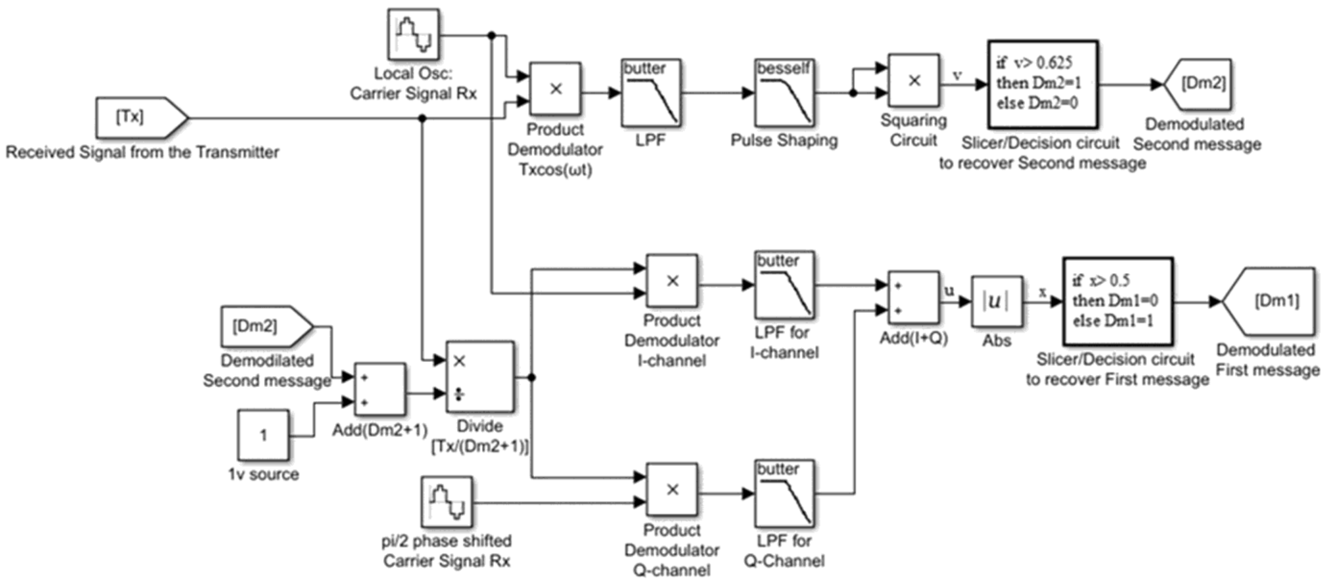

Fig. 2(c) — Schematic diagram of Two messages on One Carrier QPSK Demodulator respectively

