Communication systems simon haykin 5th edition answers book pdf 2017

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1. Solutions Manual for: Communications Systems, 5th edition by Karl Wiklund, McMaster University, Hamilton, Canada Michael Moher, Space-Time DSP Ottawa, Canada and Simon Haykin, McMaster University, Hamilton, Canada Published by Wiley, 2009. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

2. Chapter 2 2.1 (a) ( ) cos(2) , 2 2 1 c c T T g t A f t t f T π −⎡ ⎤ = ∈⎢ ⎥⎣ ⎦ = We can rewrite the half-cosine as: cos(2) rectc t A f t T π ⎛ ⎞ ⋅ ⎜ ⎟ ⎝ ⎠ Using the property of multiplication in the time-domain: [ ] 1 2( ) ( ) ( ) 1 sin( ) ( ) ( ) 2 c c G f G f G f fT f f f f AT fT π δ δ π = ∗ = − + + ∗ Writing out the convolution: [ ] sin( ) ( ) (( ) ( ) 2 sin(( )) sin(( )) 1 = 2 2 cos( ) cos( ) 1 12 2 2 c c c c c c c AT T G f f f f f d T f f T f f TA f f f f f T A fT fT f f T T πλ δ λ δ λ λ πλ π π π π π π ∞ −∞ ⎛ ⎞ = − + + − ... (b)By using the time-shifting property: 0 0 0( ) exp(2) 2 cos( ) cos( ) ( ) exp( ) 1 12 2 2 T g t t j ft t A fT fT G f j fT f f f f T T π π π π π − − = ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

3. (c)The half-sine pulse is identical to the half-cosine pulse except for the centre frequency and time-shift. 1 2 cf Ta = cos( ) cos( ) ( ) (cos( ) sin( )) 2 cos(2) cos(2) sin(2) sin(2) 4 exp(2) exp(2) 4 c c c c c c c c c A fTa fTa G f fTa j fTa f f f f A fTa fTa fTa fTa j j f f f f f f f f A j fTa j fTa f f f f π π π π π π π π π π π π π π π π ... (d) The spectrum is the same as for (b) except shifted backwards in time and multiplied by -1. cos( ) cos( ) ( ) exp( ) 1 12 2 2 exp(2) exp(2) 1 14 2 2 A fT fT G f j fT f f T T A j fT j fT f f f T T π π π π π π π ... (e) Because the Fourier transform is a linear operation, this is simply the summation of the results from (b) and (d) exp(2) exp(2) exp(2) (2) ( ) 1 14 2 2 cos(2) cos(2) 1 12 2 2 A j fT j fT j fT G f f f T T A fT fT f f T T π π π π π π π π π π ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

4. 2.2 ( )( ) ( ) ( ) exp( )sin(2)u( ) exp( )u( ) sin(2) 1 1 ( ) ( ) ( ) 1 2 2 1 1 1 2 1 2 ( ) 1 2 ( ) c c c c c c g t t f t t t t t f t G f f f f f j f j j j f f f f π π δ δ π π π = − = ... 2.3 (a) [ ] [ ] ( ) ( ) ( ) 1 ( ) ( ) ( ) 2 ( ) rect 2 1 ( ) ( ) ( ) 2 1 1 2 2( ) rect rect e o e e o o g t g t g t g t g t g t t g t A T g t g t g t t T t T g t A T T = + = + − ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

5. (b) By the time-scaling property g(-t) G(-f) [ ] [ ] [ ] [ ] 1 ( ) ( ) ( ) 2 1 sinc( )exp(2) sinc( )exp(2) sinc( )cos( ) 1 ( ) ( ) ( ) 2 1 sinc( )exp(2) sinc( )exp(2) sinc( )sin( ) e o G f G f G f fT j fT fT j fT fT fT G f G f G f fT j fT j fT fT j fT π π π π π π π π = + = ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

