higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T330(E)(A15)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

COMMUNICATION-ELECTRONICS N6

(8080246)

15 April 2015 (Y-Paper)
13:00–16:00

Calculators may be used.

This question paper consists of 7 pages and 1 formula sheet of 5 pages.

ENGINEERING

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
COMMUNICATION-ELECTRONICS N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. ALL the sketches and diagrams must be large, clear and neat.
5. Use $\pi = 3,142$.
6. Write neatly and legibly.

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QUESTION 1

1.1 Study FIGURE 1 below and select the correct word between brackets in each of the following statements. Write only the word next to the question number (1.1.1–1.1.2) in the ANSWER BOOK.

1.1.1 FIGURE 1 shows the (input/output) half section for a composite filter.

1.1.2 FIGURE 1 shows a (high/low)-pass filter.

(2 × 1) (2)

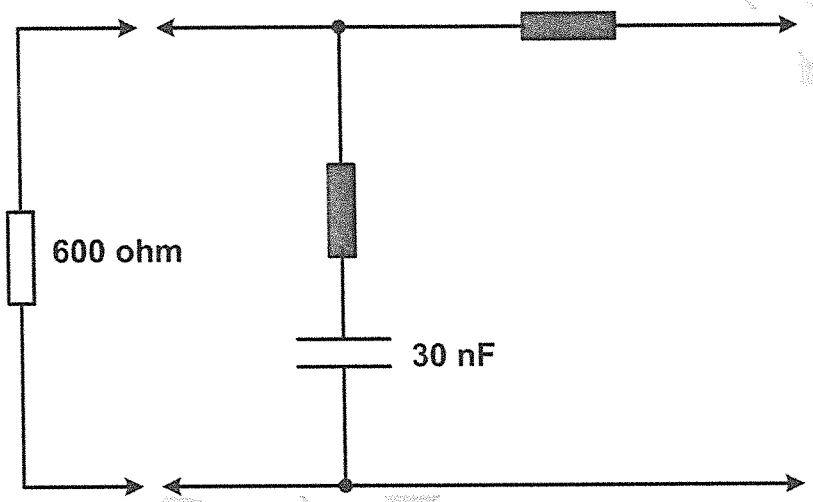


FIGURE 1

1.2 Determine the cut-off frequency for the filter in FIGURE 1. (4)

1.3 Design a T-section filter network that will eliminate all frequencies between the ranges of 7,5 kHz and 10 kHz for a 600 ohm transmission line.

Draw the completed network and insert ALL relevant values. (6)

1.4 Design the terminating half sections for a low-pass π-type filter given the following specifications:

f_c = 3,25 kHz
f_∞ = 3,75 kHz
Z_o = 600 ohms

Draw the completed filter networks and insert ALL the relevant component values. (7)
[19]

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QUESTION 2

2.1 Is an attenuator frequency sensitive? Motivate the answer. (3)

2.2 Study the attenuator network in FIGURE 2, below.

Determine the values of Z_1, Z_2 and Z_3, if the generator has to supply one third of the current to the load R_L.

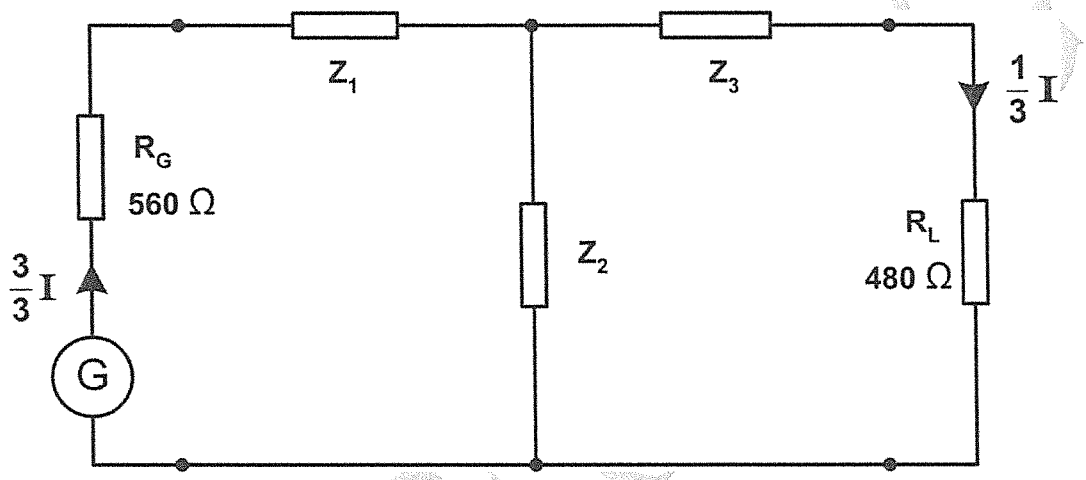


FIGURE 2 (5)

2.3 The following information for a Pi-type asymmetrical attenuator network is given:

Attenuation = 10
Output image impedance = 300 ohms
Series resistor = 4 kilo-ohms

Use the available information to determine the input image impedance. (4)

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2.4 Consider FIGURE 3 below.

Determine with the available information the attenuation of the attenuator in dB.

