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1. Given that,

Total bandwidth $= 33$ MHz $= 33{,}000$ kHz

Channel bandwidth $= 25$ kHz $\times 2$ channels

$= 50$ kHz / duplex channels

total available channels $= \frac{33{,}000}{50} = 660$ channels

(a) $N = 4$

total number of channels available per cell is $= \frac{660}{4}$

$= 165$ channels

(b) for $N = 7$,

total number of channels available per cell $= \frac{660}{7}$.

$= 94$ channels

(c) for $N = 12$,

total number of channels available per cell $= \frac{660}{12}$

$= 55$ channels

A 1 MHz spectrum for control channels implies that there are $1000/50 = 20$ control channels out of the 600 channels available. To evenly distribute the control and voice channels, simply allocate the same number of voice channels in each cell wherever possible.

(a) For $N = 4$, we can have 5 control channels and 160 voice channels per cell. Each cell only needs a single control channel (the control channels have a greater re-use distance than the voice channels). Thus 1 control channel and 160 voice channels would be assigned to each cell.

(b) for $N=7$, total number of voice channel is $=(660-20)/7 = 640/7 = 91$ voice channels are to be assigned. 4 cells with 3 control channels and 91 voice channel and 3 cells with 2 control channels are to be assigned along with 91 voice channels.

(c) For $N=12$, we can have eight cells with two controls channels and 53 voice channels. And four cells with one control channels and 54 voice channels each. In an actual system, each cell would have 1 control channel, 8 cells would have 53 voice channel and 4 cells would 54 voice channels.

Problem 2:

Solution: When $n=4$,

First let us consider a seven-cell reuse pattern, we know the co-channel reuse ratio is,

$$Q = \frac{D}{R} = \sqrt{3N} = \sqrt{3\times 7} = 4.583$$, Here, $N=7$

And also know that the signal-to-noise interference ratio is given by,

$$\frac{S}{I} = \frac{(\sqrt{3N})^n}{i_0} = \frac{(4.583)^4}{6} = 75.3$$

$$= 18.76\,dB$$

$i_0 = 6$

Since this is greater than the minimum required S/I, N=7 can be used.

(b) When $n=3$,
consider a 7-cell reuse pattern,
the signal-to-interference ratio is $= \frac{(4.583)^3}{6}$

$= 16.04 = 12.05$ dB

Since this is less than the minimum required S/I, we need to use a larger N. We know the number of cells per cluster, $N = i^2 + ij + j^2$ — (1)
using the equation given above, the next possible value of N for $i=2$, $j=2$ is $N = 2^2 + 2.2 + 2^2 = 12$

The corresponding co-channel ratio is given by the equation $Q = D/R = 6$
using equation (1), the S/I ratio is given by,

$$S/I = \frac{6^3}{6} = 36 = 15.56 \text{ dB}$$

Since this is greater than the minimum required S/I N=12 is used.

Problem 3:
Solution: Given that, user generation $A_u = 0.1$

$$GOS = 0.5\% = \frac{0.5}{100} = 0.005$$

for the erlang B chart, we obtain $A = 0.005$.
Therefore, the total number of users we can obtain from the given equation,

$A = U A_u = \frac{0.005}{0.1} = 0.05$ user

But actually one user could be supported one channel

So, $u = 1$.

(b) given that, $C = 5$

from the erlang B chart, $A = 1.13$

Hence the total number of user. $U = \frac{1.13}{0.1} = 11.3$

$= 11$ users

(c) Given that. $C = 10$, $A_u = 0.1$, $GOS = 0.005$

from erlang B chart, we obtain $A = 3.96$

Hence, the total number of users are, $u = A/A_u$

$= 3.96/0.1 = 39.6$

$= 39$ users

(d) Given, $C = 20$, $Au = 0.1$ $GOS = 0.005$

From Erlang B chart, we obtain, $A = 11.10$

Hence, the total number of users are, $U = \frac{A}{A_u}$

$= 11.10/0.1 = 111$ users

(e) Given that, $C = 100$, $A_u = 0.1$, $GOS = 0.005$

From the erlang. B chart, we obtain $A = 80.9$

Hence, total number of users are, $U = \frac{A}{A_u} = \frac{80.9}{0.1}$

$= 809$ users

Problem 4 :

Solution : System A , Given that

probability of blocking = 2% = 0.02

Number of channels per cell used in the system $c = 19$

traffic intensity per user $A_u = \lambda H = 2 \times \frac{3}{60} = 0.1$ Erlangs

For GOS = 0.02 and $c = 19$, from the Erlang B chart the total carried traffic A is obtained as 12 Erlangs. Therefore, the number of users that can be supported per cell is, $U = \frac{A}{A_u} = \frac{12}{0.1} = 120$

Since there are 394 cells, the total number of subscribers that can be supported by system A is equal to $= 120 \times 394 = 47{,}280$

System B : Given that

probability of blocking = 2% = 0.02

number of channels per cell used in the system $c = 57$

traffic intensity per user, $A_u = \lambda H = 2 \times 3/60 = 0.1$

For GOS = 0.02 and $c = 57$ from the Erlang B chart the total carried traffic, A is obtained as 45 Erlangs. therefore, the number of users that can be supported per cell, $U = \frac{A}{A_u} = \frac{45}{0.1} = 450$

Since, there are 98 cells, the total number of subscribers that can be supported by system B is equal to $= 450 \times 98 = 44{,}100$.

