REVISION EXERCISES

FREQUENCY DIVISION MULTIPLE ACCESS FOR SATELLITE ENGINEERING

1. A satellite transponder has a total RF bandwidth of 72 MHz. It is to be used in FDMA to provide 12 equal-bandwidth carriers, with a 0.5 MHz guard band between adjacent carriers and 1 MHz guard bands at the lower and upper band edges.

   (a) What is the total bandwidth consumed by guard bands?
   (b) What is the usable (information) bandwidth remaining for the 12 carriers?
   (c) What is the bandwidth of each carrier?

2. A 500 MHz transponder is divided into 24 FDMA channels. Each channel has 36 MHz useful bandwidth and 4 MHz guard band, as used in typical satellite FDMA systems.

   (a) Verify whether the full 500 MHz is used or not.

   (b) If not fully used, compute the unused bandwidth.

   (c) What percentage of the total transponder bandwidth is wasted?

3. A 36 MHz transponder is used by 8 FDMA carriers of equal bandwidth. The transponder requires 0.3 MHz guard band at each end and 0.2 MHz guard bands between adjacent carriers.

   (a) Compute the total guard-band bandwidth.
   (b) Compute the total useful bandwidth available for carriers.
   (c) (c) Compute the bandwidth allocated to each of the 8 carriers.

4. A satellite uplink band from 6.100 GHz to 6.400 GHz is allocated to FDMA access. There must be a 5 MHz guard band at each end and 2 MHz guard bands between adjacent carriers. Each carrier requires 18 MHz RF bandwidth.

   (a) Find the total usable band after removing edge guard bands.
   (b) Determine the maximum number of carriers that can be accommodated.
   (c) Compute the total guard-band bandwidth (edge plus internal).

5. In an FDMA satellite system, each earth station transmits an FM carrier occupying 30 kHz. A 1.2 MHz uplink band is available for these carriers, with 5 kHz guard bands between adjacent carriers and 10 kHz guard bands at the band edges.

   (a) Determine the maximum number of carriers that can be accommodated.
   (b) If 25 carriers are actually used, calculate the fraction of the available band wasted (unused).

6. An FDMA satellite link allocates each voice channel 4 kHz baseband bandwidth; an FDM hierarchy combines 300 voice channels into one wideband signal occupying 1.2 MHz. This wideband baseband then modulates a single RF carrier assigned to one earth station.

   (a) What is the bandwidth expansion factor from a single 4 kHz voice channel to the 1.2 MHz group?
   (b) If the transponder can support 10 such FDMA carriers (groups) with no guard bands, what total baseband equivalent voice-channel capacity does this

represent?

(c) If later 0.6 MHz of guard-band is introduced overall (leaving only 9.4 MHz for carriers), how many such carriers can now be supported?

7. A 72 MHz transponder is shared by 20 FDMA carriers. Each carrier has bandwidth B_c and requires an additional 10% of B_c on each side as an internal guard band against adjacent channel interference (i.e., occupied width per carrier is $B_c + 0.2B_c = 1.2B_c$).

    (a) Assuming no extra guard at the transponder edges and that the 20 carriers just fit, find B_c.
    (b) What is the total useful (non-guard) payload bandwidth?
    (c) What fraction of the transponder bandwidth is used as guard bands?

8. A C-band transponder operates with FDMA and has a total downlink EIRP such that the maximum permissible power per carrier is 10 W when operating with 8 equal carriers (power-limited FDMA).

    (a) What is the total RF power output of the transponder at saturation if 8 carriers at 10 W each are allowed?
    (b) If the number of carriers increases to 16 (same back-off and total available power), what is the maximum power per carrier?
    (c) Comment quantitatively on the reduction in carrier power in dB when going from 8 to 16 carriers.

9. A satellite transponder supports FDMA carriers whose C/N for a single-carrier operation is 22 dB. When N equal-power FDMA carriers share the transponder, intermodulation noise effectively degrades C/N by an additional 3 dB when $N = 12$.

    (a) What is the resulting C/N in dB for the 12-carrier case?
    (b) If C/N must not fall below 18 dB, determine the maximum number of equal-power carriers allowed assuming the degradation scales approximately as $10\log_{10}(N)$ and is 0 dB at $N = 1$.
    (c) For your N from part (b), compute the approximate degradation in dB.

10. In an FDMA satellite system, the uplink band 6.200–6.260 GHz is divided among several carriers, each using 5 MHz of RF bandwidth plus 1 MHz guard band on each side (i.e., 7 MHz total spacing per carrier).

    (a) Compute the total available uplink bandwidth.
    (b) Determine the maximum number of carriers that can be accommodated.
    (c) If only 6 carriers are used, calculate the total unused bandwidth in MHz and as a percentage of the band.

