Ecx-Antenna

Monday, 11 November 2024   12.52

ExamExampleCiEAnte...

[redacted]

Problem 3 (15%)
The normalised radiation intensity of a given antenna is given by: $U = cos(2\theta)$.
The intensity exist only in the $0 <= \theta <= \pi/2$, $0 <= \phi <= 2\pi$ region and is zero elsewhere.
Find

3.a (10%) the exact directivity (dimensionless and in dBi).

3.b (5%) the azimuthal and elevation plane half-power beamwidths in degrees (hint: an elevation plane is for a fixed ϕ).

Problem 4 (35%)
A Bluetooth receiver operating at 2500 MHz need 50 picro Watt for errorfree transmission and receive its signal from a 0 dBm transmitter by a half wave dipole antenna connected to the receiver. The transmitter can use a 50 by 50 mm antenna area.

4.a (15%) Find the maximum distance of communication if freespace propagation can be assumed.

4.b (5%) Give under which conditions the maximum distance is obtained.

4.c (5%) Find the maximum distance if the reader uses circular polarization.

4.d (10%) If the receiver and transmitter is operated above a perfect reflecting surface, what is then the maximum distance. Assume the height of both the receiver and transmitter is one meter above the reflection surface.

A)

$\cos(2\theta) \Rightarrow U_{max} = 1$

$$D_0 = \frac{4\pi \; U_{max}}{P_{rad}}$$

$$P_{rad} = A_0 \int_0^{\pi/2} \int_0^{2\pi} U \cdot \sin(\theta) \, d\phi \, d\theta = \frac{2\pi}{3}$$

$$D_0 = \frac{4\pi}{2\pi/3} \Rightarrow 6 \; [\cdot]$$

in $dB_i = 10 \cdot \log_{10}(6) = 7.782 \; [dB_i]$

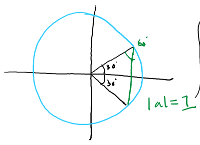
B)

for φ, Azimuth $= 360°$

for θ

$$Solve\left(U(\theta) = \frac{1}{2} U(\theta), \theta\right) = \frac{\pi}{6} = \frac{\pi}{6} \cdot \frac{180}{\pi} = 30° \quad \text{så } 60° \text{ ialt}$$

ellers, Johan resanoment.



$\cos(60°) = \frac{1}{2}$

$\sin(30°) = \frac{1}{2}$

Og vi vil gerne have den hvor vi har en $\frac{1}{2}$ og derfor har vi 60° in all

P4)

$T_x = 50mm \times 50mm \qquad 1mW \quad > 2500 \; MHz$

$R_x = D_r = 1,643 \qquad min \; power = 50 \cdot 10^{-12}$

$$D_t = \frac{4\pi A}{\lambda} = 2,18$$

A)

$$R^2 = \frac{P_t}{P_R} \cdot \frac{D_t \cdot D_r \cdot \lambda^2}{(4\pi)^2} \cdot P_Q$$

for this case

$$R = \sqrt{\frac{P_t}{P_2} \frac{D_t D_r \lambda^2}{(4\pi)^2}} = 80.85$$

B)

- Perfect polarazation
- Impedance matched
- Perfect line of sight
-

C) Så

$$R = \sqrt{\frac{P_t}{P_r} \frac{D_t \, D_r \, \lambda^2}{(4\pi)^2} \cdot P_Q} = 57,17 \;\Big|_{P_Q = \frac{1}{2}}$$

D)

$$\frac{P_r}{P_t} = D_t D_r \left(\frac{h_T h_n}{R^2}\right)^2 =$$

$$D_T D_r \frac{P_t}{P_r} h_T h_r^2 \quad = R^4$$

$$R = \sqrt[4]{D_T D_r \frac{P_T}{P_r} (h_T h_n)^2}$$

Sol-Antenna

Thursday, 2 January 2025 08.23

SolutionExamExampl...

[redacted]

Answers

Problem 3

The radiation intensity of a given antenna is : $U = |\cos(2\theta)|$ and the intensity exists in the region defined by $0 \leq \theta \leq \frac{\pi}{2}$ and $0 \leq \varphi \leq 2\pi$.

3.a. Directivity :

To find the total radiated power the radiation intensity is integrated over its closed surface S.

$$S = \begin{cases} 0 \leq \theta \leq \frac{\pi}{2} \\ 0 \leq \varphi \leq 2\pi \\ 0 \text{ elsewhere} \end{cases}$$

$$P_{rad} = \oiint_S U\, dS = \oint_0^{2\pi} \oint_0^{\frac{\pi}{2}} U \sin\theta \, d\theta \, d\varphi = \oint_0^{2\pi} d\varphi \oint_0^{\frac{\pi}{2}} |\cos(2\theta)| \sin\theta \, d\theta$$

$$P_{rad} = \oint_0^{2\pi} d\varphi \oint_0^{\frac{\pi}{2}} |1 - 2\sin^2\theta| \sin\theta \, d\theta = \oint_0^{2\pi} d\varphi \oint_0^{\frac{\pi}{2}} |\sin\theta - 2\sin^3\theta| \, d\theta \ \ (\text{because } \sin\theta \geq 0 \text{ here})$$

$$\boldsymbol{P_{rad}} = [1]_0^{2\pi} * abs\left([-\cos\theta]_0^{\frac{\pi}{2}} + \left[\frac{2}{3}\sin^2\theta\cos\theta + \frac{4}{3}\cos\theta\right]_0^{\frac{\pi}{2}} \right) = 2\pi * abs\left(1 + \left(-\frac{4}{3}\right)\right) = \boldsymbol{\frac{2}{3}\pi}$$

Note : Power must be positive.

The maximum radiation is directed along $\theta = 0$. Thus, $U_{max} = 1$.

The maximum directivity is equal to :

$$\boldsymbol{D_0} = \frac{4\pi\, U_{max}}{P_{rad}} = \boldsymbol{6}$$

$$\boldsymbol{D_0(dBi)} = 10 * \log10(6) = \boldsymbol{7{,}8\ dBi}$$

3.b. HPBW :

The half-power beamwidth can be found with the function equal to half of $U_{max}(\theta)$.

Thus, $\frac{1}{2} U_{max}(\theta) = \frac{1}{2} \Rightarrow \cos(2\theta_h) = \frac{1}{2} \Rightarrow \theta = \frac{\pi}{6} = 0{,}5236$ rad

Because U is symmetric around $\theta = 0$, **HPBW(el)** = 2*0,5236 = **1,0472 rad= 60°**

Because U doesn't depend on φ , **HPBW(az)** = 2*pi = **6,2832 rad= 360°**

Problem 4

Data:

$$f = 2500MHz \Rightarrow \lambda = \frac{c}{f} = 0.12\, m$$
$$P_r = 50.10^{-12}\, W\, , P_t = 0\, dBm = 1mW$$
$$A = 2{,}50.10^{-3} m^2$$

4.a. Free space propagation :

Friis transmission equation can be applied assuming reflection and polarization – matched lossless antennas:

$$\frac{P_r}{P_t} = \lambda^2 \frac{D_t * D_r}{(4\pi R)^2}$$

Where $\boldsymbol{D_t} = \frac{4\pi A}{\lambda^2} = \mathbf{2,181}$ and $\boldsymbol{D_r} = \mathbf{1,643}$ for the half wave dipole.

The maximum distance of communication in free space is **R = 80,85m**

4.b. The maximum distance in free space is achieved under the following conditions :

- Perfect impedance matching
- Perfect polarization matching
- Lossless antennas

4.c. In this case the reader uses circular polarization resulting in a mismatched polarization and thus losses. The polarization mismatch is 50 % with one circularly polarized antenna.

Friis law gives $R^2 = \frac{P_t}{P_r}\frac{D_t * D_r * \lambda^2}{(4\pi)^2} * \frac{1}{2}$. **R = 57,17 m**

4.d. Perfect reflecting surface:

In the case where a LOS plus a ground reflection exist the following equation applies for lossless antennas:

$$\frac{P_r}{P_t} = D_t * D_r \left(\frac{h_t h_r}{R^2}\right)^2,$$

and is valid for $R \geq \frac{4 h_t h_r}{\lambda} = 33{,}33m\ (h_t = h_r = 1m)$

Note: This equation, which replaces the Friis' law for R>33m, implies that the received power is independent of frequency and increases with the square of the height for both the MS and the BS.