System C, given that,

Probability of blocking = 2% = 0.02

Number of channels per cell, C = 100

traffic intensity per user, $A_u = \lambda H$ = 0.1 Erlangs

For GOS = 0.02 and C = 100, from the Erlang B chart, the total carried traffic A is obtained as 88 Erlangs.

Therefore the number of users that can be supported per cell is, $U = A/A_u = 88/0.1 = 880$.

Since there are 49 cells, the total number of subscriber that can be supported by System C is equal to = $880 \times 49 = 43,120$.

Therefore total number of cellular subscribers that can be supported by these three systems are =

$$= 47,280 + 44,100 + 43,120 = 134,500$$

Since, there are two million residents in the given urban area, and the total number of cellular subscribers in System A is equal to 47,280. The percentage market penetration is equal to $= \frac{47,280}{2,000,000} = 2.36\%$

Similarly, market penetration of system B is $= \frac{44,100}{2,000,000}$
$= 2.205\%$

And, the market penetration of system C $= \frac{43,120}{2000,000}$
$= 2.156\%$

The market penetration of the system combined is =

$$\frac{134,000}{2,000,000} = 6.725\%$$

Problem 5

Solution: Given that,

transmitter power, $P_t = 50W$

carrier frequency, $f_c = 900 MHz$

(a) We know that the received power in unit dBm is,

$$P_r = 10 \log\left[\frac{P_r(d_0)}{0.001 W}\right] + 20 \log\left(\frac{d_0}{d_r}\right)$$

$$P_r = 10\log\left[\frac{50}{0.001}\right] = 10 \log (50000)$$

$$= 46.989 \simeq 47 dBm$$

$$= 47 dBm$$

(b) transmitter power, $P_t(dBW) = 10 \log[P_t(W)/1 W]$

$$= 10\log\left(\frac{50}{1}\right) = 16.989$$

$$\simeq 17 dBW$$

We know that the free space power received by a receiver antenna, is $P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2}$

$$= \frac{50 \times 1 \times 1 \times (1/3)^2}{(4\pi)^2 \times (100)^2 \times 1}$$

$$= 3.5 \times 10^{-6} W$$

$$= 3.5 \times 10^{-3} mW$$

Thus, $P_r(dBm) = 10 \log P_r(mW)$

$$= 10 \log (3.5 \times 10^{-3})$$

$$= -24.5 \text{ dBm}$$

The received power at 10 km can be expressed in terms of dBm using the equation given below.

$$P_r(dBm) = 10 \log \left[\frac{P_r(d_0)}{0.001} \right] + 20 \log \left(\frac{d_0}{d} \right)$$

$$= P_r(dBm) + 20 \log \left(\frac{d_0}{d} \right)$$

$$= -24.5 + 20 \left(\frac{100}{10000} \right)$$

$$= -24.5 - 40 = -64.5 \text{ dBm}$$

Problem 6

Solution: Given that, T-R separation distance = 5 km

E-field at a distance of 1 km $= 10^{-3}$ V/m

Frequency of operation at = 900 MHz

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{900 \times 10^6} = 0.333 \text{ m}$$

(a) We know that the length of antenna is,

$$L = \frac{\lambda}{4} = \frac{0.333}{4} = 0.08325 \text{ m}$$

the effective aperture of antenna is, $A_e = 0.016 \text{ m}^2$

thus ~~gtr~~ Gain, $G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \times 0.016}{(0.333)^2}$

$$= 1.813$$

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(b) Given that, $d \gg \sqrt{h_t h_r}$, the electric field is given by,

$$E_R(d) \approx \frac{2E_0 d_0}{d} \frac{2\pi h_t h_r}{\lambda d} \approx \frac{k}{d^2} \text{ V/m}$$

$$= \frac{2\times10^{-3}\times1\times10^{-3}}{5\times10^3}\left[\frac{2\pi(50)(1.5)}{0.333\times(5\times10^3)}\right]$$

$$= 113.1\times10^{-6} \text{ V/m}$$

The received power at a distance d can be obtained by using the equation given below:

$$P_R(d) = P_d A_e = \left(\frac{113.1\times10^{-6}}{377}\right)^2\left[\frac{1.8(0.333)^2}{4\pi}\right]$$

$$\Rightarrow P_R(d=5\text{ km}) = 5.4\times10^{-13} \text{ W}$$

$$= -122.68 \text{ dBW or}$$

$$= -92.8 \text{ dBm}$$

Problem 7

Solution: We calculate the terms in the Okamura Hata model as follows:

$$a(h_m) = 3.2[\log(11.75\, h_m)]^2 - 4.97$$

$$= 3.2[\log(11.75\times1)]^2 - 4.97$$

$$= 3.2\times[1.8798] - 4.97$$

$$= 6.01536 - 4.97$$

$$= 1.045 \text{ dB}$$

$$L_p = 69.55 + 26.16 \log f_c - 13.82 \log h_b - a(h_m) + [44.9 - 6.55 \log h_b] \log d = 137.3 \text{ dB}$$

Problem 8

Solution: The distance of the mobile from the base station is $= \sqrt{20^2+30^2} = \sqrt{1300} = 36.05$ m

Using the path loss formulas for microcells, we can write the path loss as:

$$L_p = 135.41 + 12.49 \log f_c - 4.99 \log h_b + [46.84 - 2.34 \log h_b] \log d$$

$$= 68.89 \text{ dB}$$

In addition to the emperical models presented, there are theoritical models that predict the path loss in micro cellular environments which ~~ha~~ have been adopted by a variety of standard bodies.