6. 2.4. We need to find a function with the stated properties. We can verify that: ( ) sgn( ) u( ) u( )G f j f j f W j f W= − + − − − − meets the stated criteria. By duality g(f) G(-t) 1 1 1 1 1 ( ) ( ) exp(2) ( ) exp(2) 2 2 2 2 1 sin(2) 2 g t j t j Wt j t j Wt j t j t Wt j t t δ π δ π π π π π π π π π ... = + 2.5 By the differentiation property: [ ] ( ) 2 ( ) 1 ( )exp(2) ( )exp(2) 2 ( )sin(2) dg t F j fG f dt H f j f H f j f j f H f f π π τ π τ π τ π τ ... But 2 2 ( ) exp( )H f f π π τ= − 2 2 2 2 2 2 0 1 ( ) exp( )sin(2) sin(2) exp( ) 2 exp( )sinc(2) lim ( ) 2 sinc(2) G f f fT f fT f f T f f fT G f T fT τ π π π ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

7. 2.6 (a) If g(t) is even and real then * * * * * * 1 ( ) [( ) ( )] 2 1 1 ( ) ( ) 2 2 ( ) ( ) ( ) is all real G f G f G f G f G f G f G f G f G f G f = + − = − = ∴. If g(t) is odd and real then * * * * * * 1 ( ) [( ) ( )] 2 1 1 ( ) ( ) 2 2 ( ) ( ) ( ) ( ) must be all imaginary G f G f G f G f G f G f G f G f G f G f = − − − = ∴. (b) The previous step can be repeated n times so: ( ) ( ) (2) ( ) ( ) But each factor (2) represents another differentiation. ( ) ( ) 2 Replacing with ( ) ( ) 2 n n n n n n n n n d j ft G t g f df j ft j t G t g f g h j t h t H f π π π π ... 2 and ( ) ( ) ( ) ( ) g t g t g t g t g t G f G f = − − = = = − (2) ( ) ( ) by duality ( ) ( ) 2 d j t G t g f df j d t G t g f df n π π − − ⋅ − Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

8. (c) Let ( ) ( ) ( ) and ( ) ( ) 2 n n nj h t t g t H f G f π ... (d) 1 1 * 2 2 ( ) ( ) ( ) ( ) g t G f g t G f− 1 2 1 2 * 1 2 1 2 1 2 ( ) ( ) ... (e) * 1 2 1 2 * 1 2 * 1 2 1 2 * 1 2 1 2 ( ) ( ) ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

9. 2.7 (a) 2 2 ( ) sinc ( ) ( ) max ( ) (0) sinc (0) The first bound holds true. g t AT fT g t dt AT G f G f AT AT ∞ −∞ = = = = ∴. ∫ (b) 2 ( ) 2 2 ( ) 2 sinc ( ) sin( ) sin( ) 2 sin( ) 2 sin( ) dg t dt A dt j fG f fAT fT fT fT fAT fT fT fT A fT fT π π π ... But, sin( ) 1 and sinc( ) 1 sin( ) 2 sin( ) 2 2 ( ) 2 fT fT f fT f A fT A fT j fG f A π π π π π π ≤ ∀ ≤ ∀ ∴. ⋅ ≤ ∴. ≤ Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

10. 2.7 c) 2 2 2 2 2 2 2 2 (2) ( ) 4 ( ) sin ( ) 4 ( ) 4 sin ( ) 4 j f G f f G f f f T A fT fT A fT f T A T π π π π π ... = = = ≤ The second derivative of the triangular pulse is plotted as: Integrating the absolute value of the delta functions gives: 2 2 2 2 2 ( ) 4 ( ) (2) ( ) d g t A dt dt T d g t j f G f dt dt π ∞ −∞ ∞ −∞ = ∴. ≤ ∫ ∫ Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

11. 2.8. (a) 1 2 1 2 2 1 ( ) ( ) ( ) ( ) ( ) ( ) by the commutative property of multiplication g t g t G f G f G f G f ∗ = b) [ ] [ ] [ ] [ ] [ ] [ ] 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 ( ) ( ) ( ) ( ) ( ) ( ) Because multiplication is commutative, the order of the multiplication doesn't matter. ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) g f g f g f G f G f G f G f G f G f G f G f G f G f G f g f g f g f ∗ ∗ ∴. = ∴. ∗ ∗ c) Taking the Fourier transform gives: [ ]1 2 3 1 2 2 3 1 2 1 2 ( ) ( ) ( ) Multiplication is distributive so: ( ) ( ) ( ) ( ) ( ) ( ) ( ) G f G f G f G f G f G f g t g t g t + + Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