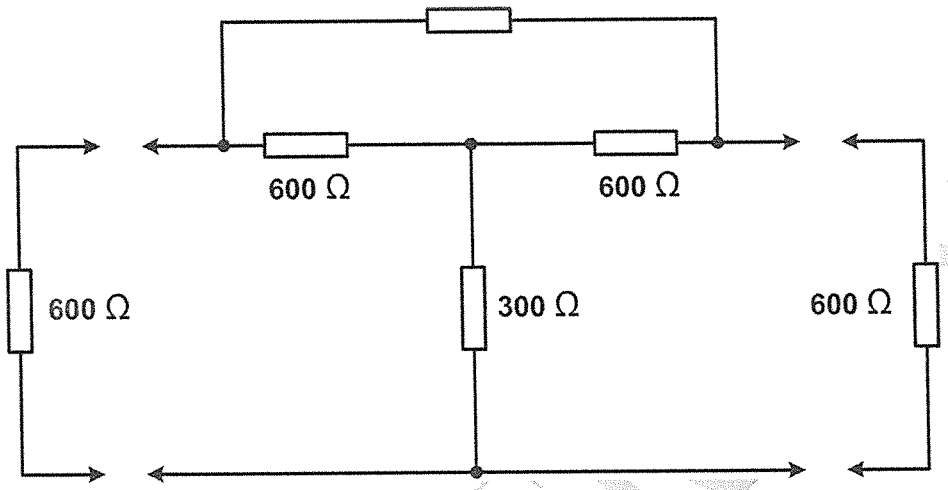


FIGURE 3 (3)

2.5 Show, by means of a sketch, how the attenuator in FIGURE 3 can be made variable. (2)
[17]

QUESTION 3

3.1 Explain how the reactive component can be tuned out of a transmission line. Make use of a simple sketch to support your description. (4)

3.2 The following resistive loads are connected to a 600 ohm transmission line:

3.2.1 750 ohms

3.2.2 900 ohms

Calculate the SWR in each instance. (2 × 1) (2)

3.3 Which of the loads in QUESTION 3.2 is the most suitable? Motivate the answer. (2)

3.4 A Smith chart can be used to obtain the SWR on a transmission line.

Give a brief description of how this is accomplished. (6)
[14]

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QUESTION 4

4.1 What is the cause of the following?

4.1.1 Atmospheric noise (1)

4.1.2 Man-made noise (1)

4.1.3 Thermal noise (2)

4.2 Which of the noise sources in QUESTION 4.1 can be controlled? (1)

4.3 An FM-receiver has an input resistance of 5 kilo-ohms and an equivalent resistance of 7,2 kilo-ohms. The amplifier has a gain of 20 which is developed across a load resistor of 18 kilo-ohms.

Take Boltzmann's constant as $1,38 \times 10^{-23}$J/K.

Calculate the following:

4.3.1 The RMS noise voltage generated at 25 °C and a bandwidth of 20 kHz

4.3.2 The noise figure, if the receiver is connected to a signal generator which has an impedance of 300 ohms

(2 × 3) (6)

4.4 The following information concerning a two-stage amplifier is given:

	STAGE 1	STAGE 2
Gain	10	15
Input resistance	9 kΩ	20 kΩ
Equivalent resistance	12 kΩ	15 kΩ
Output resistance	18 kΩ	30 MΩ

Determine the following:

4.4.1 The equivalent noise resistance (5)

4.4.2 The output noise voltage for a bandwidth of 9 MHz and a temperature of 25 °C (2)

[18]

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QUESTION 5

5.1 Draw a neat, labelled circuit diagram of a Class C modulator using an NPN transistor.

Indicate ALL the relevant waveforms. (7)

5.2 Discuss the full operation of the Class C modulator in QUESTION 5.1. (5)

5.3 Discuss sampling with reference to TDM. Make use of neat sketches to support the answer. (6)
[18]

QUESTION 6

6.1 Define the *bandwidth of an antenna.* (2)

6.2 An antenna has a gain of 20 and receives $5{,}25 \times 10^{-13}$ watt at a frequency of 100 MHz.

Determine the power density around the antenna in W/m^2. (3)

6.3 A radar installation is used to detect a 9 m^2 target at a distance of 100 km. The frequency of operation is 3 GHz and both the transmitter and receiver antennas have a gain of 20 each.

In order to detect the target successfully, a minimum power of $1{,}8 \times 10^{-18}$ watt is needed. There is however an attenuation of 0,002 dB/km.

Determine the minimum transmitter power required to detect this target. (9)
[14]

TOTAL: 100

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COMMUNICATION-ELECTRONICS N6

FORMULA SHEET

1. Filters

Low-pass

$$f_c = \frac{1}{\pi \sqrt{L \,.\, C}} \qquad Z_o = \sqrt{\frac{L}{C}}$$

High-pas

$$f_c = \frac{1}{4 \,.\, \pi \sqrt{L \,.\, C}} \qquad Z_o = \sqrt{\frac{L}{C}}$$

Low-pass m-derived sections (also for half sections)

T-section *π-section*

$$\text{Series } L = \frac{m \,.\, L}{2} \qquad \text{Shunt } C = \frac{m \,.\, C}{2}$$

$$\text{Shunt } C = m \,.\, C \qquad \text{Series } L = m \,.\, L$$

$$\text{Shunt } L = \frac{1 - m^2}{4 \,.\, m} \,.\, L \qquad \text{Series } C = \frac{1 - m^2}{4 \,.\, m} \,.\, C$$

$$m = \sqrt{1 - \frac{f_c^2}{f_\infty^2}} \qquad L = \frac{Z_o}{\pi \,.\, f_c} \qquad C = \frac{1}{\pi \,.\, Z_o \,.\, f_c}$$

High-pass m-derived sections (also for half sections)

