Performance of amplitude modulation in noise engineering essay

Engineering

Steve Mauro CaruanaY2S2 2013Theory: Performance of Amplitude Modulation in Noise[Q1] Amplitude Modulation with carrier: Synchronous Demodulation. Received Signal:√2 [A + m(t)]Cos wctSi = (√2) 2 [A + m(t)] 2 = [A + m(t)] 2 {Input Signal Power}2Si = A2 + m2 + 2A. m(t)Si = A2 + m2if message is dc component.[√2[A + m(t)] Cos wct * √2[Cos wct]]L. P. F=> m(t)So = m2{Output Signal Power}So = m2 = m2* Si Useful Input Power. No NB m2 + A2 NBSo = m2 * γNo m2 + A2Here the output is now smaller, and this is expected because when we are transmitting an AM signal with carrier, not the entire useful input power is used in the message, loosing performance. Therefore we have to set for higher γ, else the carrier would be inferior. If | m(t)| MAX = mp , A ≥ mpFor maximum SNR, we should choose A = mpSo = m2 * γNo mp2 + A2 Smallest possible value of A is mp.= 1 * γ1 + mp2 / m2mp2 ≥ 1 , mp2 ≤ γAt least 3dB Power andm2m2 2two times as much. Although a 6dB to 9dB loss in power efficiency is more typically. So = γ = γdB - 4. 77dBNo dB 3 dBSo what we can conclude is that there is a cost associated with performance, power efficiency etc, when we transmit with carrier. We do this because it gets simpler to demodulate it. With an envelope detector we will get the same performance as the synchronous detector does. Amplitude Modulation with envelope detectorThe process is very similar that we start with the received signal:[A + m(t)]Cos wctThe actual received signal input to demodulator is : yi(t) = [A + m(t)]Cos wct + ni(t)This represents the output of its Band Pass Filter / the front end of the receiver. In this case we will have a Bandwidth of 2B. yi(t) = [A + m(t) + nc(t)]Cos wct + ns(t) Sin wctSi = A2 + m22The envelope of the signal above . . .= Ei(t) . Cos[wct + Θ(t)]where Ei(t) is the envelope = √[A + m(t)

+ mc(t)]2 + ns2(t)Signal part no linear dependence. Finally the envelope detector will produce an output proportional to the envelope. To simplify matters we make some assumptions; Small Noise AssumptionThis is essentially to say that the signal power at the input is much greater than the noise power at the input(ie. the signal is much stronger than the noise). A + m(t) >> ni(t) , for all typeA + m(t) >> nc(t) , ns(t) , for all typeEi(t) ≈ A + m(t) + nc(t)]So = m2 = m2 * SiNo 2NBA2 + m2 NBThereforeSo = m2 * γNo m2 + A2The output here is not as exactly the same for a synchronous demodulation. For a synchronous demodulation this expression is valid irrespective of the input. For the case of the envelope detector it is only valid when the input SNR is insufficiently large. So in higher SNR situations, it highly matters that we do not loose any further in Power efficiency, not loosing performance. Large Noise AssumptionThe received signal is much weaker than the noise: ni(t) >> A + m(t)This will imply that both: nc(t) , ns(t) >> A + m(t) , for all values of t. The envelope: Ei(t) ≈ √ nc2(t) + ns2(t) + 2nc(t) [A + m(t)]ThereforeEi(t) = En(t) √ 1 + 2[A + m(t)] . Cos Ɵn(t)]En(t)or even better . . . Ei(t) = √ En2(t) + 2nc(t) [A + m(t)]Ei(t) = En(t) √ 1 + 2[A + m(t)] nc(t)En2(t)Quality of nc(t) Ratio. En(t)En2(t) Ɵn(t)ns(t)nc(t)Phase of Noise part. Ei(t) ≈ En(t) √ 1 + 2[A + m(t)] . Cos Ɵn(t)]En(t)Which represents the equation for the instantaneous envelope becomes; Ei(t) ≈ En(t) 1 + [A + m(t)] . Cos Ɵn(t)]En(t)Ei(t) = En(t) + [A + m(t)] . Cos Ɵn(t)] {Noise Waveform}noise noiseThe envelope detector will produce this kind of output. What we will get is almost entirely noise.=> Totally Noisy, with no component which we consider as proportional to m(t). Now if we were to plot for a synchronous detector { Plot output SNR vs γ = Si / NB = SNR}1 When

Si >> Noise falls below some value we start moving down. 2 Eventually at lower SNR's the output does not resemble the input at all in terms of message. 3 Output here degrades much more than the input SNR degrades. This is seen in the envelope detector and is called the threshold effect. So the threshold effect is that the output SNR does not degrade gracefully as the input SNR is reduced. We must operate at threshold value; γth is in the order of 10dB (ie. γnth ~ 10dB)This means that unless my input signal falls below 10dB our continuity will be represented by the linear part of the graph 1 . We must keep in mind that Modulation is used to simplify the receiver but at the same time we do not want to loose performance. Calculation of γthreshold. Probability density function of noise envelope: En(t) = √ nc2(t) + ns2(t)ni(t) = nc(t) Cos wct + ns(t) Sin wctGaussian Quadrature Components. Given that the density function ofpnc(α) = pns(α) = 1. e - α2 / 2б2 , α > 0√2 π бthen we can show thatpEn(α) = α. e - α2 / 2б2 , α > 0б2which is only defined for positive values of the argument { En(t) }б2 => noise variance of nc(t) and ns(t), which is equal to ni(t), equal to 2NB.(ie. б2 = 2NB)This is the noise variance of variable signal coming out of the Band Pass Filter, before the envelope detector. We can say that; Noise EnvelopeThreshold: If En > A