The maximum distance for polarization matched antennas is **R = 92,01 m.**

Antenna-Quick-Fix

Thursday, 2 January 2025 10.34

TABLE 4.3 Summary of Important Parameters and Associated Formulas and Equation Numbers for a Dipole in the Far Field

Parameter	Formula	Equation Number
	Infinitesimal Dipole $(l \leq \lambda/50)$	
Normalized power pattern	$U = (E_{\theta n})^2 = C_0 \sin^2\theta$	(4-29)
Radiation resistance R_r	$R_r = \eta\left(\frac{2\pi}{3}\right)\left(\frac{l}{\lambda}\right)^2 = 80\pi^2\left(\frac{l}{\lambda}\right)^2$	(4-19)
Input resistance R_{in}	$R_{in} = R_r = \eta\left(\frac{2\pi}{3}\right)\left(\frac{l}{\lambda}\right)^2 = 80\pi^2\left(\frac{l}{\lambda}\right)^2$	(4-19)
Wave impedance Z_w	$Z_w = \frac{E_\theta}{H_\phi} \simeq \eta = 377$ ohms	
Directivity D_0	$D_0 = \frac{3}{2} = 1.761$ dB	(4-31)
Maximum effective area A_{em}	$A_{em} = \frac{3\lambda^2}{8\pi}$	(4-32)
Vector effective length ℓ_e	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta l \sin\theta$ $\lvert\boldsymbol{\ell}_e\rvert_{\max} = \lambda$	(2-92) Example 4.2
Half-power beamwidth	HPBW = 90°	(4-65)
Loss resistance R_L	$R_L = \frac{l}{P}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{l}{2\pi b}\sqrt{\frac{\omega\mu_0}{2\sigma}}$	(2-90b)
	Small Dipole $(\lambda/50 < l \leq \lambda/10)$	
Normalized power pattern	$U = (E_{\theta n})^2 = C_1 \sin^2\theta$	(4-36a)
Radiation resistance R_r	$R_r = 20\pi^2\left(\frac{l}{\lambda}\right)^2$	(4-37)
Input resistance R_{in}	$R_{in} = R_r = 20\pi^2\left(\frac{l}{\lambda}\right)^2$	(4-37)
Wave impedance Z_w	$Z_w = \frac{E_\theta}{H_\phi} \simeq \eta = 377$ ohms	(4-36a), (4-36c)
Directivity D_0	$D_0 = \frac{3}{2} = 1.761$ dB	
Maximum effective area A_{em}	$A_{em} = \frac{3\lambda^2}{8\pi}$	
Vector effective length ℓ_e	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta \frac{l}{2}\sin\theta$	(2-92)
	$\lvert\boldsymbol{\ell}_e\rvert_{\max} = \frac{l}{2}$	(4-36a)
Half-power beamwidth	HPBW = 90°	(4-65)
	Half Wavelength Dipole $(l = \lambda/2)$	
Normalized power pattern	$U = (E_{\theta n})^2 = C_2\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]^2 \simeq C_2 \sin^3\theta$	(4-87)
Radiation resistance R_r	$R_r = \frac{\eta}{4\pi}C_{in}(2\pi) \simeq 73$ ohms	(4-93)

(continued overleaf)

TABLE 4.3 *(continued)*

Parameter	Formula	Equation Number
Input resistance R_{in}	$R_{in} = R_r = \frac{\eta}{4\pi} C_{in}(2\pi) \simeq 73$ ohms	(4-79), (4-93)
Input impedance Z_{in}	$Z_{in} = 73 + j42.5$	(4-93a)
Wave impedance Z_w	$Z_w = \frac{E_\theta}{H_\phi} \simeq \eta = 377$ ohms	
Directivity D_0	$D_0 = \frac{4}{C_{in}(2\pi)} \simeq 1.643 = 2.156$ dB	(4-91)
Vector effective length ℓ_e	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta \frac{\lambda}{\pi} \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$	(2-91)
	$\lvert\boldsymbol{\ell}_e\rvert_{max} = \frac{\lambda}{\pi} = 0.3183\lambda$	(4-84)
Half-power beamwidth	HPBW = 78°	(4-65)
Loss resistance R_L	$R_L = \frac{l}{2P}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{l}{4\pi b}\sqrt{\frac{\omega\mu_0}{2\sigma}}$	Example (2-13)
	Quarter-Wavelength Monopole ($l = \lambda/4$)	
Normalized power pattern	$U = (E_{\theta n})^2 = C_2 \left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]^2 \simeq C_2 \sin^3\theta$	(4-87)
Radiation resistance R_r	$R_r = \frac{\eta}{8\pi} C_{in}(2\pi) \simeq 36.5$ ohms	(4-106)
Input resistance R_{in}	$R_{in} = R_r = \frac{\eta}{8\pi} C_{in}(2\pi) \simeq 36.5$ ohms	(4-106)
Input impedance Z_{in}	$Z_{in} = 36.5 + j21.25$	(4-106)
Wave impedance Z_w	$Z_w = \frac{E_\theta}{H_\phi} \simeq \eta = 377$ ohms	
Directivity D_0	$D_0 = 3.286 = 5.167$ dB	
Vector effective length ℓ_e	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta \frac{\lambda}{\pi} \cos\left(\frac{\pi}{2}\cos\theta\right)$	(2-91)
	$\lvert\boldsymbol{\ell}_e\rvert_{max} = \frac{\lambda}{\pi} = 0.3183\lambda$	(4-84)

Power (dBm)	Power (W)
-30 dBm	0,000001 W
-20 dBm	0,00001 W
-10 dBm	0,0001 W
0 dBm	0,001 W
1 dBm	0,0012589 W
2 dBm	0,0015849 W
3 dBm	0,0019953 W
4 dBm	0,0025119 W
5 dBm	0,0031628 W
6 dBm	0,0039811 W
7 dBm	0,0050119 W
8 dBm	0,0063096 W
9 dBm	0,0079433 W
10 dBm	0,01 W
20 dBm	0,1 W
30 dBm	1 W
40 dBm	10 W
50 dBm	100 W

husk this fucken!

Prefix		Base 10	Decimal	Adoption [nb 1]
Name	Symbol			
quetta	Q	10^{30}	1 000 000 000 000 000 000 000 000 000 000	2022[3]
ronna	R	10^{27}	1 000 000 000 000 000 000 000 000 000	
yotta	Y	10^{24}	1 000 000 000 000 000 000 000 000	1991
zetta	Z	10^{21}	1 000 000 000 000 000 000 000	
exa	E	10^{18}	1 000 000 000 000 000 000	1975[4]
peta	P	10^{15}	1 000 000 000 000 000	
tera	T	10^{12}	1 000 000 000 000	

Prefix		Base 10	Decimal	Adoption [nb 1]
Name	Symbol			
quetta	Q	10^{30}	1 000 000 000 000 000 000 000 000 000 000	2022[3]
ronna	R	10^{27}	1 000 000 000 000 000 000 000 000 000	
yotta	Y	10^{24}	1 000 000 000 000 000 000 000 000	1991
zetta	Z	10^{21}	1 000 000 000 000 000 000 000	
exa	E	10^{18}	1 000 000 000 000 000 000	1975[4]
peta	P	10^{15}	1 000 000 000 000 000	
tera	T	10^{12}	1 000 000 000 000	1960
giga	G	10^{9}	1 000 000 000	
mega	M	10^{6}	1 000 000	1873
kilo	k	10^{3}	1 000	1795
hecto	h	10^{2}	100	
deca	da	10^{1}	10	
—	—	10^{0}	1	—
deci	d	10^{-1}	0.1	1795
centi	c	10^{-2}	0.01	
milli	m	10^{-3}	0.001	
micro	μ	10^{-6}	0.000 001	1873
nano	n	10^{-9}	0.000 000 001	1960
pico	p	10^{-12}	0.000 000 000 001	
femto	f	10^{-15}	0.000 000 000 000 001	1964
atto	a	10^{-18}	0.000 000 000 000 000 001	
zepto	z	10^{-21}	0.000 000 000 000 000 000 001	1991
yocto	y	10^{-24}	0.000 000 000 000 000 000 000 001	
ronto	r	10^{-27}	0.000 000 000 000 000 000 000 000 001	2022[3]
quecto	q	10^{-30}	0.000 000 000 000 000 000 000 000 000 001	