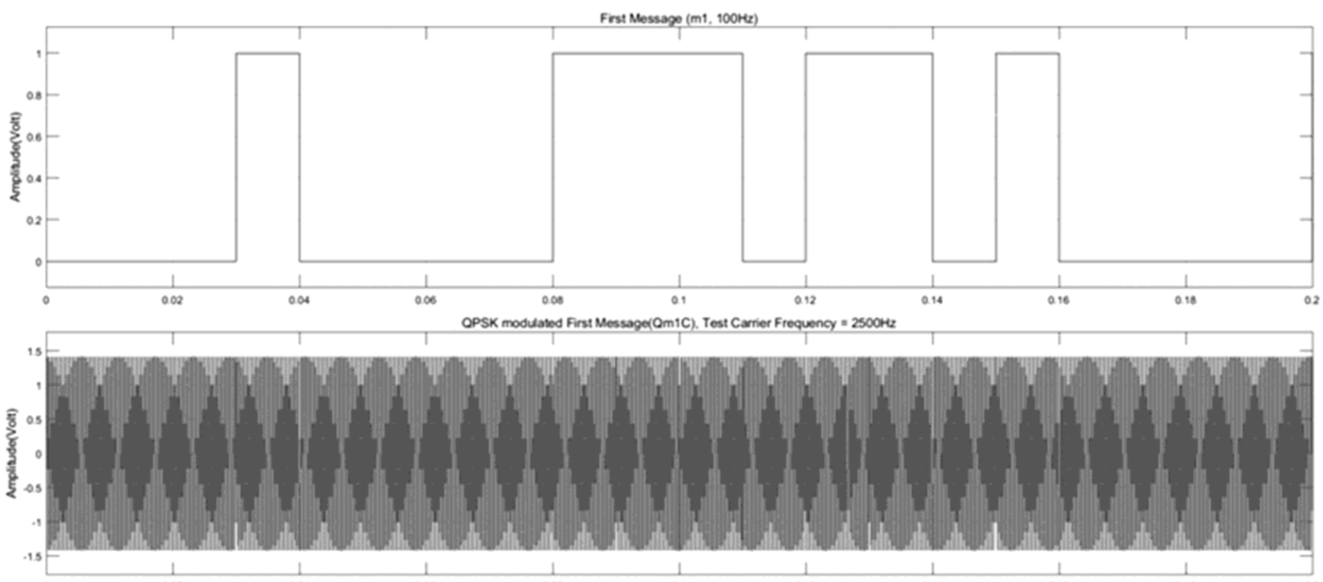

Fig. 3(a) — First message signal (upper graph) and it's QPSK modulated version (lower graph)

decision making circuit or comparator with reference voltage set at 0.625volt shall recover the second message or the demodulated version of the second message Dm_2(refer Figure. 2c). Comparing the demodulated second message (Dm_2) and the actual second message Transmitted (m_2), we can see that almost exact recovery has been obtained (refer Figure.3c).

Stage 2: Recovery of First Message

Once the Second message is recovered as Dm_2, simply dividing the Transmitted/Received signal (T_x) by Dm_2+1 shall reproduce Qm_1C in the receiver, cause $Tx=M_2(Qm_1C)$ and $Dm_2+1=m_2+1=M_2$ (refer Fig. 2c for the divider labelled as $[T_x/\ (Dm_2+1)]$). Now refer to the section marked as 'Demodulation of first message' in Fig.2c which is simply a conventional model of QPSK demodulator. Same QPSK demodulator section shall recover the first message m_1 from $Qm_1C=M1_e(t)\ \cos(\omega_c t)+\ M1_o(t)\ \sin(\omega_c t)$. (refer Fig. 3d).

The Novelty of the proposed modulation and design

A new Modulator and Demodulator design has been proposed in this paper to communicate two