12. 2.9 a) Let 1 2( ) ( ) ( )h t g t g t= ∗ ( ) ( ) [ ] 1 2 1 2 1 1 2 2 1 1 2 2 ( ) 2 ( ) 2 ( ) ( ) 2 ( ) ( ) ( ) ( ) 2 ( ) ( ) ( ) ( ) ( ) dh t j fH f dt j fG f G f j fG f G f dg t j fG f G f dg t dt dg td g t g t g t dt dt π π π π = ... b) 2.10. 1 2 1 2 1 2 1 1 2 2 1 1 2 1 2 1 (0) (0)1 ( ) ( ) ( ) ( ) 2 2 (0)1 ( ) ( ) ( ) ( ) 2 2 (0)1 ( ) ( ) ( ) 2 2 ( ) ( ) ( ) ( ) t G G g t g t dt G f G f f j f G f G f G f j f G f G f G f ... ( ) 0 if ( ) 0 if for when 0 and for when 0 and for 0 when 2 for - 0 when 2 Over the range of integration , , the integr X W X f f W f W f W W f W f W f W W f W f W f W W f W f W f W W ν ν ν ... al is non-zero if 2f W≤ Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

13. 2.11 a) Given a rectangular function: 1 ( ) rect g t T T ⎛ ⎞ = ⎜ ⎟ ⎝ ⎠, for which the area under g(t) is always equal to 1, and the height is 1/T. 1 rect sinc( ) t fT T T ⎛ ⎞ ⎜ ⎟ ⎝ ⎠ Taking the limits: 0 0 1 lim rect ( ) 1 lim sinc( ) 1 T T t t T T fT T δ → → ⎛ ⎞ = ⎜ ⎟ ⎝ ⎠ = b) 2.12. 1 1 ( ) sgn( ) 2 2 By duality: 1 1 ( ) ( ) 2 2 1 ( ) ( ) 2 2 G f f G f t j t g t t t δ π δ π = + − ∴. = + − 1 2 sinc(2) 2 sinc(2) rect 2 g t W W Wt W W W = ⎛ ⎞ ⎜ ⎟ ⎝ ⎠ lim 2 sinc(2) lim rect 1 2 W W W Wt t W δ →∞ →∞ = ⎛ ⎞ = ⎜ ⎟ ⎝ ⎠ Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

14. 2.13. a) By the differentiation property: ( ) 2 2 2 2 ( ) 2 ( ) 1 ( ) exp(2) 4 i i i i i i i j f G f k j f G f k j f t f π π π π = − ∴. = − ∑ ∑ b)the slope of each non-flat segment is: b a A t t ± − [ ] ( ) [ ] 2 2 2 2 1 ( ) exp(2) exp(2) exp(2) exp(2) 4 cos(2) cos(2) 2 b a a b a b a b a A G f j f t j f t j f t j f t A f t f t f t f t π π π π π π ... But: [ ] 1 sin(( ))sin(( )) cos(2) cos(2) 2 b a b a b a bf t t f t t f t f t ... by a trig identity. [ ]2 2 ( ) sin(( ))sin(( )) ( ) b a b a b a A G f f t t f t t f t t t π π ... − 2.14 a) let g(t) be the half cosine pulse of Fig. P2.1a, and let g(t-t0) be its time-shifted counterpart in Fig.2.1b ( )( ) ( )( ) * 2 2* 0 0 0 0 2* 0 0 ( ) ( ) ( ) ( )exp(2) ( )exp(2) ( ) exp(2)exp(2) ( )exp(2) ( )exp(2) ( ) ( ) G f G f G f j ft G f j ft G f j ft j ft G f G f ε π π π π π π π = = − = ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

15. 2.14 b)Given that the two energy densities are equal, we only need to prove the result for one. From before, it was shown that the Fourier transform of the half-cosine pulse was: [ ] 1 sinc(( )) sinc(( )) for 2 2 c c c AT f f T f f T + − = After squaring, this becomes: 2 22 2 2 2 2 sin (( )) sin (( )) 2 sin(( )) sin(( )) 2 4 ... The first term reduces to: ( ) ( ) ( ) 2 2 2 2 2 2 2 2 sin cos cos2 2 2 c fT fT fT fT ... The second term reduces to: ( ) ( ) 2 2 2 2 2 sin cos2 2 c fT fT fT ... The third term reduces to: 2 2 2 2 2 2 2 2 2 sin(( ))sin(( )) cos( ) cos (2) 2 1( ) ( ) 4 1 cos(2) 1 4 c c c c f f T f f T f T f f T f f f T A f T fT ... Summing these terms gives: ( ) ( )2 22 2 2 2 22 2 2 2 cos cos cos ( ) 2 1 14 1 1 2 22 ( ) fT fTA fT fT f f f f fT T T T ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