MODEL ANSWERS

1. (a) Guard bands: edges = $2 \times 1 = 2$ MHz; internal = $11 \times 0.5 = 5.5$ MHz; total = 7.5 MHz.
   (b) Usable = $72 - 7.5 = 64.5$ MHz.
   (c) Each carrier = $64.5/12 = 5.375$ MHz.

2. (a) Each "slot" = 36 + 4 = 40 MHz; for 24 channels: $24 \times 40 = 960$ MHz. This exceeds 500 MHz, so such a configuration cannot fit in 500 MHz.

   (b) If total band is 500 MHz and 24×36 MHz useful = 864 MHz, clearly not feasible; maximum channels = $500/40 = 12.5$, so 12 full channels; used = $12 \times 40 = 480$ MHz; unused = $500 - 480 = 20$ MHz.

   (c) Wasted percentage = $(20/500) \times 100 \approx 4\%$.

3. (a) Edge guards: $2 \times 0.3 = 0.6$ MHz; internal guards: $7 \times 0.2 = 1.4$ MHz; total = 2.0 MHz.

   (b) Useful = $36 - 2 = 34$ MHz.

   (c) Per carrier = $34/8 = 4.25$ MHz.

4. (a) Total band = $6.400 - 6.100 = 300$ MHz. Usable after edge guards = $300 - 2 \times 5 = 290$ MHz.

   (b) Each carrier plus inter-carrier guard consumes 18 MHz + 2 MHz = 20 MHz. Max carriers = $\lfloor 290/20 \rfloor = 14$.

   (c) Used by 14 carriers including internal guards = $14 \times 20 = 280$ MHz. Total guard = edges 10 MHz + internal $13 \times 2 = 26$ MHz = 36 MHz.

5. (a) Total band = 1.2 MHz; subtract edges: $1.2 - 2 \times 10$ kHz $= 1.18$ MHz for carriers and internal guards. Each "slot" = 30 kHz + 5 kHz = 35 kHz. Max carriers = $\lfloor 1180/35 \rfloor = 33$.

   (b) If 25 used, occupied = $25 \times 35 = 875$ kHz inside the 1.18 MHz active region, plus 20 kHz edges = 895 kHz total. Wasted = 1.2 MHz $- 0.895$ MHz $= 0.305$ MHz. Fraction wasted ≈ $0.305/1.2 \approx 25.4\%$.

6. (a) Expansion factor = 1.2 MHz/4 kHz $= 1200/4 = 300$.

   (b) With 10 such carriers, total voice capacity = $10 \times 300 = 3000$ voice channels.

   (c) If only 9.4 MHz is available and each carrier needs 1.2 MHz, max carriers = $\lfloor 9.4/1.2 \rfloor = 7$. Total voice channels = $7 \times 300 = 2100$.

7. (a) Total occupied = $20 \times 1.2B_c = 72$ MHz, so $B_c = 72/(20 \times 1.2) = 72/24 = 3$ MHz.

   (b) Useful payload per carrier = 3 MHz, so total useful = $20 \times 3 = 60$ MHz.

   (c) Guard per carrier = $0.2 \times 3 = 0.6$ MHz, total guard = $20 \times 0.6 = 12$ MHz; fraction = $12/72 = 1/6 \approx 16.7\%$.

8. (a) Total power = $8 \times 10 = 80$ W.

   (b) With same total power: $P_{\text{per}} = 80/16 = 5$ W.

   (c) Reduction = $10\log_{10}(10/5) = 10\log_{10}(2) \approx 3.01$ dB.

9. (a) Resulting C/N for 12 carriers = $22 - 3 = 19$ dB.

   (b) Degradation model: $D(N) = 10\log_{10}(N)$ dB, with $D(1) = 0$. To keep C/N ≥ 18 dB: $22 - D(N) \geq 18 \Rightarrow D(N) \leq 4$ dB. So $10\log_{10}(N) \leq 4 \Rightarrow \log_{10}(N) \leq 0.4 \Rightarrow N \leq 10^{0.4} \approx 2.51$. So maximum integer $N = 2$.

   (c) For $N = 2$, degradation $D(2) = 10\log_{10}(2) \approx 3.01$ dB; resulting C/N ≈ $22 - 3.01 = 18.99$ dB.

10. (a) Total available uplink bandwidth = $6.260 - 6.200 = 60$ MHz.
    (b) Each carrier requires 7 MHz spacing, so max carriers = $\lfloor 60/7 \rfloor = 8$.

    (c) For 6 carriers: occupied = $6 \times 7 = 42$ MHz. Unused = $60 - 42 = 18$ MHz. Percentage unused = $(18/60) \times 100 = 30\%$.