S. No.	Dielectric Material	Relative Permittivity	Loss Tangent
1	Air	1.0006	0
2	FR4 epoxy	4.4	0.02
3	Bakelite	4.8	0.0002
4	Duroid	2.2	0.0009
5	Quartz glass	3.78	0
6	Foam	1.03	0
7	Polystyrene	2.55	0
8	Plexiglas	2.59	0.0068
9	Fused quartz	3.78	0
10	E glass	6.22	0.0023
11	RO4725JXR	2.55	0.0022
12	RO4730JXR	3	0.0023
13	Rogers RT/duroid 5870/5880	2.33/2.2	0.0012/0.0009
14	Teflon	2.1	0.001
15	Taconic CER-10	10	0.0035
16	Taconic RF-30	3	0.0014
17	Taconic RF-35	3.5	0.0018

TABLE 26.1 Dielectric Constants and Dielectric Strengths of Various Materials at Room Temperature

Material	Dielectric Constant κ	Dielectric Strength[a] (V/m)
Air (dry)	1.000 59	3×10^6
Bakelite	4.9	24×10^6
Fused quartz	3.78	8×10^6
Neoprene rubber	6.7	12×10^6
Nylon	3.4	14×10^6
Paper	3.7	16×10^6
Polystyrene	2.56	24×10^6
Polyvinyl chloride	3.4	40×10^6
Porcelain	6	12×10^6
Pyrex glass	5.6	14×10^6
Silicone oil	2.5	15×10^6
Strontium titanate	233	8×10^6
Teflon	2.1	60×10^6
Vacuum	1.000 00	—
Water	80	—

[a] The dielectric strength equals the maximum electric field that can exist in a dielectric without electrical breakdown. Note that these values depend strongly on the presence of impurities and flaws in the materials.

Ecx-Networking

Friday, 3 January 2025 08.15

examExam
pleNetwo...

Exam problems examples (networking part with TKM).

Problem 1.

Download a file cap3.pcapng. Open it with wireshark and answer the following questions:

1. a) Find the IP address assigned by DHCP to the client computer b) What is the MAC address of the client computer?
2. The same computer makes an ARP request. What is the Target's IP address and MAC address?
3. NTP (Network Time Protocol) is used to synchronize time and dates between computers. The capture contains some NTP packets. a)How many NTP packets does the capture contain? b) What date does the NTP server say it is?

Problem 2.

Assume that it takes 1 ms from a bit leaves A to the bit is received in B. Assume also that the bandwidth of the line is 5Mbit/s. How long does it take to transfer the frame of 1500 bytes from A to B? (round to nearest ms).

Problem 3.

What is the difference between error detection and error correction. Give an example where it is more suitable to use error correction mechanisms.

Problem 4.

Which layer header contains

a) MAC address
b) Destination IP address
c) SYN bits when a connection is established

Problem 5.

What is the purpose of Inter Frame Space in 802.11 MAC protocol?

Problem 6.

a) Why authentication is needed? b) given that two devices share a common secret, how authentication can be done?

Problem 1.

Download a file cap3.pcapng. Open it with wireshark and answer the following questions:

1. a) Find the IP address assigned by DHCP to the client computer b) What is the MAC address of the client computer?
2. The same computer makes an ARP request. What is the Target's IP address and MAC address?
3. NTP (Network Time Protocol) is used to synchronize time and dates between computers. The capture contains some NTP packets. a)How many NTP packets does the capture contain? b) What date does the NTP server say it is?

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
2	0.000160947	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
3	1.000552726	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
4	1.000693942	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
5	2.343419534	0.0.0.0	255.255.255.255	DHCP	335	DHCP Discover - Transaction ID 0xbb0bc02e
6	2.343618497	192.168.122.1	192.168.122.43	DHCP	342	DHCP Offer - Transaction ID 0xbb0bc02e
7	2.348326426	0.0.0.0	255.255.255.255	DHCP	347	DHCP Request - Transaction ID 0xbb0bc02e
8	2.348490619	192.168.122.1	192.168.122.43	DHCP	345	DHCP ACK - Transaction ID 0xbb0bc02e
9	3.002276047	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
10	3.002614385	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
11	3.760636291	192.168.122.1	192.168.122.255	UDP	86	57621 → 57621 Len=44
12	5.699378825	52:54:00:7f:e3:df	Broadcast	ARP	42	Who has 192.168.122.1? Tell 192.168.122.43
13	5.699405510	52:54:00:26:63:d3	52:54:00:7f:e3:df	ARP	42	192.168.122.1 is at 52:54:00:26:63:d3
14	5.699509813	192.168.122.43	192.168.122.1	DNS	87	Standard query 0x8c45 A api.snapcraft.io OPT
15	5.699565537	192.168.122.43	192.168.122.1	DNS	87	Standard query 0x4e48 AAAA api.snapcraft.io OPT
16	5.699803865	192.168.122.1	192.168.122.43	DNS	87	Standard query response 0x4e48 AAAA api.snapcraft.io OPT
17	5.700205858	192.168.122.1	192.168.122.43	DNS	183	Standard query response 0x8c45 A api.snapcraft.io A 91.189.92.20 A 91.189.92.38 A 91.189.92.39 A 91.189.92.40 A 91.189.92.41 A 91.189.92.19 OPT
18	5.824067213	192.168.122.43	192.168.122.1	DNS	87	Standard query 0x99ea AAAA api.snapcraft.io OPT
19	5.824134404	192.168.122.1	192.168.122.43	DNS	87	Standard query response 0x99ea AAAA api.snapcraft.io OPT
20	34.377316123	192.168.122.43	192.168.122.1	DNS	85	Standard query 0xf238 A ntp.ubuntu.com OPT
21	34.377652061	192.168.122.43	192.168.122.1	DNS	85	Standard query 0xe4df AAAA ntp.ubuntu.com OPT
22	34.378541941	192.168.122.1	192.168.122.43	DNS	149	Standard query response 0xf238 A ntp.ubuntu.com A 91.189.91.157 A 91.189.94.4 A 91.189.89.198 A 91.189.89.199 OPT
23	34.378644112	192.168.122.1	192.168.122.43	DNS	141	Standard query response 0xe4df AAAA ntp.ubuntu.com AAAA 2001:67c:1560:8003::c7 AAAA 2001:67c:1560:8003::c8 OPT
24	34.380693425	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
25	34.480819221	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server
26	60.287131027	192.168.122.1	192.168.122.255	UDP	86	57621 → 57621 Len=44
27	66.657850615	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
28	66.758738234	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server
29	78.772120824	192.168.122.43	192.168.122.1	UDP	72	38384 → 5678 Len=30
30	114.574553950	192.168.122.1	224.0.0.251	MDNS	87	Standard query 0x0000 PTR _spotify-connect._tcp.local, "QM" question
31	116.398532831	192.168.122.1	239.255.255.250	SSDP	167	M-SEARCH * HTTP/1.1
32	117.002885220	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
33	118.004196954	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
34	119.005807284	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
35	120.007169364	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
36	123.512286057	192.168.122.1	192.168.122.255	UDP	86	57621 → 57621 Len=44
37	130.907827292	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
38	131.007764506	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server
39	172.974264001	192.168.122.1	192.168.122.255	UDP	86	57621 → 57621 Len=44
40	234.534572937	192.168.122.1	192.168.122.255	UDP	86	57621 → 57621 Len=44
41	234.574768068	192.168.122.1	224.0.0.251	MDNS	87	Standard query 0x0000 PTR _spotify-connect._tcp.local, "QM" question
42	236.398577211	192.168.122.1	239.255.255.250	SSDP	167	M-SEARCH * HTTP/1.1
43	237.005672660	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
44	238.006783463	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
45	239.007723992	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
46	240.009260948	192.168.122.1	239.255.255.250	SSDP	208	M-SEARCH * HTTP/1.1
47	259.158805105	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
48	259.258975514	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server

```
Hops: 0
Transaction ID: 0xbb0bc02e
Seconds elapsed: 1
Bootp flags: 0x0000 (Unicast)
Client IP address: 0.0.0.0
Your (client) IP address: 192.168.122.43
Next server IP address: 192.168.122.1
Relay agent IP address: 0.0.0.0
Client MAC address: 52:54:00:7f:e3:df (52:54:00:7f:e3:df)
Client hardware address padding: 00000000000000000000
Server host name not given
Boot file name not given
```

a

b

default getway. Hvis ikke andet, så her

2) ARP

No.	Time	Source	Destination	Protocol	Length	Info
9	3.002276047	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
10	3.002614385	192.168.122.1	224.0.0.251	MDNS	82	Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
11	3.760636291	192.168.122.1	192.168.122.255	UDP	86	57621 → 57621 Len=44
12	5.699378825	52:54:00:7f:e3:df	Broadcast	ARP	42	Who has 192.168.122.1? Tell 192.168.122.43
13	5.699405510	52:54:00:26:63:d3	52:54:00:7f:e3:df	ARP	42	192.168.122.1 is at 52:54:00:26:63:d3
14	5.699509813	192.168.122.43	192.168.122.1	DNS	87	Standard query 0x8c45 A api.snapcraft.io OPT
15	5.699565537	192.168.122.43	192.168.122.1	DNS	87	Standard query 0x4e48 AAAA api.snapcraft.io OPT
16	5.699803865	192.168.122.1	192.168.122.43	DNS	87	Standard query response 0x4e48 AAAA api.snapcraft.io OPT

Så:

```
42 Who has 192.168.122.1? Tell 192.168.122.43
42 192.168.122.1 is at 52:54:00:26:63:d3
```

Dig på 192... fortæl det til 19.2

192, her med MACadr, 52:54..