16. 2.14 b)Cont'd By rearranging the previous expression, and summing over a common denominator, we get: ( ) ( ) 2 2 2 2 2 2 2 2 2 2 2 4 22 2 4 2 2 2 2 2 2 cos ( ) 4 1 4 cos ( ) 1 14 4 1 16 cos ( ) 4 1 A T fT f T A T fT f T A T fT f ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

17. 2.15 a)The Fourier transform of ( ) 2 ( ) dg t j fG f dt π Let ( ) '( ) dg t g t dt = By Rayleigh's theorem: 2 2 ( ) ( )g t dt G f df ∞ ∞ −∞ −∞ =∫ ∫ ... Using integration by parts, we can show that: 2 2 2 2 ( ) ( ) 1 ( ) 16 1 4 d t g t dt g t dt W T W T ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

18. 2.15 b) For 2 ( ) exp( )g t tπ= − 2 2 2 2 2 2 2 2 2 ( ) exp( ) exp(2) exp(2) exp(2) g t f t t f df W T ... Using a table of integrals: 2 2 0 2 2 2 2 2 2 2 2 2 1 exp( ) for 0 4 1 1 exp(2) 4 2 1 1 exp(2) 4 2 1 exp(2) 2 1 1 4 4 2 1 2 1 4 1 4 x ax dx a a a t dt t f dt t T W TW π π π ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

19. 2.16. Given: 2 ( ) and ( ) , which implies that ( ) x t dt h t dt ∞ ∞ −∞ −∞ < ∞ < ∞ ∫ ∫ ... However, if 2 4 ( ) then ( ) and ( )x t dt X f dX f df ... This result also applies to h(t). ( ) ( ) ( )Y f H f X f ... By Rayleigh's theorem: 2 2 ( ) ( ) y t dt Y f df ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

20. 2.17. The transfer function of the summing block is: [ ]1( ) 1 exp(2) H f j fTπ= − −. The transfer function of the integrator is: 2 1 ( ) 2 H f j fπ = These elements are cascaded : ( ) ( ) ( ) [ ] ( ) [ ] 1 1 2 1 2 2 2 2 2 1 exp(2) 2 1 1 2exp(2) exp(4) 2 H f H f H f j fT j f ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

21. 2.18.a) Using the Laplace transform representation of a single stage, the transfer function is: 0 0 0 1 ( ) 1 1 1 1 ( ) 1 H f s RCs s RC τ τ = = + + These units are cascaded, so the transfer function for N stages is: ( ) 1 ( ) ( ) 1 N N H f H f s τ ⎛ ⎞ = = ⎜ ⎟ ⎝ ⎠ + b) For N→∞, and 1 2 0 2 4 T N τ = ( ) 0 0 1 ln( ) ln 1 2 ln 1 2 ln 1 ln 1 ... , then for very large ... We use the Taylor series expansion of ln(1)z:. + ( ) ... (next page) Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

22. 2.18 (b) Cont'd Taking the limit as N→∞: ( ) 2 2 1 1 2 2 1 lim 1 2 1 2 m m N m fT ... ( ) exp( )exp(1 2 ( ) exp( ) 2 H f f T j N fe H f f T ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

23. 2.19.a) ( ) ( )( ) T t T y t x dτ τ τ − = − ∫ This is the convolution of a rectangular function with x(t). The interval of the rectangular function is [(t-T),T], and the midpoint is T/2. T sinc( ), but the function is shifted by . 2 ( ) sinc( )exp( ) t rect T fT T Y f T fT j fT X f π ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

b)BW = 1 1 RC T = ( ) exp(2) 1 2 2 1 exp( ) ( ) 2 2 1 exp( ) ( ) 2 2 1 exp( ) ( ) 2 2 exp(2) ( ) 2 ( ) 2 ... (b) Using the property of ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