T-section *π-section*

$$\text{Series } C = \frac{2 \,.\, C}{m} \qquad \text{Series } C = \frac{C}{m}$$

$$\text{Shunt } C = \frac{4 \,.\, m}{1 - m^2} \,.\, C \qquad \text{Series } L = \frac{4 \,.\, m}{1 - m^2} \,.\, L$$

$$\text{Shunt } L = \frac{L}{m} \qquad \text{Shunt } L = \frac{2 \,.\, L}{m}$$

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$$m = \sqrt{1 - \frac{f_\infty^2}{f_c^2}} \qquad L = \frac{Z_o}{4 \,.\, \pi \,.\, f_c} \qquad C = \frac{1}{4 \,.\, \pi \,.\, Z_o \,.\, f_c}$$

Band-pass sections

$$\textit{Series } L = \frac{Z_o}{2 \,.\, \pi \,[f_2 - f_1]} \qquad \textit{Series } C = \frac{f_2 - f_1}{2 \,.\, \pi \,.\, Z_o \,.\, f_1 \,.\, f_2}$$

$$\textit{Shunt } L = \frac{Z_o \,[f_2 - f_1]}{4 \,.\, \pi \,.\, f_1 \,.\, f_2} \qquad \textit{Shunt } C = \frac{1}{\pi \,.\, Z_o \,[f_2 - f_1]}$$

Band-stop sections

$$\textit{Series } L = \frac{Z_o \,[f_2 - f_1]}{2 \,.\, \pi \,.\, f_1 \,.\, f_2} \qquad \textit{Series } C = \frac{1}{2 \,.\, \pi \,.\, Z_o \,[f_2 - f_1]}$$

$$\textit{Shunt } L = \frac{Z_o}{4 \,.\, \pi \,.\, [f_2 - f_1]} \qquad \textit{Shunt } C = \frac{f_2 - f_1}{\pi \,.\, Z_o \,.\, f_1 \,.\, f_2}$$

2. *Attenuators*

Symmetrical

Bridged T-type

$$Z_B = Z_o \,[N - 1]$$

$$Z_c = \frac{Z_o}{N - 1}$$

$$Z_A = Z_o$$

where $dB = 20 \log N$

Asymmetrical

L-type

$$Z_A = \sqrt{R_1 \,(R_1 - R_2)}$$

$$Z_B = \sqrt{\frac{(R_1 \,.\, R_2^2)}{R_1 - R_2}}$$

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T-Type

$$Z_1 = R_1\left[\frac{N^2+1}{N^2-1}\right] - 2\sqrt{R_1 \,.\, R_2}\left[\frac{N}{N^2-1}\right]$$

$$Z_2 = 2\sqrt{R_1 \,.\, R_2}\left[\frac{N}{N^2-1}\right]$$

$$Z_3 = R_2\left[\frac{N^2+1}{N^2-1}\right] - 2\sqrt{R_1 \,.\, R_2}\left[\frac{N}{N^2-1}\right]$$

where $dB = 20 \log N$

π-type

$$Z_A = R_1\left[\frac{N^2-1}{N^2-2\,.\,N\,.\,S+1}\right]$$

$$Z_B = \frac{\sqrt{R_1 \,.\, R_2}}{2}\left[\frac{N^2-1}{N}\right]$$

$$Z_c = R_2\left[\frac{N^2-1}{N^2-2\,.\,N/S+1}\right]$$

where $dB = 20 \log N$ *and* $S = \sqrt{\frac{R_1}{R_2}}$

Insertion loss $= 20 \log \frac{I_1}{I_2}$

3. *Transmission lines*

$$Z_o = \sqrt{Z_{o/c} \,.\, Z_{s/c}} \qquad Z_o = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$\gamma = \sqrt{[R + j\omega L][G + j\omega C]} \qquad \gamma = \alpha + j\beta$$

$$\lambda = \frac{2\,.\,\pi}{\beta} \qquad V = \frac{\omega}{\beta} \qquad t = \frac{d}{v}$$

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$$L.G = C.R$$

$$VSWR = \frac{Z_R}{Z_o} \text{ or } \frac{Z_o}{Z_R}$$

$$Also\ VSWR = \frac{1+\rho}{1-\rho}$$

$$\rho = \frac{Z_R - Z_o}{Z_R + Z_o}$$

$$\rho = \frac{V_{(reflected)}}{V_{(incident)}}$$

Normalised impedance

$$Z_o^{'} = \frac{R}{Z_o} \pm j\frac{X}{Z_o}$$

4. *Noise*

$$E_n = \sqrt{4KT\Delta f R} \qquad E_n = \sqrt{4KT\Delta f\ [R_1 + R_2]}$$

$$R_{eq} = R_A + \frac{R_B}{A_1^2} + \frac{R_c}{A_1^2 \cdot A_2^2}$$

$$where\ R_A = R_{1in} + R_{1eq}$$

$$R_B = \frac{R_{1(out)} \cdot R_{2(in)}}{R_{1(out)} + R_{2(in)}} + R_{2(eq)}$$

$$R_c = R_{2out}$$

$$F = 1 + \frac{R_{eq}^{'}}{R_a} \qquad R_{eq}^{'} = R_{eq} - R_t$$

$$F = \frac{S/N_{(in)}}{S/N_{(out)}} \qquad F = 1 + \frac{T_{eq}}{T_o}$$

$$C = \Delta f \log_2 [1 + S/N]$$

$$where\ dB = 10 \log S/N$$

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5. *Modulation*

$$m = \frac{V_m}{V_c} \qquad \eta = \frac{P_{dc}}{P_c} \times 100\%$$

$$P_{dc} = I_{mean} \times V_{dc} \qquad P_{\text{mod}} = \frac{P_{SB}}{\eta}$$

$$P_{SB} = \frac{m^2 \,.\, P_c}{2}$$

$$P_T = P_c + P_{SB}$$

6. *Antennae*

$$P_r = P_d \times A \qquad A = \frac{\lambda^2}{4 \,.\, \pi} \qquad \lambda = \frac{c}{f}$$