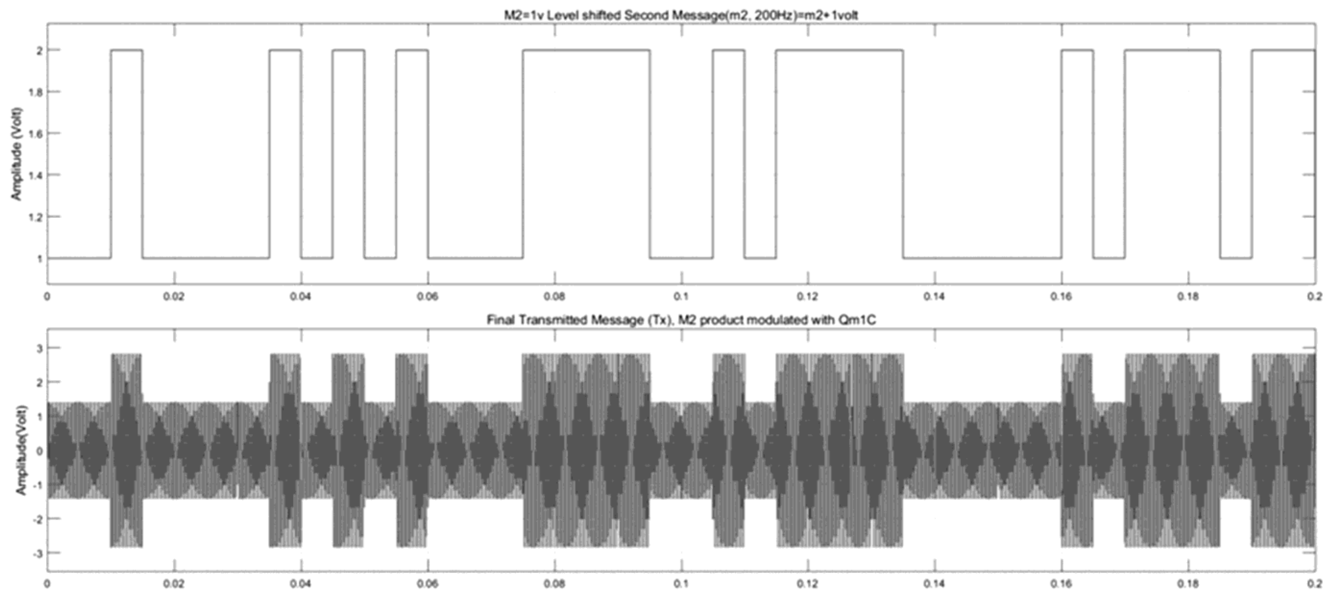

Fig. 3(b) — Level shifted Second Message Signal i.e M2=m2+1(upper graph)and Final Transmitted Signal after modulating M2 with QPSK modulated first signal i.e Qm1C(lower graph)

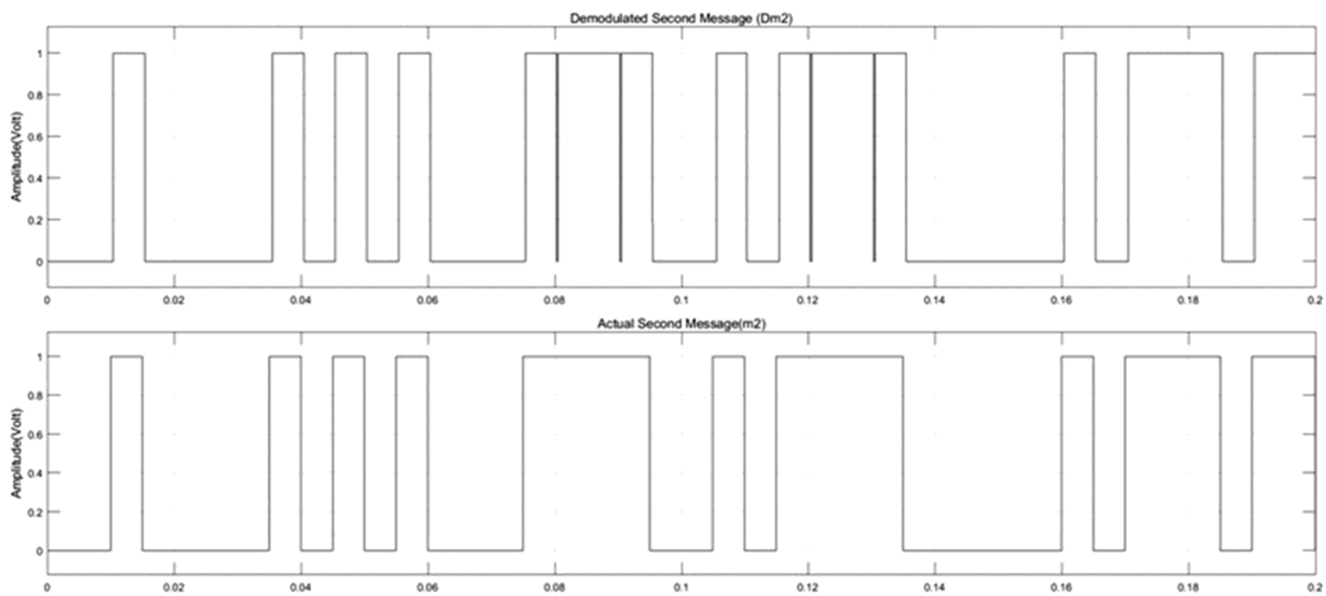

Fig. 3(c) — Comparison between QPSK Demodulated Second message signal (upper graph) and actual Second message Signal (lower graph)