24. 2.20. a) For the sake of convenience, let h(t) be the filter time-shifted so that it is symmetric about the origin (t = 0). 1 1 2 2 0 1 1 2 1 1 ( ) exp(2) 2 cos(2) N N k k k k N k k k ... Let G(f) be the filter returned to its correct position. Then 1 ( ) ( )exp(2) 1 2 N ... which is a time-shift of 1 2 N − samples. b) By inspection, it is apparent that: ( ) exp(( ))G f j f Nπ= − This meets the definition of linear phase. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

25. 2.21 Given an ideal bandpass filter of the type shown in Fig P2.7, we need to prove the response of the filter for ... If 0cf f− is large compared to 2B, then the response is zero in the steady state. However: ... Since 0cf f− is large, assume that the portion of the amplitude spectrum lying inside the passband is approximately uniform with a magnitude of 04 ( )c A f fπ − . The phase spectrum of the output: Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

26. Taking the envelope by retaining the positive frequency components, shifting them to the origin, and scaling by 2: 0 0 exp 2 2 if( ) 2 ( ) 0 otherwise ... < 0, the frequencies are shifted inwards by Δf. ( ) contains {99.98,199.98,399.98} HzoV f.∴ (b) When the lower side-band is transmitted, and Δf>0, then the baseband frequencies are shifted outwards by Δf. ( ) contains {100.02,200.02,400.02} HzoV f.∴ Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

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67. 3.22. 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 ( ) ( ) cos(2) cos(2) [cos(2 ( )) cos(2 ( ))] 2 v t v t A A f t f t t f f t f f t π φ π φ ... The low-pass filter will only pass the first term. 1 2 1 2 1 2 1 1 ( ) ( ) [cos((2 ( ))] 2 LFP v t v t A A W f tπ φ φ ... Let v0(t) be the final output, before band-pass filtering. ... After band-pass filtering, retain only the second term. 2 1 2 1 2 2 [cos(2 (2) ... rearranging and solving for : 1 n n n φ φ ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

68. 3.23. Assume that the mixer performs a multiplication of the two signals. 1 2 ( ) {1,2,3,4,5,6,7,8,9} MHz ( ) {100,200,300,400,500,600,700,800,900} kHz ... This system essentially produces a DSB-SC signal centred around the frequency of y1(t). The lowest frequencies that can be produced are: 1 2 1 1 2 2 1 2 1 ( ) [cos(2 ( )) cos(2 ( ))] 2 1 MHz 0.9 MHz 100 kHz 1.1 MHz o y t y t f f t f f t ... The highest frequencies that can be produced are: 1 1 2 2 9 MHz 8.1 MHz 900 kHz 9.9 MHz ... The resolution of the system is the bandwidth of the output signal. Assuming that no branch can be zeroed, the narrowest bandwidth occurs when there is a modulation frequency of 900 kHz. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

69. 3.24 Given the presence of the filters, only the baseband signals need to be considered. All of the other product components can be discarded. (a) Given the sum of the modulated carrier waves, the individual message signals are extracted by multiplying the signal with the required carrier. For m1(t), this results in the conditions: ... For the other signals: ... Similarly: ... (b) Given that the maximum bandwidth of m(t) is W, then the separation between fa and fb must be | fa- fb|>2W in order to account for the modulated components corresponding to fa- fb. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

70. 3.25 b) The charging time constant is ( ) 1f sr R C sμ+ = The period of the carrier wave is 1/fc = 50 μs. The period of the modulating wave is 1/fm = 0.025 s. The time constant is much shorter than the modulating wave and therefore should track the message signal very well. The discharge time constant is: 100lR C sμ = . This is twice the period of the carrier wave, and should provide some smoothing capability. From a maximum voltage of V0, the voltage Vc across the capacitor after time t = Ts is: ... Using a Taylor series expansion and retaining only the linear terms, results in the linear approximation of 0 1 s c l T V V R C ⎛ ⎞ = −⎜ ⎟ ⎝ ⎠. The signal will decay by a factor of 0.94 from its initial value after a period of Ts seconds. From the figure, however, it is somewhat slower than what was calculated using the linear approximation. In a real circuit, it would also be expected that the decay would be slower, as the voltage does not simply turn off, but rather decreases over time. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

71. 3.25 c) The output of a high-pass RC circuit can be described according to: ... Using first order differences to approximate the derivatives results in the following difference equation: ... The high-pass filter applied to the envelope detector eliminates the DC component. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