$$P_r = P_d \times A \,.\, G_r \quad \textit{where} \qquad dB = 10 \log G$$

$$P_d = \frac{E^2}{120 \,.\, \pi} \qquad P_d = \frac{P_t \,.\, G_t}{4 \,.\, \pi \,.\, d^2}$$

$$P_d = \frac{30 \,.\, G \,.\, P_t}{120 \,.\, \pi \,.\, d^2} \qquad P_t = \frac{[4 \,.\, \pi]^3 \,.\, d^4 \,.\, P_r}{G_t \,.\, G_r \,.\, Q \,.\, \lambda^2}$$

$$P_r = \frac{10 \,.\, P_t \,.\, G_t}{4 \,.\, \pi \,.\, d^2} \qquad E_r = \frac{\sqrt{30 \,.\, P_r}}{d}$$

$$E_S = \frac{\sqrt{30 \,.\, P_t \,.\, G_t}}{d} \qquad A = \frac{G \,.\, \lambda^2}{4 \,.\, \pi}$$

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MARKING GUIDELINE

NATIONAL CERTIFICATE

APRIL EXAMINATION

COMMUNICATION-ELECTRONICS N6

15 APRIL 2015

This marking guideline consists of 13 pages.

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QUESTION 1

1.1 1.1.1 Input

1.1.2 Low-pass filter

(2 × 1) (2)

1.2 Shunt C = m.C m = 0,6

$$\therefore C = \frac{\text{Shunt C}}{m}$$

$$= \frac{30\times10^{-9}}{0,6}$$

$$= 50 \text{ nF}$$

$$C = \frac{1}{\pi . Z_o . f_c}$$

$$\therefore f_C = \frac{1}{\pi . Z_o . C}$$

$$= \frac{1}{3,142\times600\times50\times10^{-9}}$$

$$= 10,609 \text{ kHz}$$

(4)

1.3 $$\text{Series L} = \frac{Z_o\,(f_2 - f_1)}{2.\pi.f_1.f_2}$$

$$= \frac{600\,(10000 - 7500)}{2\times3,142\times10\times10^3\times7,5\times10^3}$$

$$= 3,183 \text{ mH}$$

$$\text{Series C} = \frac{1}{2.\pi.Z_o\,(f_2 - f_1)}$$

$$= \frac{1}{2\times3,142\times600\times(10000-7500)}$$

$$= 106,09 \text{ nF}$$

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$$\text{Shunt L} = \frac{Z_o}{4.\pi.(f_2 - f_1)}$$

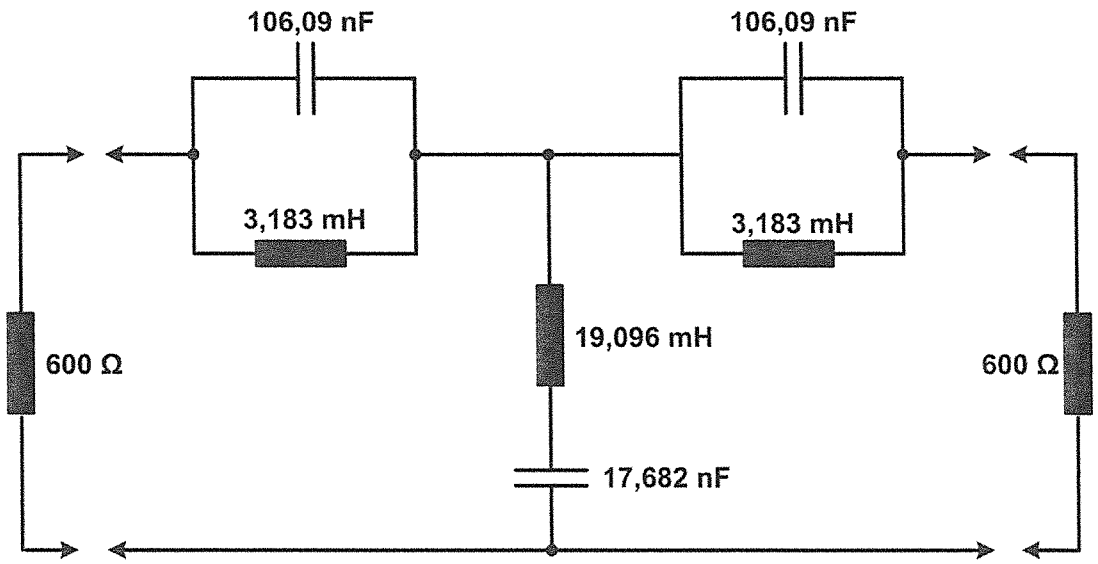
$$= \frac{600}{4 \times 3{,}142 \times (10000 - 7500)}$$

$$= 19{,}096 \text{ mH}$$

$$\text{Shunt C} = \frac{f_2 - f_1}{\pi.Z_o.f_1.f_2}$$

$$= \frac{10000 - 7500}{3{,}142 \times 600 \times 10000 \times 7500}$$

$$= 17{,}682 \text{ nF}$$



(6)