3) NTP

No.	Time	Source	Destination	Protocol	Length	Info
24	34.380693425	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
25	34.480819221	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server
27	66.657850615	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
28	66.758738234	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server
37	130.907827292	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
38	131.007764506	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server
47	259.158805105	192.168.122.43	91.189.91.157	NTP	90	NTP Version 4, client
48	259.258975514	91.189.91.157	192.168.122.43	NTP	90	NTP Version 4, server

Der er 8 styks.

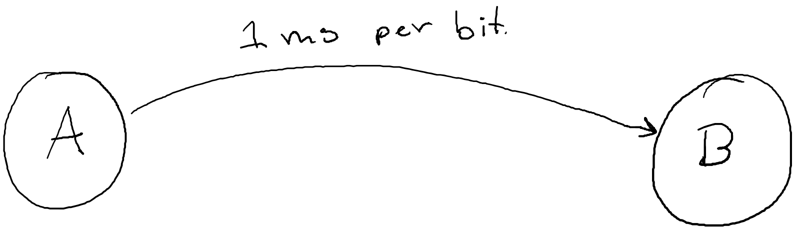
```
Network Time Protocol (NTP Version 4, server)
  Flags: 0x24, Leap Indicator: no warning, Version number: NTP Version 4, Mode: server
  [Request In: 27]
  [Delta Time: 0.100887619 seconds]
  Peer Clock Stratum: secondary reference (2)
  Peer Polling Interval: 3 (8 seconds)
  Peer Clock Precision: -24 (0,000000060 seconds)
  Root Delay: 0,046432 seconds
  Root Dispersion: 0,023010 seconds
  Reference ID: 132.163.96.1
  Reference Timestamp: Dec 14, 2021 13:19:45.270827755 UTC
  Origin Timestamp: Dec 14, 2021 13:26:49.219124305 UTC
  Receive Timestamp: Dec 14, 2021 13:26:49.992623017 UTC
  Transmit Timestamp: Dec 14, 2021 13:26:49.992645397 UTC
```

Dato en er Dec 14 2021

Ref. timestamp er sidst vi spurgte om klokken

Problem 2.

Assume that it takes 1 ms from a bit leaves A to the bit is received in B. Assume also that the bandwidth of the line is 5Mbit/s. How long does it take to transfer the frame of 1500 bytes from A to B? (round to nearest ms).



1500 byte = 12000 bits

$5 \text{ M bit/s} = 5 \cdot 10^6$

$$\frac{1500 \cdot 8}{5 \cdot 10^6} = 0.0024 \, [s] = 2,4 \, m[s]$$

Med et delay på en ms, = 3,4 = 4 m[s]

Problem 3.

What is the difference between error detection and error correction. Give an example where it is more suitable to use error correction mechanisms.

I error detection kan man se at der er en fejl, men du kan ikke gøre noget ved det, men du kan spørge igen om det.

I correction, kan du se det OG FIXE det selv.
Det er smart der hvor det tager lang tid at sende frem og tilbage, så det er besværligt at skulle vente på et svar tilbage.

Problem 4.

Which layer header contains

a) MAC address L2
b) Destination IP address L3
c) SYN bits when a connection is established L4

OSI (Open Source Interconnection) 7 Layer Model

Layer	Application/Example	Central Device/ Protocols		DOD4 Model
Application (7) Serves as the window for users and application processes to access the network services.	**End User layer** Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management	**User Applications** SMTP	GATEWAY Can be used on all layers	Process
Presentation (6) Formats the data to be presented to the Application layer. It can be viewed as the "Translator" for the network.	**Syntax layer** encrypt & decrypt (if needed) Character code translation • Data conversion • Data compression • Data encryption • **Character Set Translation**	JPEG/ASCII EBDIC/TIFF/GIF PICT		
Session (5) Allows session establishment between processes running on different stations.	**Synch & send to ports** (logical ports) Session establishment, maintenance and termination • Session support - perform security, name recognition, logging, etc.	**Logical Ports** RPC/SQL/NFS NetBIOS names		
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	**TCP** Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing PACKET FILTERING	TCP/SPX/UDP		Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting	**Routers** IP/IPX/ICMP		Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card —— Switch —— NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control	**Switch Bridge WAP** PPP/SLIP Land Based Layers		Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts	**Hub**		

Problem 6.

a) Why authentication is needed? b) given that two devices share a common secret, how authentication can be done?

Authentication er dit ID-kort.
Authorazation er at du har adgang til det sted med dit ID-kort

a) Så det er vigtigt at vi kun sender vores information der hen hvor at den skal, til dem vi stoler på.
b) A, sender en random besked. B, incrypter og sender den retur. A ack. Så kan B sende random besked, A incrypter retur, og B ack. Så er alle sikre på at alle har den key, som man beder om.

Sol-Networking

Friday, 3 January 2025 08.15

examExam
pleNetwo...

Answers to the example problems.

Problem 1.

1. a) 192.168.122.43 b) 52:54:00:7f:e3:df
2. 192.168.122.1, 52:54:00:26:63:d3
3. a) 8 packets b) 2. December 14.

Problem 2.

Answer: 3,4ms
8*1500 bits/(5*10^6)bits/sec = 2,4*10^-3 s= 2,4ms
Time to send the frame 2,4ms + propagation time 1 ms = 3,4ms

Problem 4.

a) L2
b) L3
c) L4

Problem 5.
To introduce priorities and to give higher priorities to the packets like ACK

Ecx-mod1

Friday, 3 January 2025 08.15

old_modula
tion_exam

Problem 1

v(t) denotes a baseband signal to be amplitude modulated:

$$v(t) = 0.5 \cdot \cos(200 \cdot \pi \cdot t) + 1.0 \cdot \cos(400 \cdot \pi \cdot t)$$

a. The coefficients for an ordinary AM-modulation are:
1. amplitude sensitivity: 0,5
2. carrier frequency: 2 kHz
3. carrier amplitude: 10

Calculate the AM-signal $v_{AM}(t)$ and plot the spectrum $V_{AM}(f)$

b. Determine the result of a double-sideband–suppressed-carrier modulation (DSB-SC) of *v(t)* – with a carrier frequency and a carrier amplitude similar to "**a**".
I.e. calculate the signal $v_{dsb\text{-}SC}(t)$ and plot the spectrum $V_{dsb\text{-}SC}(f)$

c. Compare the spectrum $V_{AM}(f)$ with the spectrum $V_{dsb\text{-}SC}(f)$

Problem 2

Consider the signals *x(t)* and *y(t)*:

$x(t)$	=	$A_x(\sin(2 \cdot \pi \cdot 5.000 \cdot t) + \mathrm{sinc}(2 \cdot W_x \cdot t))$;	Bandwidth W_x ~ 8 kHz
$y(t)$	=	$A_y(\sin(2 \cdot \pi \cdot 14.000 \cdot t) + \mathrm{sinc}(2 \cdot W_y \cdot t))$;	Bandwidth W_y ~ 12 kHz

Determine the Nyquist sampling rate for:

a. the signals *x(t)* and *y(t)*

b. the signals $x^2(t)$ and $y^2(t)$

c. the signal $x(t) \cdot y(t)$

Problem 3

A FM signal with modulation index β = 2 is transmitted through an ideal bandpass filter with center frequency f_c, (carrier amplitude 1 volt) and bandwidth $7 \cdot f_m$, where f_c is the carrier frequency and f_m is the frequency of the sinusoidal modulating wave.
Determine the magnitude spectrum of the filter output.