72. Problem 3.25. MATLAB code function [y,t,Vc,Vo]=AM_wave(fc,fm,mi) %Problem 3.25 %Inputs: fc Carrier Frequency % fm Modulation Frequency % mi modulation index %Problem 3.25 (a) fs=160000; %sampling period deltaT=1/fs; %sampling period t=linspace(0,.1,.1/deltaT); %Create the list of time periods y=(1+mi*cos(2*pi*fm*t)).*cos(2*pi*fc*t); %Create the AM wave %Problem 3.25 (b) %%%%Create the envelope detector%%%% Vc=zeros(1,length(y)); Vc(1)=0; %initial voltage for k=2:length(y) if (y(k)>Vc(k-1)) Vc(k)=y(k); else Vc(k)=Vc(k-1)-0.023*Vc(k-1); end end %Problem 3.25 (c) %%%Implement the high pass filter%%% This implements bias removal Vo=zeros(1,length(y)); Vo(1)=0; RC=.001; beta=RC/(RC+deltaT); for k=2:length(y) Vo(k)=beta*Vo(k-1)+beta*(Vc(k)-Vc(k-1)); end

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82. Problem 4.7. ( ) cos(( )) ( ) 2 ( ) c c p s t A t f t k t m t θ θ π = = − + Let β = 0.3 for m(t) = cos(2πfmt). ( ) cos(2) [cos(2)cos(cos(2) sin(2))sin(2)] for small : cos(cos(2)) 1 sin(sin(2)) cos(2) ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 83. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 84. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 85. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 86. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 87. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

88. Problem 4.14. 2 2 1 ( ) cos(2 sin(2)) ... The square-law device produces a new FM signal centred at 2fc and with a frequency deviation of 2β. This doubles the frequency deviation. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 89. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

90. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 91. 4.17. Consider the slope circuit response: The response of]X(f)[after the resonant peak is the same as for a single pole low-pass filter. From a table of Bode plots, the following gain response can be obtained: ... Where fB is the frequency of the resonant peak, and B is the bandwidth. For the slope circuit, B is the filter's bandwidth of cutoff frequency. For convenience, we can shift the filter to the origin (with 1( )X f as the shifted version). ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

92. Because the filters are symmetric about the central frequency, the contribution of the second filter is identical. Adding the filter responses results in the slope at the central frequency being: ... In the original definition of the slope filter, the responses are multiplied by -1, so do this here. This results in a total slope of: ... As can be seen from the following plot, the linear approximation is very accurate between the two resonant peaks. For this plot B = 500, f1=-750, and f2=750. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 93. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 94. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 95. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 96. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 97. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 98. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

99. Problem 4.23 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 100. Problem 4.24 The amplitude spectrum corresponding to the Gaussian pulse ... is given by the magnitude of its Fourier transform. ... where we have used the convolution theorem Problem 4.25 The Carson rule bandwidth for GSM is ( ) 2 ... The peak deviation is given by ... With BT = 0.3 and T = 3.77 microseconds, the peak deviation is 59.7 kHz From Figure 4.22, the one-sided 3-dB bandwidth of the modulating signal is approximately 50 kHz. Combining these two results, the Carson rule bandwidth is ( )2 59.7 50 219.4 kHz TB = + = The 1-percent FM bandwidth is given by Figure 4.9 with 59.7 1.19 50 f W β Δ = = = . From the vertical axis we find that 6TB f = Δ , which implies BT = 6(59.7) = 358.2 kHz. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

101. Problem 4.26. a) Beta # of side frequencies 1 2 2 5 8 10 14 b)By experimentation, a modulation index of 2.408, will force the amplitude of the carrier to be about zero. This corresponds to the first root of J0(β), as predicted by the theory. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

102. Problem 4.27. a)Using the original MATLAB script, the rms phase error is 6.15 % b)Using the plot provided, the rms phase error is 19.83% Problem 4.28 a)The output of the detector signal is multiplied by -1. This results from the fact that m(t)=cos(t) is integrated twice. Once to form the transmitted signal and once by the envelope detector. In addition, the signal also has a DC offset, which results from the action of the envelope detector. The change in amplitude is the result of the modulation process and filters used in detection. b)If ( ) 0.5cos 2 3 m f s f t t π ... then some form of clipping is observed. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