1.4

$$L = \frac{Z_o}{\pi . f_c}$$

$$= \frac{600}{3,142 \times 3,25 \times 10^3}$$

$$= 58,757 \text{ mH}$$

$$C = \frac{1}{\pi . Z_o . f_c}$$

$$= \frac{1}{3,142 \times 600 \times 3,25 \times 10^3}$$

$$= 163,215 \text{ nF}$$

$$\text{Shunt } C = \frac{m.C}{2}$$

$$= \frac{0,6 \times 163,215 \times 10^{-9}}{2}$$

$$= 48,965 \text{ nF}$$

$$\text{Series } L = m.L$$

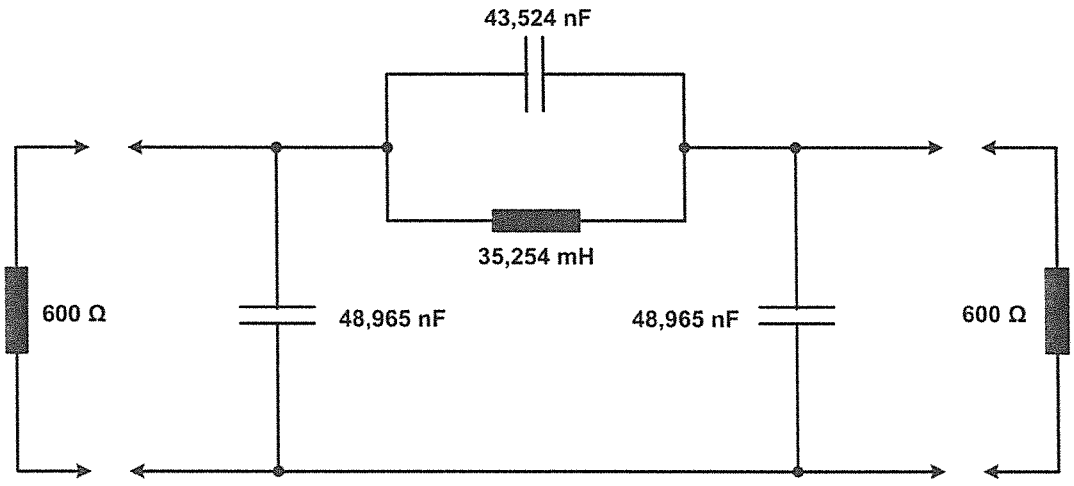
$$= 0,6 \times 58,757 \times 10^{-3}$$

$$= 35,254 \text{ mH}$$

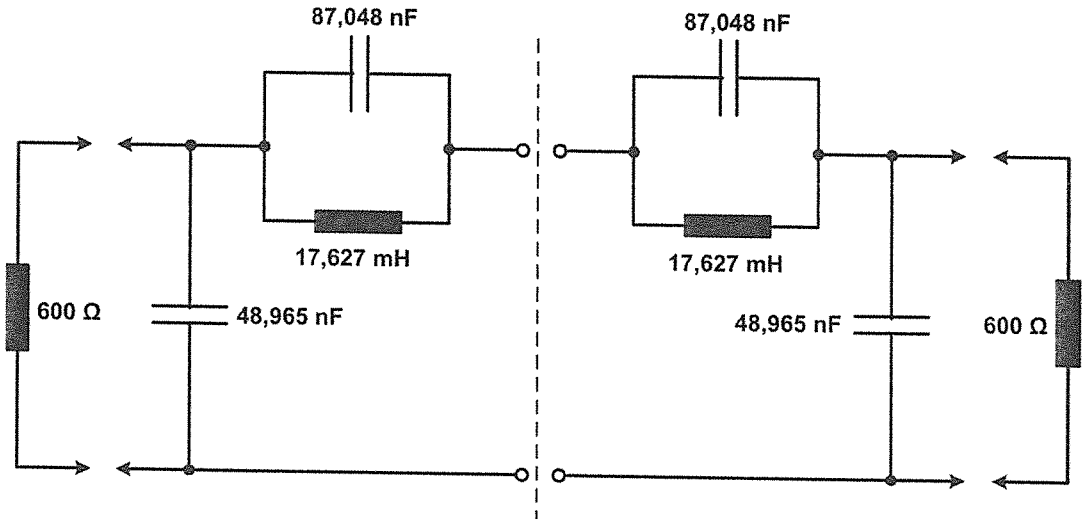
$$\text{Series } C = \frac{1 - m^2}{4m} \cdot C$$

$$= \frac{1 - 0,6^2}{4 \times 0,6} \times 163,215 \times 10^{-9}$$

$$= 43,524 \text{ nF}$$



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(7)
[19]

QUESTION 2

2.1 No, an attenuator only consists of resistive components, which are not frequency sensitive. (3)

2.2 $$N = \frac{I_{(in)}}{I(out/uit)}$$

$$= \frac{3}{1}$$

$$= 3$$

$$Z_1 = R_G\left[\frac{N^2+1}{N^2-1}\right] - 2\sqrt{R_G.R_L}\left[\frac{N}{N^2-1}\right]$$

$$= 560\left[\frac{3^2+1}{3^2-1}\right] - 2\sqrt{560\times 480}\left[\frac{3}{3^2-1}\right]$$

$$= 311{,}156 \text{ ohms}$$

$$Z_2 = 2\sqrt{R_G.R_L}\left[\frac{N}{N-1}\right]$$

$$= 2\sqrt{560\times 480}\left[\frac{3}{3^2-1}\right]$$

$$= 388{,}844 \text{ ohms}$$

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$$Z_3 = R_L\left[\frac{N^2+1}{N^2-1}\right] - 2\sqrt{R_G.R_L}\left[\frac{N}{N^2-1}\right]$$

$$= 480\left[\frac{3^2+1}{3^2-1}\right] - 2\sqrt{560\times 480}\left[\frac{3}{3^2-1}\right]$$

$$= 211{,}156 \text{ ohms}$$

(5)