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If noise amplitude is greater than the signal and carrier amplitude of this such property. A ∞P[En ≥ A] = ∫ α. e - α2 / 2б2 d αThe shaded area. б2= e - A2 / 2б2 is ≈ 0. 01 at the point of threshold. now A2 = 4. 6052б2This means ; б2 = 2NB => A2 = 4. 6054NBSi = A2 + m2(t)2Received Signal Powerwhere A2 represents the power of the amplitude carrier. m2(t) represents the message power. Si = A2 + 0. 5 A2 = 3 A22 4Therefore γthreshold = Si = 3 A2 ≈ 13. 8dB or ≈ 11. 4dB. NB 4NB[Q2] The parameters of the Band Pass Filter used in the Mixer are as follows; kHzfstop1: 70 , 92fstop2: 108 , 130Magnitude: Astop1: 60dBAstop2: 60dBBand Pass Filter after Envelope Detector; kHzfstop1: 10 , 500fstop2: 8000 , 16000Magnitude: Astop1: 60dBAstop2: 60dBThereforeMinimum Frequency Allowed = 10 HzMaximum Frequency Allowed = 130 kHz[Q3] The value of RC is adjusted such that the negative rate of the envelope will never exceed the exponential discharge rate of the RC network. Value of RC used in the envelope detector is that of 0. 018315638 seconds. For the specific case of tone modulation (the message signal is a sinusoid), the time constant RC is related to the parameters of the AM signal by: RC ≤ √ 1 - m22 π fx m[Q4] The intermediate frequency If must be changed such as to modify the 'Envelope Detector' and 'Band Pass Filter 1' to: flo = fc + fif899kHz = 693kHz + fiffif = 206 kHz[Q5a] After setting noise power to 0 and modulation index to 1; Transmitted Carrier Power: PT = Pc (1 + m2 / 2)But Pc = Ac2 / 2{ Ac = 1}Pc = 0. 5 WTherefore PT = 0. 75 WWhich is equal to the Transmit Power = 0. 75W.[Q5b] Power in transmitted side-bands; The power in each side band PSB is given by: PSB = PLSB = PUSB = Pc m2 /4ThereforePSB = (0. 5)(1)2/ 4PSB = 0. 5WFor the total power transmitted Side Bands; PTSB = 0. 5W + 0. 25WPTSB = 0. 75WWhich is equal to the Received Signal Power = 0. 75W. [Q5c] Demodulated baseband Signal Power: PDBS = 0W. Although in our model we get a really small value, practically 0. 00290252W. What is causing this transient ? The possible generation of parasitic offsets due to the (first multiplication) switching found in the Envelope Detector. Saved Clean output signals as: Mixer_Out = AmOut(:, 2); Bandpass_out = Output(:, 2);[Q6a] After setting the carrier amplitude to zero and channel noise power to 0. 1W; The received noise after the mixer => Detected Noise[Q6b] Its frequency content is of => 100kHz[Q6c] The noise power after the mixer is 0. 0008657W. The noise at the output of the receiver is 0. 09993W.[Q6c] The pre-detection and the post-detection SNR at this noise level will be both 0, because the noise transmitted is 0 and also we have the amplitude 0. S = Ac2 Pm= 0N pos 2NoBS = Ac2 PmN pre 4NoB

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S = Ac2 Pm= 0N pos 2NoWS = 0. 5Ac2 PmN ref No W[Q7] After setting the carrier amplitude back to 1: If we compare the pre and post detection SNRs we see that there is a gain of 2 in the processing since the channel noise is eliminated. S = Ac2 Pm= 2N pos 2NoBS = Ac2 PmN pre 4NoBIf we use the same transmit power in a baseband system, we see that we would achieve the same SNR. Thus there is no wasted power in the DSB-SC transmit scheme. But no gain either. S = Ac2 Pm= 1N pos 2NoBS = Ac2 PmN pre 4NoBDifference in output; Questions => Q6Q7Transmit Power0W0. 66WReceived Signal Power0. 09993W0. 7598WDisplay30. 0008657W0. 0008661WDemodulated Signal Power0. 000201W0. 000201WCarrier Amplitude is 1Channel Noise Power is 0. 1WCarrier Amplitude is 0Channel Noise Power is 0. 1WAlthough Q6 and Q7 have different Carrier Amplitude the final result after passing through the: AM Modulator, Mixer and Envelope Detector; is the same. The Demodulated Signal Power is for both of them 0. 000201W.

[Q8]

Questions => Q8Transmit Power0. 66WReceived Signal Power0. 7598WDisplay30. 0008661WDemodulated Signal Power0. 000201WThis shows a difference after the mixer in 'display 3' only.[Q9] After changing the constant index modulation to 0. 8 and varying the power from 0W up to 20W: ForQ9 at 0WQ9 at 10WQ9 at 20WTransmit Power0. 66W0. 66W0. 66WReceived Signal Power0. 66W10. 65W20. 64WDisplay30. 002306W0. 08658W0. 1731WDemodulated Signal Power0. 002021W0. 0201W0. 0402WAs we increase the noise power, the Received Signal Power also increases by a large amount of an approximate factor of 1. 94. Also the Demodulated Signal Power increases slightly at a rather slow pace. [Q10]Irrespective of the chosen Carrier Amplitude, the power in each stage of our Simulink model increases proportionally, and with an increase in power, our noise value also increases.