103. The above signal has been multiplied by a constant gain factor in order to highlight the differences with the original message signal. c)The earliest signs of distortion start to appear above about fm =4.0 kHz. As the message frequency may no longer lie wholly within the bandwidth of either the differentiator or the low-pass filter. This results in the potential loss of high-frequency message information. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

104. 4.29. By tracing the individual steps of the MATLAB algorithm, it can be seen that the resulting sequence is the same as for the 2nd order PLL. ( ) is the phase error ( ) in the theoretical model.ee t φ The theoretical model of the VCO is: ... and the discrete-time model is: VCOState VCOState 2 (1) ... which approximates the integrator of the theoretical model. The loop filter is a PI-controller, and has the transfer function: ( ) 1 a H f j f = + This is simply a combination of a sum plus an integrator, which is also present in the MATLAB code: Filterstate Filterstate ( ) Integrator ( ) Filterstate ( ) Integrator +input e t v t = + b)For smaller kv, the lock-in time is longer, but the output amplitude is greater. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

105. c)The phase error increases, and tracks the message signal. d)For a single sinusoid, the track is lost if 0 0wherem f v c vf K K k k A A= For this question, K0=100 kHz, but tracking degrades noticeably around 60-70 kHz. e)No useful signal can be extracted. By multiplying s(t) and r(t), we get: sin(VCOState) sin(4 VCOState) 2 c vf c f A A k f t ... This is substantially different from the original error signal, and cannot be seen as an adequate approximation. Of particular interest is the fact that this equation is substantially more sensitive to changes in φ than the previous one owing to the presence of the gain factor ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 106. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

107. Chapter 5 Problems 5.1. (a) Given 2 2 ( )1 ( ) exp( ) 2 2 X x x f x μ σ πσ − = − and 2 Y X= ... , then by applying the time-shifting and scaling properties: ... For any odd value of n, taking ( )n x n d d φ ν leaves the lowest non-zero derivative as ν2k-n . When this derivative is taken for v=0, then [ ]n E X =0. For even values of n, only the terms in the resulting derivative that correspond to ν2k-n = ν0 are non-zero. In other words, only the even terms in the sum that correspond to k = n/2 are retained. ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

108. 5.2. (a) All the inputs for x ≤0 are mapped to y = 0. However, the probability that x > 0 is unchanged. Therefore the probability density of x ≤0 must be concentrated at y=0. (b) Recall that) 1 where ( ) is an even function.x f x dx f x ∞ −∞ =∫ Because fy(y) is a probability distribution, its integral must equal 1. ... Therefore, the integral over the delta function must be 0.5. This means that the factor k must also be 0.5. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

109. 5.3 (a) (b) ( ) ( )y P y ... Use the cumulative Gaussian distribution, ... Assume: ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 110. Problem 5.4 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 111. Problem 5.5 If, for a complex random process Z(t) ... then (i) The mean square of a complex process is given by ... (ii) We show ( )ZR τ has conjugate symmetry by the following ... where we have used the change of variable s = t - τ. (iii) Taking an approach similar to that of Eq. (5.67) ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

112. Problem 5.6 a) ... Let ω1=2πf1 ω2=2πf2 After distributing the terms, consider the first term: ... The expectation over θ1 goes to zero, because θ1 is distributed uniformly over [-π,π]. This result also applies to the term ... Both cross-terms go to zero. ... If f1 = f2, the only cross terms may be different: ... But, unless θ1=θ2, the cross-terms will also go to zero. ... If θ1=θ2, then the cross-terms become: ... After computing the expectations, the cross-terms simplify to: ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 113. Problem 5.7 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 114. Problem 5.8 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 115. Problem 5.9 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 116. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 117. Problem 5.10 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 118. Problem 5.11 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 119. Problem 5.12 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 120. Problem 5.13 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 121. Problem 5.14 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 122. Problem 5.15 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 123. Problem 5.16 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 124. Problem 5.17 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 125. Problem 5.18 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 126. Problem 5.19 Problem 5.20 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 127. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 128. Problem 5.21 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 129. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 130. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 131. Problem 5.22 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 132. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 133. Problem 5.23 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 134. Problem 5.24 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 135. Problem 5.25 Problem 5.26 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 136. Problem 5.27 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 137. Problem 5.28 c)Given filter, ( )H f , let ln ( )H fα = and the Paley-Wiener criterion for causality is: ... For the filter of part (b) ... The first and the last terms have no impact on the absolute integrability of the previous expression, and so do not matter as far as evaluating the above criterion. This leaves the only condition: ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 138. Problem 5.29 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 139. Problem 5.30 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 140. Problem 5.31 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 141. Problem 5.32 Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 142. Problem 5.33 (a) The receiver position is given by x(t) = x0+vt Thus the signal observed by the receiver is ... The Doppler shift of the frequency observed at the receiver is ... From the plots, it can be seen that both the real and imaginary components are approximately Gaussian. ... the right-hand side of Eq.(5.173) is equal to its conjugate. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 143. Problem 5.33 (b) ... where the second line comes from the symmetry of cos and sin under a -π/2 translation. Eq. (5.174) follows directly from this upon noting that, since the expectation result is real-valued, the right-hand side of Eq.(5.173) is equal to its conjugate. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