Problem 1

v(t) denotes a baseband signal to be amplitude modulated:

$$v(t) = 0.5 \cdot \cos(200 \cdot \pi \cdot t) + 1.0 \cdot \cos(400 \cdot \pi \cdot t)$$

a. The coefficients for an ordinary AM-modulation are:

1. amplitude sensitivity: 0,5
2. carrier frequency: 2 kHz
3. carrier amplitude: 10

Calculate the AM-signal $v_{AM}(t)$ and plot the spectrum $V_{AM}(f)$

b. Determine the result of a double-sideband–suppressed-carrier modulation (DSB-SC) of *v(t)* – with a carrier frequency and a carrier amplitude similar to "**a**".
I.e. calculate the signal $v_{dsb\text{-}SC}(t)$ and plot the spectrum $V_{dsb\text{-}SC}(f)$

c. Compare the spectrum $V_{AM}(f)$ with the spectrum $V_{dsb\text{-}SC}(f)$

A) $V(t) = 0.5 \cos(\underset{f=100}{200} \cdot \pi \cdot t) + 1.0 \cdot \cos(\underset{f=200}{400} \cdot \pi \cdot t)$

$100 \cdot 2\pi \cdot t$ $\qquad$ $200 \cdot 2\pi \cdot t$

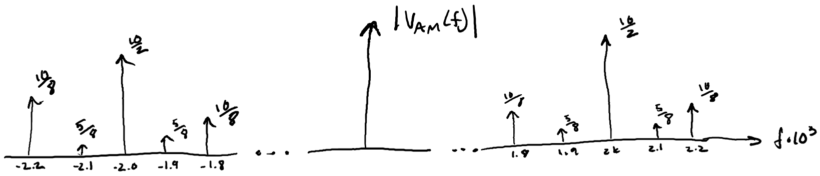
$$V_{AM}(t) = A_c \cdot f_c \cdot V(t) = \underset{A_c}{10} \cdot \underbrace{\cos(2k \cdot 2\pi \cdot t)}_{f_c} \cdot \underbrace{V(t)}_{V(t)}$$

$$V_{AM} = A_c \left[1 + k_a (v(t)) \right] \cdot f_c$$

$$= 10 \left[1 + 0{,}5 \left(0{,}5 \cos(100 \cdot 2\pi t) + 1.0 \cos(200 \cdot 2\pi t) \right] \cos(2k \cdot 2\pi t) \right.$$

$$10 \cos(2k \cdot 2\pi t) + 10 \tfrac{1}{4} \cos(100 \cdot 2\pi t) \cdot \cos(2k \cdot 2\pi t)$$

$$+ 10 \tfrac{1}{2} \cos(200 \cdot 2\pi t) \cdot \cos(2k \cdot 2\pi t)$$



for $\cos(A) \cdot \cos(B) = \dfrac{\cos(A+B)}{2} + \dfrac{\cos(A-B)}{2}$

aka, du får halvdelen af den positive og negative

B)

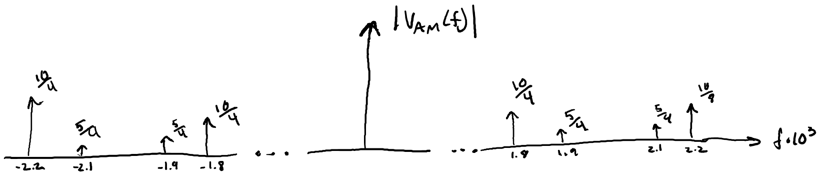
$$V_{am} = A_c \cdot V_c(t) \cdot V(t)$$

$$= 10 \cdot \cos(2k \cdot 2\pi) \cdot \left[\tfrac{1}{2} \cos(100 \cdot 2\pi t) + \cos(200 \cdot 2\pi t) \right]$$

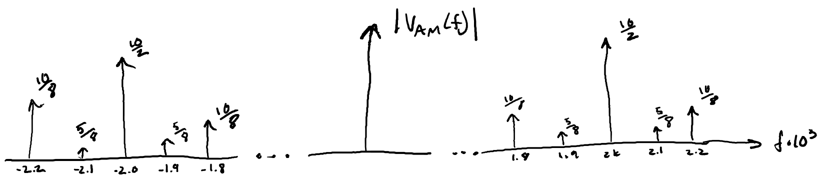
$$= \frac{10}{2} \cos(100 \cdot 2\pi \cdot t) \cos(2k \cdot 2\pi) t + 10 \cos(200 \cdot 2\pi t) \cos(2k\, 2\pi t)$$

$\frac{10}{4}\cos(2100\cdot 2\pi t)+\frac{10}{4}\cos(1900\cdot 2\pi t)+$
$\frac{10}{2}\cos(2200\cdot 2\pi t)+\frac{10}{2}\cos(1800\cdot 2\pi t)$

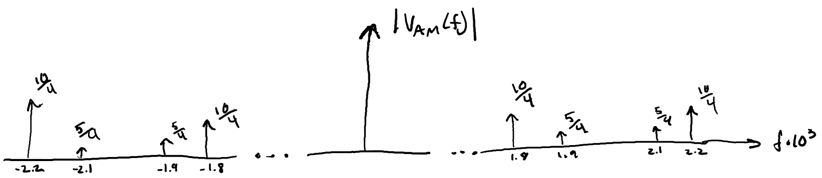
og de findes for negative og pos med $\frac{1}{2}$ amp af det



c)



smaller peaks by $\frac{1}{2}$ grundet fc er med her



Ingen fc, det er urealistisk i den virkelige verden.

Problem 2

Consider the signals *x(t)* and *y(t)*:

$x(t)$	=	$A_x(\sin(2\cdot\pi\cdot 5.000\cdot t) + \mathrm{sinc}(2\cdot W_x\cdot t));$	Bandwidth W_x ~ 8 kHz
$y(t)$	=	$A_y(\sin(2\cdot\pi\cdot 14.000\cdot t) + \mathrm{sinc}(2\cdot W_y\cdot t));$	Bandwidth W_y ~ 12 kHz

Determine the Nyquist sampling rate for:

a. the signals $x(t)$ and $y(t)$

b. the signals $x^2(t)$ and $y^2(t)$

c. the signal $x(t)\cdot y(t)$

$A_x(\sin(5k\cdot 2\pi t) + \mathrm{sinc}(8k\cdot 2\pi\cdot t)$

$A_x(\sin(14k\cdot 2\pi\cdot t) + \sin(12k\cdot 2\pi\cdot t)$

A) for x, $8k > 5k$, hence, $8k\cdot 2 = 16$ kHz

for y $14k > 12k$ hence $14k\cdot 2 = 28$ khz

B) x^2 & y^2 $\quad f\cdot f = Hz + Hz$

for x $8k\cdot 2 = 16k$ $\quad 16\cdot 2 = 32$ khz

for y $14k\cdot 2 = 28k$ $\quad 28k\cdot 2 = 56k$ Hz for y $14k \cdot 2 = 28k \quad 28k \cdot 2 = \underline{\underline{56k\,Hz}}$

c) $x \cdot y$

$8k + 14k = 22k \quad 22k \cdot 2 = \underline{\underline{44k\,Hz}}$

Sol-mod1

Saturday, 4 January 2025 08.09

old_modulation_exa...

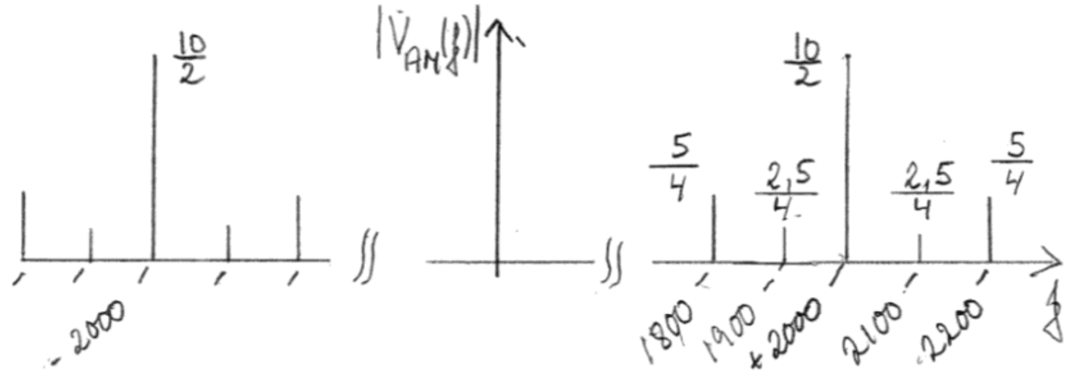
EXAM : INTRODUCTION TO WIRELESS COMMUNICATION