2.3

$$Z_B = \frac{\sqrt{R_1.R_2}}{2} \cdot \left[\frac{N^2-1}{N}\right]$$

$$2\,Z_B = \sqrt{R_1.R_2} \cdot \left[\frac{N^2-1}{N}\right]$$

$$8\times 10^3 = \sqrt{300\,.\,R_1} \cdot \left[\frac{10^2-1}{10}\right]$$

$$8\times 10^3 = \sqrt{300\,.\,R_1} \times [9{,}9]$$

$$\sqrt{300\,.\,R_1} = 808{,}081$$

$$300R_1 = 652{,}995\times 10^3$$

$$\therefore R_1 = 2{,}177\ k\Omega$$

(4)

2.4

$$Z_C = \frac{Z_o}{N-1}$$

$$\therefore N = \frac{Z_o}{Z_c} + 1$$

$$= \frac{600}{300} + 1$$

$$= 3$$

$$dB = 20 \log N$$

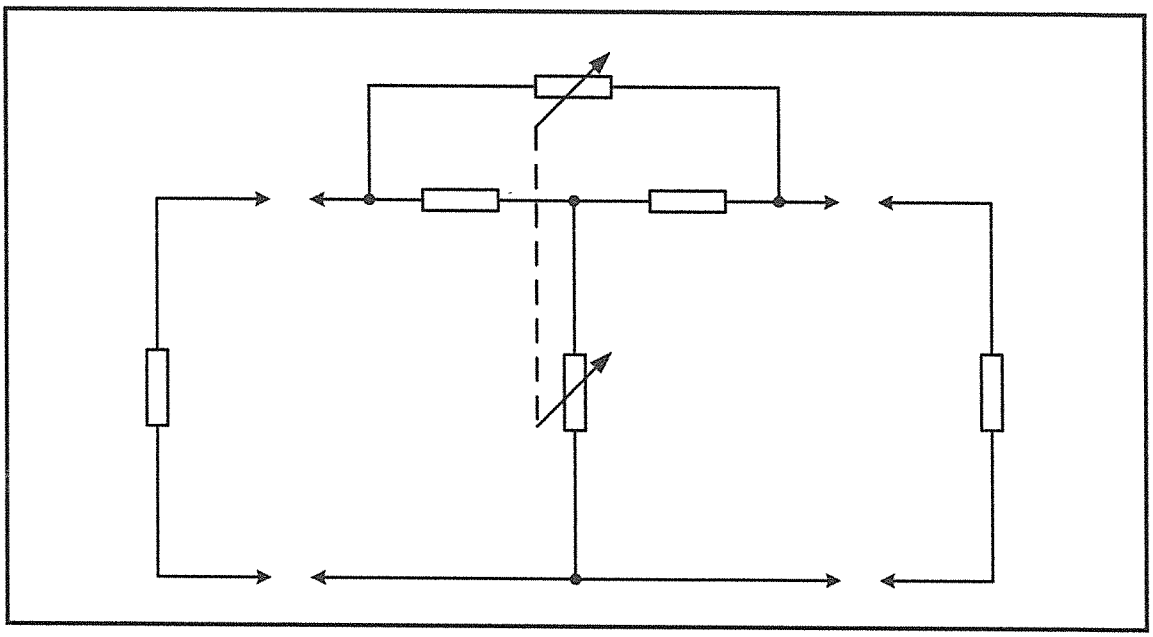
$$= 20 \log 3$$

$$= 9{,}542$$

(3)

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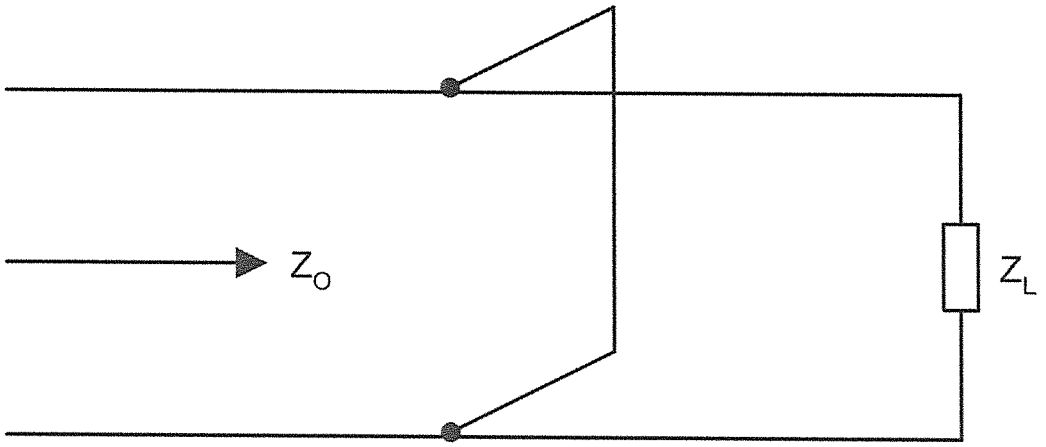
2.5



(2)
[17]

QUESTION 3

3.1 Make use of a stub constructed as shown below:



The stub is a short piece of wire which is short-circuited across the transmission line. (4)

3.2 3.2.1 $$\text{SWR/SVG} = \frac{Z_L}{Z_o}$$

$$= \frac{750}{600}$$

$$= 1,25$$

3.2.2 $\text{SWR/SVG} = \frac{Z_L}{Z_o}$

$= \frac{900}{600}$

$= 1,5$ (2×1) (2)