144. Problem 5.34 The histogram has been plotted for 100 bins. Larger numbers of bins result in larger errors, as the effects of averaging are reduced. Distance Relative Error 0 0.94% 1σ 2.6 % 2σ 4.8 % 3σ 47.4% 4σ 60.7% The error increases further from the mean. It is also important to note that the random numbers generated by this MATLAB procedure can never be greater than 5. Thus, this is very different from the Gaussian distribution, for which there is a non-zero probability for any real number. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 145. 5.34 Code Listing %Problem 5.34 %Set the number of samples to be 20,000 N=20000 N=100; Z=zeros(1,20000); for i=1:N for j=1:5 Z(i)=Z(i)+2*(rand(1)-0.5); end end sigma=sqrt(var(Z-mean(Z))); %Calculate a Gaussian with the same variance as Z G=1/(sqrt(2*pi)*sigma)*exp(-(l.^2)/(2*sigma^2)); %Create a gaussian function with the same variance as Z [X,C]=hist(Z,M); l=linspace(C(1),C(M),M); delta2=abs(l(1)-l(2)); X=X/(20000*delta2);

146. 5.35 (a) For the generated sequence: 2 ˆ 0.0343 0.0493 ˆ 5.597 y y μ σ = = The theoretical values are: μy = 0 (by inspection). The theoretical value of 2 yσ =5.56. See 5.35 (c) for the calculation. 5.35 (b) From the plots, it can be seen that both the real and imaginary components are approximately Gaussian. In addition, from statistics, the sum of two zero-mean Gaussian signals is also Gaussian distributed. As a result, the filter output must also be Gaussian. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 147. 5.35 (c) Rh(z) = H(z)H(z-1) = But, Ry(z) = Rh(z)Rw(z) Taking the inverse z-transform: ... From the plots, the measured and observed autocorrelation are almost identical. ... Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved. 148. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

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182. There are several features to comment on: (i) The component at +4 kHz is due to aliasing of the -6 kHz sinusoid; and the component at -4kHz is due to aliasing of the +6 kHz sinusoid. (ii) The lower frequency is at 2 kHz is six times larger than that at 4 kHz. One would expect the power ratio to be 4:1, not 6:1. The difference is due to relationship between the FFTsize (period) and the sampling rate. (Try a sampling rate of 10.24 kHz and compare.) (b) The spectrum with a 11 kHz sampling rate is shown below. -6 -4 -2 0 2 4 6 0 0.5 1 1.5 2 2.5 x 10 5 Frequency (kHz) AmplitudeSpectrum As expected the 2kHz component is unchanged in frequency, while the aliased component is shifted to reflect the new sampling rate. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

183. Problem 7.23 (a) The expanding portion of the μ-law compander is given by ... (b) (i) For the non-companded case, the rms quantization error is determined by step size. The step size is given by the maximum range over the number of quantization steps 2 2Q A Δ = For this signal the range is from +10 to -10, so A = 10 and with Q = 8, we have Δ = 0.078. From Eq. ( ), the rms quantization error is then given by ... (ii) For a fair comparison, the signal must have similar amplitudes. The rms error with companding is 0.0037 which is significantly less. The plot is shown below. Note that the error is always positive. 0 50 100 150 200 250 300 350 400 450 -0.005 0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 Rest TBD. Copyright © 2009 John Wiley & Sons, Inc. All Rights Reserved.

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