PROBLEM 1 :

a) $$v_{AM}(t) = A_c\,[1 + k_a \cdot v(t)] \cdot \cos(2\pi f_c t)$$

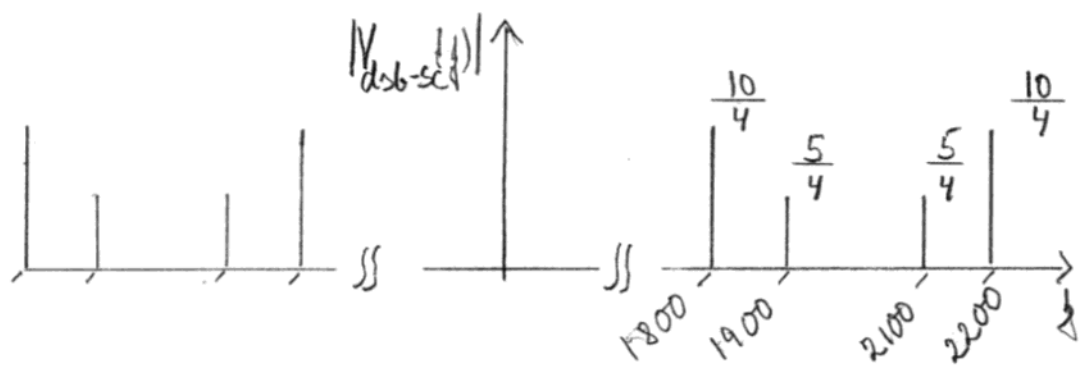
$$= 10\,[1 + 0{,}5(0{,}5\cdot\cos(200\pi t) + \cos(400\pi t))] \cdot \cos(2\pi \cdot 2\cdot 10^3 t)$$

$$= 10\,[1 + 0{,}25\cos(2\pi\cdot 100t) + 0{,}5\cdot\cos(2\pi\cdot 200t)] \cdot \cos(2\pi\cdot 2\cdot 10^3 t)$$



b) $$v_{dsb\text{-}sc}(t) = A_c \cdot v(t) \cdot \cos(2\pi \cdot f_c \cdot t)$$

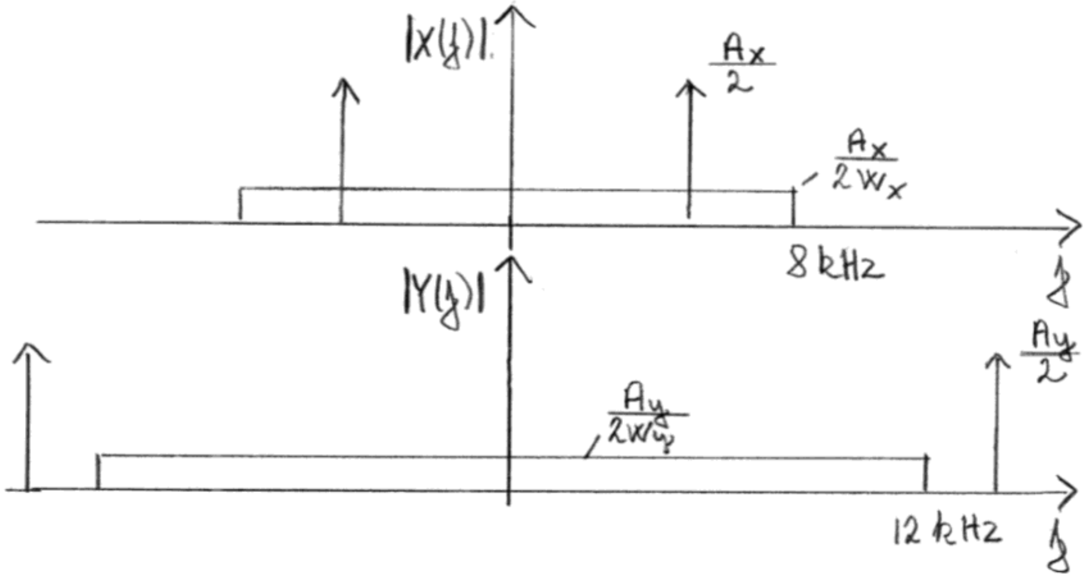
$$= 10\cdot(0{,}5\cdot\cos(2\pi\cdot 100t) + \cos(2\pi\cdot 200t))\cdot\cos(2\pi\cdot 2\cdot 10^3 t)$$



c) . . . .

PROBLEM 2:

②



The Nyquist sampling rates:

a) $x(t)$: 16 kHz $\wedge$ $y(t)$: 28 kHz

b) $x^2(t)$: 32 kHz $\wedge$ $y^2(t)$: 56 kHz

c) $x(t) \cdot y(t)$: 44 kHz

(b and c solved by convolution in the frequency-domain)

③

PROBLEM 3:

For $\beta = 2$ $\left(= \frac{\Delta f}{f_m}\right.$, wideband FM) we have:

$J_0(2) \sim 0{,}27$

$J_1(2) \sim 0{,}57$

$J_2(2) \sim 0{,}36$

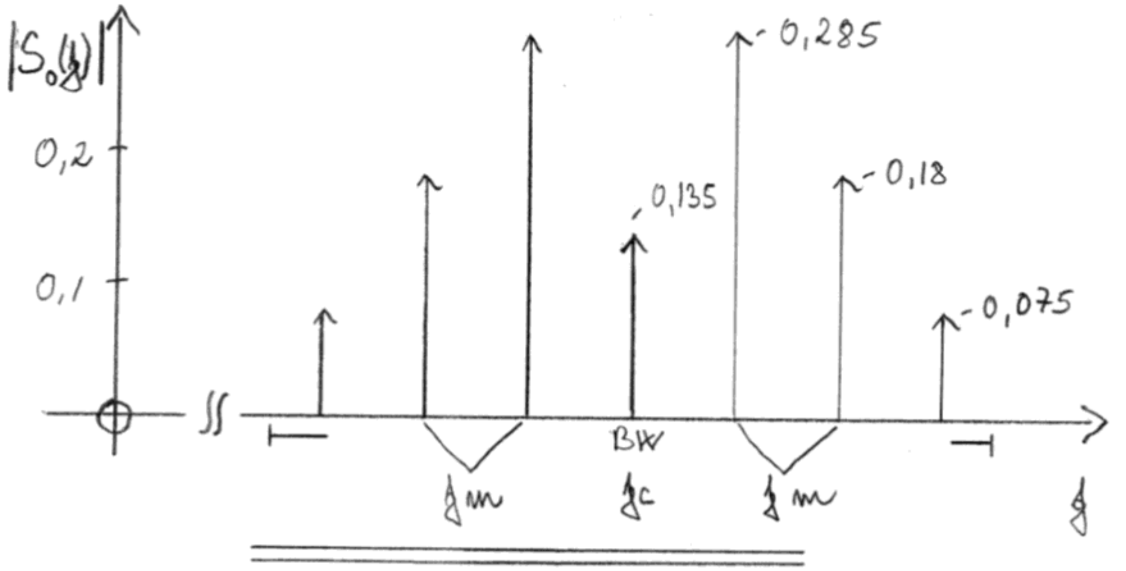
$J_3(2) \sim 0{,}15$

$(J_4(2) \sim 0{,}03)$

The output of the bandpass filter with the bandwidth $7 \cdot f_m$ is approximately (J-values):

$$\begin{aligned} s_0(t) = \; & 0{,}27 \cos(2\pi f_c t) \\ & + 0{,}57 \left(\cos(2\pi \cdot (f_c + f_m)t) + \cos(2\pi (f_c - f_m)t)\right) \\ & + 0{,}36 \left(\cos(2\pi \cdot (f_c + 2 f_m)t) + \cos(2\pi (f_c - 2 f_m)t)\right) \\ & + 0{,}15 \left(\cos(2\pi \cdot (f_c + 3 f_m)t) + \cos(2\pi (f_c - 3 f_m)t)\right) \end{aligned}$$

The magnitude spectrum of $s_0(t)$ for positive frequencies:



Ecx-mod2

Saturday, 4 January 2025 08.08

extra_exercises

Extra exercises

Exercise 1

Your friend has bought two Icom IC-9100, a multiple band HF/VHF/UHF radio capable of doing FM modulation and demodulation. He is using them to transmit a modulating signal $m(t) = 2\cos(2\pi\, 1000t)$. The power of the FM signal is 50 W, and it has a carrier frequency of $f_c = 100$ MHz and a peak frequency deviation $\Delta f = 10$ kHz.

a) Write the waveform expression for the FM waveform without any integral
b) Determine the approximated bandwidth of the FM waveform. Is the modulated signal a Narrow-Band or a Wide-Band Signal? (explain)

Your friend is very curious about the possibilities of the Icom IC-9100, and he is now considering the option of digitalizing the information and using BFSK as modulation scheme, with a space frequency of $f_{space} = 99.95$ MHz and a mark frequency of $f_{mark} = 100.05$ MHz.

c) If the digital signal is transmitted at a rate of $R_b = 3$ kbps, how much bandwidth is needed for the BFSK transmission?