3.3 The 750 ohm load since the SWR is closer to unity. (2)

3.4 1. Normalise impedance.
$Z_O = \frac{R}{Z_o} \pm j\frac{X}{Z_o}$

2. Plot R on the centre line and X on the circle.

3. Follow the two lines until they intersect one another and plot this point.

4. Draw the circle with a radius equal to the centre of the chart and the point plotted in the step above.

5. Read off the SWR at the bottom of the circle where it intersects the centre line. (6)
[14]

QUESTION 4

4.1 4.1.1
- Lightning
- Static electricity (Any 1 × 1) (1)

4.1.2
- Ignition systems
- Electric motors (Any 1 × 1) (1)

4.1.3
- Fluorescent lights
- The random motion of atoms and molecules in all types of material (2)

4.2 Man-made noise (1)

4.3 4.3.1 $E_n = \sqrt{4.K.T.\Delta F.(R_1 + R_2)}$

$= \sqrt{4 \times 1,38 \times 10^{-23} \times (273 + 25) \times 20 \times 10^3 \times \left(7,2 \times 10^3 + 5 \times 10^3\right)}$

$= 2,003\ \mu V$ (3)

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4.3.2 $$R'_{eq} = \left[R_{eq} - R_t\right] + \frac{R_{out/uit}}{A^2}$$

$$= \left[7{,}2\times10^3 - 5\times10^3\right] + \frac{18\times10^3}{20^2}$$

$$= 2{,}245\ k\Omega$$

$$\therefore F = 1 + \frac{R'_{eq}}{R_a}$$

$$= 1 + \frac{2245}{300}$$

$$= 8{,}483 \qquad (3)$$

4.4 4.4.1 $$R_{eq} = R_A + \frac{R_B}{A_1^2} + \frac{R_C}{A_1^2 \cdot A_2^2}$$

$$R_A = R_{1(IN)} + R_{1(eq)}$$

$$= 9\times10^3 + 12\times10^3$$

$$= 21\ k\Omega$$

$$R_C = R_{2(OUT)}$$

$$= 30\ M\Omega$$

$$R_B = \frac{R_{1(OUT)} \cdot R_{2(IN)}}{R_{1(OUT)} + R_{2(IN)}} + R_{2(eq)}$$

$$= \frac{18\times10^3 \times 20\times10^3}{\left(18\times10^3\right) + \left(20\times10^3\right)} + 15\times10^3$$

$$= 24{,}474\ k\Omega$$

$$\therefore R_{eq} = R_A + \frac{R_B}{A_1^2} + \frac{R_C}{A_1^2 \cdot A_2^2}$$

$$= 21\times10^3 + \frac{24{,}474\times10^3}{10^2} + \frac{30\times10^6}{10^2 \times 15^2}$$

$$= 22{,}578\ k\Omega \qquad (5)$$

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4.4.2 $E_n = \sqrt{4.K.T.\Delta f.R}$

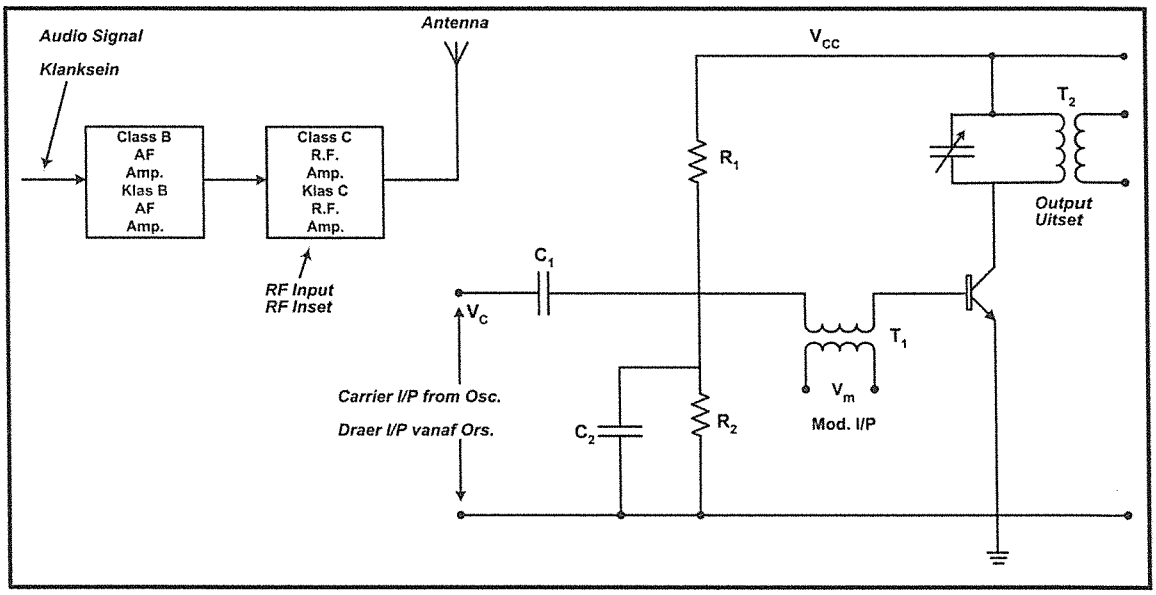
$= \sqrt{4 \times 1{,}38\times10^{-23} \times 298 \times 9\times10^{6} \times 22{,}578\times10^{3}}$

$= 57{,}815\ \mu V$ (2)

[18]