messages simultaneously using one carrier signal. A level shifted ASK modulator combined with a conventional BPSK or QPSK modulator (refer Fig.1a and Fig. 2a respectively). Advantage of this unique ‘One Carrier Two Messages Digital Modulation’ method is very prominent. Unlike any other traditional or latest digital modulation methods say ASK, FSK, BPSK, QPSK, QAM or APSK, it can propagate TWO different digital messages on the same carrier on the same time. The two basic rules for this proposed modulation are that two different message signals must have different frequencies and the low frequency message needs to be treated as the first message or $m_1(t)$ as described above. For first modulation here BPSK has been considered but QPSK or higher level PSK also can be used

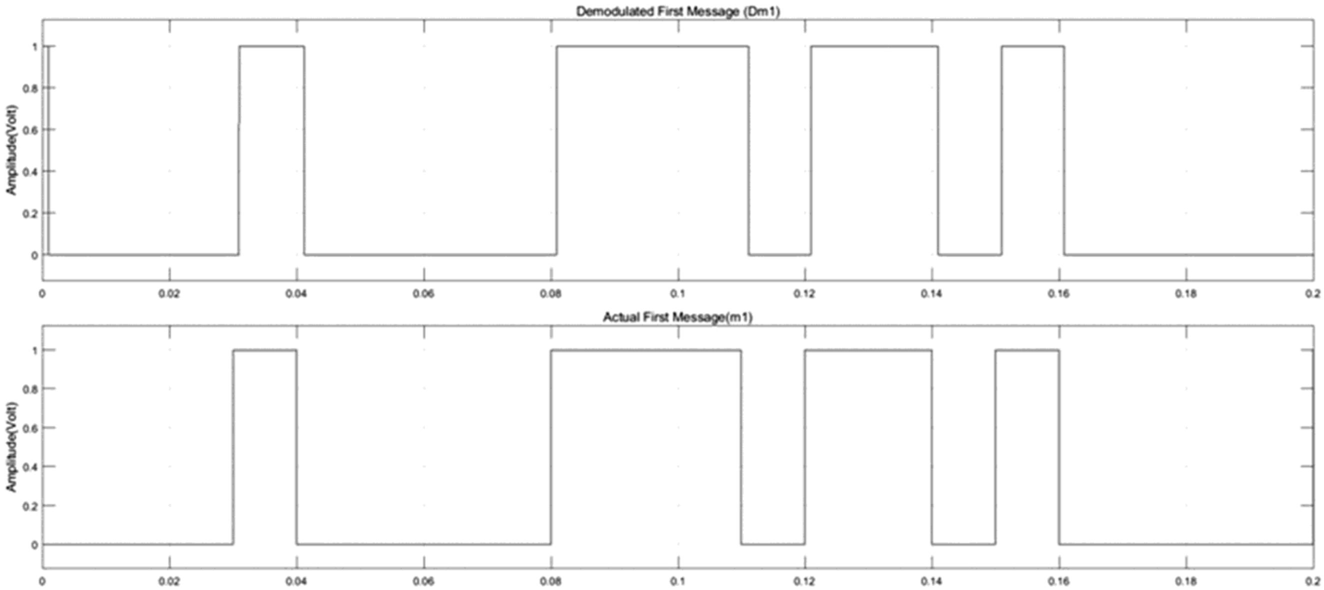

Fig. 3(d) — Comparison between QPSK Demodulated First message signal (upper graph) and actual First message Signal (lower graph)

for second modulation, but certainly not QAM or APSK modulation to be considered for the first modulation cause the second modulation is a level shifted ASK modulation.

Conclusion

An unique idea and design of 'One Carrier Two Messages' Digital Modulation and Demodulation has been presented here by combining Level shifted ASK and BPSK together (which can be Level shifted ASK-QPSK also) which can propagate Two different digital messages over the same carrier on same time which might have a great deal of application in cryptography or in channel equalizer in the future.

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