Exercise 2

Consider the baseband signal $m(t) = 2\cos(2\pi 100\, t) - \cos(2\pi 500\, t)$. The signal is AM-modulated by a carrier wave $c(t)$.

a) Determine the resulting (traditional) AM-signal $v_{AM}(t)$ and plot the amplitude spectrum $V_{AM}(f)$ when $f_c = 1500$ kHz, the carrier amplitude is $A_c = 10$ and the amplitude sensitivity is $k_a = 0.2$.
b) Determine the result of a double-sideband–suppressed-carrier modulation (DSB-SC) of $m(t)$ – with the carrier amplitude decreased by a factor of five compared to the amplitude modulated (AM) signal: calculate the signal $v_{dsb-SC}(t)$ and plot the amplitude spectrum $V_{dsb-SC}(f)$.
c) In view of the results, explain briefly the advantages and disadvantages of DSB-SC versus standard AM.

Exercise 3

Consider the following baseband signal $v(t) = 3\sin(2\pi 200\, t) - 2\sin(2\pi 800\, t)$

The signal is modulated by the carrier wave $c(t)$ in an AM-transmitter:
$c(t) = A_c \cos(2\pi f_c t)$. The power of the carrier signal is 8 W.

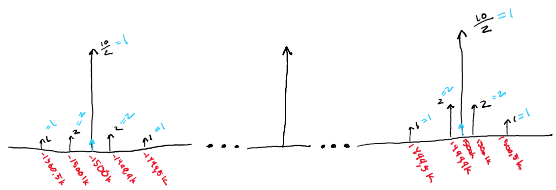
$$V_{am}(t) = A_c\left[1 + k_a \cdot V(t)\right] v_c(t)$$

$$= 10\left[1 + 0.2\left(2\cos(100 \cdot 2\pi t) - \cos(500 \cdot 2\pi t)\right)\right]\cos(1500k\, 2\pi t)$$

$$= 10\cos(1500k \cdot 2\pi t) + 10\tfrac{2}{5}\cos(100 \cdot 2\pi)\cdot\cos(1500k\, 2\pi t) - 10\tfrac{1}{5}\cos(500 \cdot 2\pi t)\cdot\cos(1500k\, 2\pi t)$$

$$= 10\cos(1500k \cdot 2\pi t) + \tfrac{20}{10}\cos(1500.1k\, 2\pi t) + \tfrac{20}{10}\cos(1499{,}9k\, 2\pi t) - \tfrac{10}{10}\cos(1500.5k\, 2\pi t) - \tfrac{10}{10}\cos(1499{,}5k\, 2\pi t)$$

Og i b, med $\frac{1}{5}$ supression se de blå tal på tegningen nede unden



1. Determine the maximum usable amplitude sensitivity k_a for an ordinary AM-modulation

2. Determine the resulting AM-signal $v_{AM}(t)$ and plot the amplitude spectrum $V_{AM}(t)$ for $f_c = 1500$ kHz.

Exercise 4

An FM signal with carrier frequency f_c =750 kHz is generated in an FM system with frequency sensitivity $k_f = 15$ kHz/V. For a sinusoidal modulating signal of the form $m(t) = A_m \cos(2\pi f_m t)$ with $f_m = 25$ kHz and $A_m = 5$ V, the FM signal is given by: $s(t) = A_c \cos\left(2\pi f_c t + \beta \sin(2\pi f_m t)\right)$

where β is the modulation index.

a. Determine the values of the frequency deviation Δf, the modulation index , and plot/sketch the amplitude spectrum

b. Via an ideal multiplicator, the FM signal $s(t)$ is now squared. Determine the values of the frequency deviation and the modulation index of the resulting signal $s^2(t)$, and plot/sketch the amplitude spectrum of this signal

Exercise 5

A communication system transmits at 100 kbps. For each of the following modulation types, determine the bandwidth of the transmission.

a) FSK, with frequency deviation 200 kHz.
b) OOK
c) QPSK
d) 16-PSK
e) 16-QAM
f) 512-QAM

a)

FSK: $2 \cdot R_{sym} + 2 \cdot \beta R = 2 \cdot 200k + 2 \cdot 100k\,Hz = 600k\ Hz$

b)

OOK, har 2 modes.

$$BW_{ook} = \frac{2R_b}{\log_2(2)} = \frac{200k}{1} = 200k\ Hz$$

c)

$$BW_4 = \frac{200k}{\log_2(4)} = 100k\ Hz$$

d)

$$BW_{16} = \frac{200k}{\log_2(16)} = 50k\ Hz$$

f)

$$BW_{512} = \frac{200k}{\log_2(512)} = 22.2k\ Hz$$

Sol-mod2

Saturday, 4 January 2025 08.09

Solution_to
_extra_ex...

EIT5 solutions to extra exercises

Israel Leyva-Mayorga

EXERCISE 1

We are given $m(t) = 2\cos(2\pi 1000t)$, $f_c = 100$ MHz, and $\Delta f = 10$ kHz. Therefore:

- $A_m = 2$ V
- $f_m = 1000$ Hz
- $P_c = 50$ W and $P_c = A_c^2/2$. Hence, $A_c = \sqrt{P_c/2} = 5\,\text{V}$
- $k_f = 10/2 = 5$ kHz/V
- $\beta = \Delta f / f_m = 10$

a) The FM waveform is given as

$$s_{\text{FM}}(t) = A_c \cos\left[2\pi\left(f_c t + k_f \int_0^t m(\tau)d\tau\right)\right] \tag{1}$$

Then, we calculate the integral

$$\int_0^t m(\tau)d\tau = \int_0^t 2\cos(2\pi 1000\tau)d\tau = \frac{\sin(2\pi 1000t)}{\pi 1000} \tag{2}$$

And so, we get the FM waveform

$$s_{\text{FM}}(t) = 5\cos\left[2\pi\left(10^7 t + \frac{5\sin(2\pi 1000t)}{\pi 1000}\right)\right] \tag{3}$$

b) The bandwidth of an FM signal can be approximated using the Carson's rule as

$$B_{\text{FM}} \approx 2\Delta f + 2f_m^* \tag{4}$$

Since we have a single modulating carrier $f_m^* = f_m$ and we get

$$B_{\text{FM}} \approx 2\times 10^4 + 2\times 10^3 = 22\text{kHz} \tag{5}$$

Since $\beta = 10$, we have a wideband FM signal

c) We are given $f_{space} = 99.95$ MHz and $f_{mark} = 100.05$ MHz and $R_b = 3$ kbps.

The bandwidth of a BFSK signal is approximated as

$$B_{\text{BFSK}} \approx f_{mark} - f_{space} + 2R_{sym} \tag{6}$$

So, we need to find $R_{sym} = R_b/\log_2 M$. Since the signal is binary (BFSK), the number of symbols $M = 2$ and we get $R_{sym} = 3\,\text{kbauds}$.

$$B_{\text{BFSK}} \approx 100.05\cdot 10^6 - 99.95\cdot 10^6 + 2\cdot 3\cdot 10^3 = 106\,\text{kHz} \tag{7}$$

EXERCISE 2

We are given $m(t) = 2\cos(1\pi 100t) - \cos(2\pi 500t)$.

a) The carrier is $c(t) = 10\cos(2\pi 1.5 \cdot 10^6 t)$ and the amplitude sensitivity is $k_a = 0.2$.
The traditional AM (DSBAM) modulated signal is

$$\begin{aligned} v_{\text{AM}}(t) &= A_c\left(1 + k_a m(t)\right)\cos(2\pi f_c t) \\ &= 10\Big(1 + 0.4\cos(2\pi 100t) - 0.2\cos(2\pi 500t)\Big) \\ &\quad \times \cos(2\pi 1.5 \cdot 10^6 t) \end{aligned} \tag{8}$$