QUESTION 5

5.1

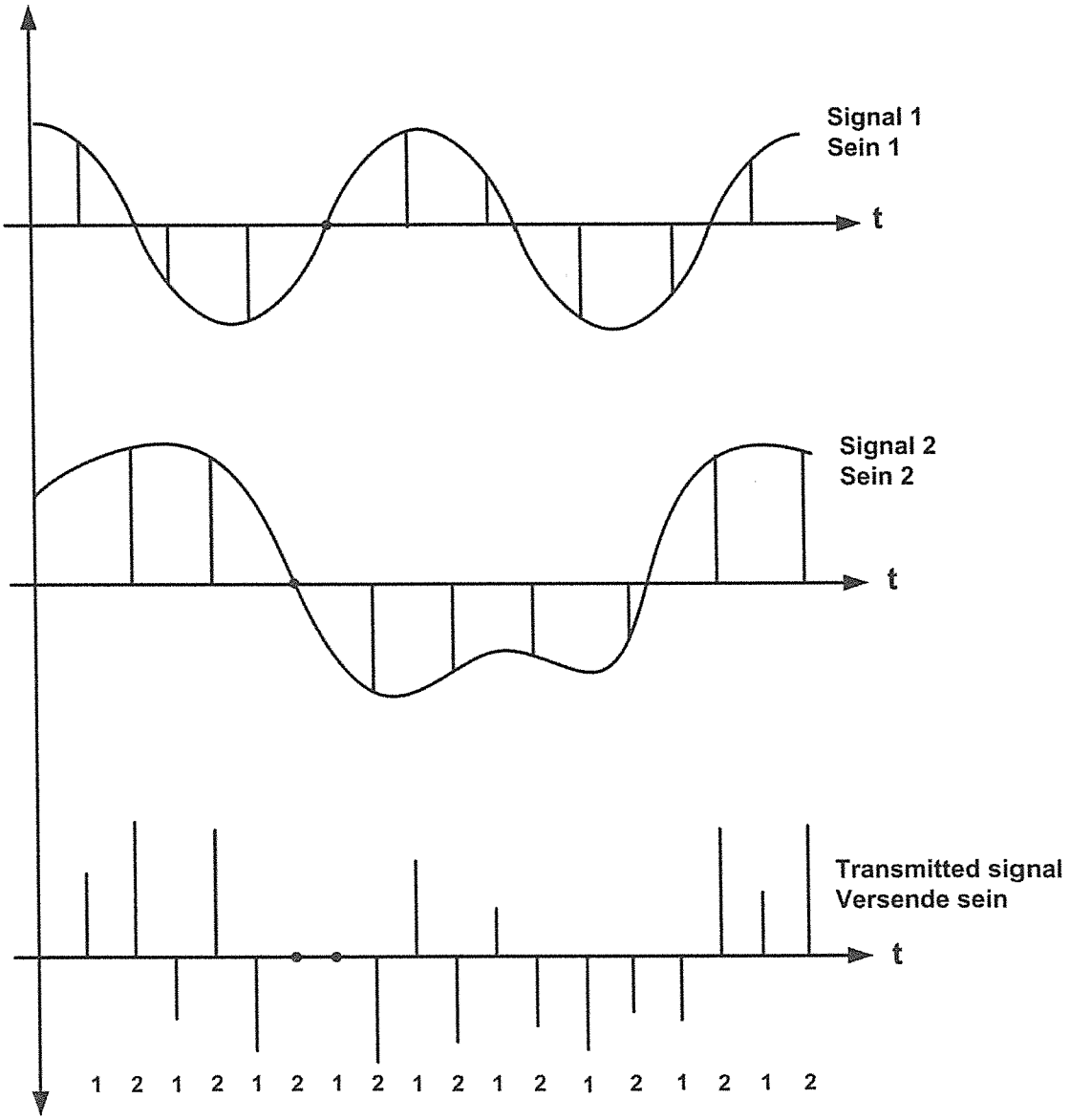


(7)

5.2 **Explanation of circuit in QUESTION 5.1**

The carrier voltage V_C is applied to the base of Q_1 and is constant in the absence of a modulating signal V_m. Class C bias is supplied by the ratio R_1/R_2. When a modulating voltage V_m is applied via T_1 the base voltage will vary in sympathy and an AM output is obtained via T_2. (5)

5.3 Sampling is a process whereby parts of a signal are taken at a tempo of $t = \frac{1}{2} f$ seconds and only the sample is transmitted.



(6)
[18]

QUESTION 6

6.1 It is the angular separation between the two half-power points (-3 dB) on the radiation pattern of an antenna. (2)

6.2 $$\lambda = \frac{C}{f}$$

$$= \frac{3\times10^{8}}{100\times10^{6}}$$

$$= 3 \text{ m}$$

$$A = \frac{G.\lambda^{2}}{4.\pi}$$

$$= \frac{20\times3^{2}}{4\times3,142}$$

$$= 14,322 \text{ m}^2$$

$$Pr = Pd \,.\, A$$

$$\therefore Pd = \frac{Pr}{A}$$

$$= \frac{5,25\times10^{-13}}{14,322}$$

$$= 36,657 \times 10^{-15} \text{ W/m}^2$$ (3)

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6.3 Path loss = $2 \times 100 \times 0,002$

$= 0,4$ dB

Path loss = $\text{antilog } \frac{\text{dB}}{10}$

$= \text{antilog } \frac{0,4}{10}$

$= 1,096$

$\lambda = \frac{c}{f}$

$= \frac{3 \times 10^8}{3 \times 10^9}$

$= 0,1$ m

$P_t = \frac{[4\pi]^3 \cdot d^4 \cdot P_r}{G_t \cdot G_A \cdot Q \cdot \lambda^2} \times 1,096$

$= \frac{[4 \times 3,142]^3 \times \left[100 \times 10^3\right]^4 \times \left[1,8 \times 10^{-18}\right]}{20 \times 20 \times 9 \times 0,1^2} \times 1,096$

$= 10,879$ kW (9)
[14]

TOTAL: 100

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