And, hence, its spectrum is

$$\begin{aligned} V_{\text{AM}}(f) = 5\,&\left(\delta\left(f - 1.5 \cdot 10^6\right) + \delta\left(f + 1.5 \cdot 10^6\right)\right) \\ &+ \left(\delta\left(f - 1.5 \cdot 10^6 - 100\right) + \delta\left(f + 1.5 \cdot 10^6 + 100\right)\right) \\ &+ \left(\delta\left(f - 1.5 \cdot 10^6 + 100\right) + \delta\left(f + 1.5 \cdot 10^6 - 100\right)\right) \\ &-0.5\left(\delta\left(f - 1.5 \cdot 10^6 - 500\right) + \delta\left(f + 1.5 \cdot 10^6 + 500\right)\right) \\ &-0.5\left(\delta\left(f - 1.5 \cdot 10^6 + 500\right) + \delta\left(f + 1.5 \cdot 10^6 - 500\right)\right) \end{aligned} \tag{9}$$

b) Now the amplitude of the carrier is $A_c = 2$ V
The DSB-SC AM signal is

$$\begin{aligned} v_{\text{DSB-SC}}(t) &= A_c k_a m(t)\cos(2\pi f_c t) \\ &= \Big(0.8\cos(2\pi 100t) - 0.4\cos(2\pi 500t)\Big)\cos(2\pi 1.5 \cdot 10^6 t) \end{aligned} \tag{10}$$

An its spectrum is

$$\begin{aligned} V_{\text{DSB-SC}}(f) = 0.2&\left(\delta\left(f - 1.5 \cdot 10^6 - 100\right) + \delta\left(f + 1.5 \cdot 10^6 + 100\right)\right) \\ +0.2&\left(\delta\left(f - 1.5 \cdot 10^6 + 100\right) + \delta\left(f + 1.5 \cdot 10^6 - 100\right)\right) \\ -0.1&\left(\delta\left(f - 1.5 \cdot 10^6 - 500\right) + \delta\left(f + 1.5 \cdot 10^6 + 500\right)\right) \\ -0.1&\left(\delta\left(f - 1.5 \cdot 10^6 + 500\right) + \delta\left(f + 1.5 \cdot 10^6 - 500\right)\right) \end{aligned} \tag{11}$$

c) DSB-SC is much more power efficient: all the power is in the sidebands (no carrier). On the other hand,

$$\frac{5^2}{5^2 + 1^2 + 1^2 + (-0.5)^2 + (-0.5)^2} = 0.909 \tag{12}$$

of the power is in the carrier for DSBAM. On the downside, the simple envelope detector cannot be used for DSB-SC.

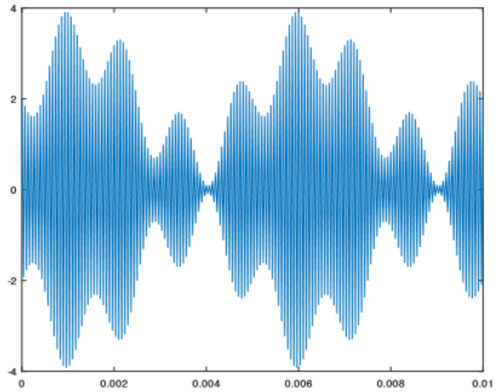


Fig. 1. Signal for exercise 3 with $k_a = 1/5$.

EXERCISE 3

This type of exercise will not be in the exam

We are given (changed the signal's name) $m(t) = 3\sin(2\pi 200t) - 2\sin(2\pi 800t)$.

The signal is modulated with $c(t) = A_c \cos(2\pi f_c t)$ with power $P_c = 8$ W.

1. As in the first exercise, we get the amplitude of the carrier as $A_c = \sqrt{P_c/2} = 2$ V.

For ordinary AM modulation we need to avoid phase reversals, which occur when $\mu = k_a A_m > 1$. In other words, we need to ensure that

$$|k_a m(t)| < 1 \qquad \text{for all } t \tag{13}$$

We can rewrite $k_a m(t)$ as

$$x(t) = 3k_a \sin(2\pi 200t) - 2k_a \sin(2\pi 800t) \tag{14}$$

We can approximate the maximum of $|x(t)| \approx 4.79$ using numerical methods. Therefore, we have that $k_a \leq 1/4.79$.

2. We will make $k_a = 1/5$. Hence, the modulated signal is given by

$$\begin{aligned} v_{\text{AM}}(t) &= A_c\,(1 + k_a m(t)) \cos(2\pi f_c t) \\ &= 2\left(1 + \frac{3}{5}\sin(2\pi 200t) - \frac{2}{5}\sin(2\pi 800t)\right) \\ &\quad \times \cos(2\pi 1.5 \cdot 10^6 t) \end{aligned} \tag{15}$$

Then, the spectrum of this signal is

$$\begin{aligned} V_{\text{AM}}(f) = &\left(\delta\left(f - 1.5 \cdot 10^6\right) + \delta\left(f + 1.5 \cdot 10^6\right)\right) \\ &+ \frac{6}{20j}\left(\delta\left(f - 1.5 \cdot 10^6 - 200\right) + \delta\left(f + 1.5 \cdot 10^6 + 200\right)\right) \\ &+ \frac{6}{20j}\left(\delta\left(f - 1.5 \cdot 10^6 + 200\right) + \delta\left(f + 1.5 \cdot 10^6 - 200\right)\right) \\ &- \frac{4}{20j}\left(\delta\left(f - 1.5 \cdot 10^6 - 800\right) + \delta\left(f + 1.5 \cdot 10^6 + 800\right)\right) \\ &- \frac{4}{20j}\left(\delta\left(f - 1.5 \cdot 10^6 + 800\right) + \delta\left(f + 1.5 \cdot 10^6 - 800\right)\right) \end{aligned} \tag{16}$$

Exercise 4

We are given $f_c = 750$ kHz and $k_f = 15$ kHz/V plus the modulating signal

$$m(t) = 5\cos(2\pi 25 \cdot 10^3 t) \tag{17}$$

and the modulated signal

$$s(t) = A_c \cos\left(2\pi 750 \cdot 10^3 t + \beta \sin(2\pi 25 \cdot 10^3 t)\right) \tag{18}$$

a. The frequency deviation is $\Delta f = k_f A_m = 75$ kHz, the modulation index is $\beta = \Delta f / f_m = 3$. Due to the Carson's rule, 98% of the spectrum is contained within

$$B_{\text{FM}} \approx 2\Delta f + 2f_m^* = 150 \cdot 10^3 + 20 \cdot 10^3 = 170\,\text{kHz} \tag{19}$$

centered at frequency $f_c = 750$ kHz.
b) To square the signal we need

$$\cos(2A) = \cos^2(A) - \sin^2(A) = 1 - 2\sin^2(A) = 2\cos^2(A) - 1 \tag{20}$$

Then

$$\cos^2(A) = \frac{\cos(2A) + 1}{2} \tag{21}$$

The term $1/2$ is simply a DC shift.

$$s^2(t) = \frac{A_c}{2} \cos\left(2\pi(2 \cdot 750 \cdot 10^3)t + 2\beta \sin(2\pi 25 \cdot 10^3 t)\right) + \frac{1}{2} \tag{22}$$

We have that $\Delta f = 2\beta f_m = 6 * 25 \cdot 10^3 = 150\,\text{kHz}$ and the modulation index is $\beta' = 2\beta = 6$. The spectrum now has a delta at frequency 0 due to the DC shift.

EXERCISE 5

We have that

$$R_b = NR_{sym} = R_{sym}\log_2 M = 100\text{kbps} \tag{23}$$

Then, for all the modulations except FSK, the bandwidth is $B = 2R_{sym}$.
a)$M = 2$, so, the bandwidth for BFSK is

$$B_{\text{BFSK}} \approx f_{mark} - f_{space} + 2R_{sym} = 2 \cdot 200 \cdot 10^3 + 2 \cdot 100 \cdot 10^3 = 600\,\text{kHz} \tag{24}$$

b) $M = 2$ so, the bandwidth is

$$B_{\text{OOK}} = 2R_{sym} = \frac{2R_b}{\log_2 M} = 200\,\text{kHz} \tag{25}$$

c) $M = 4$ so, the bandwidth is

$$B_{\text{QPSK}} = 2R_{sym} = \frac{2R_b}{\log_2 4} = 100\,\text{kHz} \tag{26}$$

d) $M = 16$ so, the bandwidth is

$$B_{\text{16-PSK}} = 2R_{sym} = \frac{2R_b}{\log_2 16} = 50\,\text{kHz} \tag{27}$$

e)Same as in d)
f) $M = 512$ so, the bandwidth is

$$B_{\text{512-QAM}} = 2R_{sym} = \frac{2R_b}{\log_2 512} = 22.222\,\text{kHz} \tag{28}$$