1) 

\[ R' = (2) \left( 8.4 \times 10^{-3} \frac{\Omega}{m} \right) = 16.8 \times 10^{-3} \frac{\Omega}{m} \]

\[ C' = \frac{\varepsilon_r \varepsilon_0 \pi}{\cosh^{-1} \left( \frac{s}{\delta} \right)} \]

\[ \varepsilon_r = 2.25 \]
\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ F/m} \]
\[ s = \left[ \frac{1}{2} (\varepsilon) + 2 \right] (0.245) \]
\[ + \frac{1}{2} (.5) \times 10^{-3} \text{ m} \]
\[ \delta = 0.99 \times 10^{-3} \text{ m} \]

\[ C' \approx 4.8 \times 10^{-11} \frac{F}{m} \]

\[ L' = \frac{M_r \mu_0 \cosh^{-1} \left( \frac{s}{\delta} \right)}{\pi} \]

\[ M_r = 1 \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ H/m} \]

\[ L' \approx 5.2 \times 10^{-7} \text{ H/m} \]

\[ L' \approx 0 \]
\[ Z_0 = \sqrt{\frac{R' + j2\pi f L'}{G' + j2\pi f C'}} \]

\[ R' \approx 1.68 \times 10^{-1} \]

\[ L' \approx 5.2 \times 10^{-7} \]

\[ G' \approx 0 \]

\[ C' \approx 4.8 \times 10^{-9} \]

If \( R' \ll Z_{\pi f L'} \)

\[ R' \ll \frac{f}{2\pi L'} \]

\[ 50 \text{ kHz} \ll f \]

Then

\[ Z_0 \approx \sqrt{\frac{L'}{C'}} \approx \left\lfloor 100 \, \Omega \right\rfloor \]
2) If $R' \approx 0$ and $C' \approx 0$

or $R' \ll 2\pi f L$ and $C' \approx 0$

\[ f \gg 50 \text{ kHz} \]

then the circuit model is

\[ Z_0 = 100 \Omega \]

Bad impedance mis-match at both ends of cable.
Set \[ \frac{1000 \frac{R_i}{1000 + R_i}}{} = 100 \]

\[ 1000 R_i = 10^5 + 100 R_i \]

\[ 900 R_i = 10^5 \]

\[ R_i = 111.5 \Omega \]

\[ \frac{V}{1000} \left( \frac{1000 R_i}{1000 + R_i} \right) = V \left( \frac{111}{1000 + 111} \right) = 0.1 \]

\[ V \]

\[ 100 \Omega \]

\[ \frac{V}{100} \]

\[ 0.1V \]

Voltage is cut to 10% of original.
$Z_0 = 100$

Impossible to compensate for cap w/o adding Inductance.

Add this.

Note: $V$ is cut in half

Answer to part A and B are both "YES"
But we have a problem.

\[ Z_o = 100 \]

The CMOS input sees only 0.05 of the original voltage. So if the original circuit toggled between 0 and 3.3 volts, now the logic gate input sees 0 and 
\[(0.05)(3.3) = 0.165 \text{ volts}\]

will not count as a logic 1 level.
4) CMOS

\[ 1k \Omega \]

\[ 2k \]

\[ 100 \]

\[ z_o = 100 \]

OP AMP. (INVERTING)

\[ 1k \Omega \]

\[ 3.3 \text{ volts} \]

\[ \frac{3.3}{2} \text{ volts} \]

CMOS / OP AMP

INVERTING

AMP CIRCUIT

ANOTHER CHOICE

CMOS

\[ 100 \Omega \]

\[ z_o = 100 \]

NON-INVERTING

OP-AMP.

Data entering LINE INVERTED.

That's why I gave it a gain of 2.
two choices for receiver.

**Inverting**

\[ Z_o = 100 \]

**Non-Inverting**

\[ Z_o = 100 \]
5) you can increase the gain at either transmitter, or receiver, or both.
At the transmit side - make sure you do not go above power supply voltage, or max volt allowed by cable.

**Inverting Tx**

![Inverting Tx Diagram]

**Non-Inverting Tx**

![Non-Inverting Tx Diagram]
**Inverting Rx**

- \( Z_o = 100 \)
- 100 \( \Omega \) (resistor)
- CMOS

**Non-Inverting Rx**

- \( Z_o = 100 \)
- 3100 \( \Omega \) (resistor)
- 1K\( \Omega \) (resistor)
- CMOS

Note: The diagram includes a 200 \( \Omega \) resistor with an annotation to increase its value.
6) Assume AM transmitters use \( \frac{1}{4} \) wave monopole.

\[ v = \lambda f \]

\[ 3 \times 10^8 = \lambda f \]

\[ \frac{\lambda}{4} = \frac{3 \times 10^8}{4 f} \]

\[
\begin{array}{|c|c|}
\hline
f & \lambda/4 \\
\hline
530 \text{ kHz} & 141 \text{ m} \\
1700 \text{ kHz} & 44 \text{ m} \\
\hline
\end{array}
\]

Range of AM Band.
7) Assume FM uses $\frac{1}{2}$ wave dispoziz.

$$\frac{\lambda}{2} = \frac{3 \times 10^8}{2f}$$

$$f \approx 100 \text{ MHz}$$

$$\frac{\lambda}{2} \approx 1.5 \text{ meters}.$$ 

\[ \text{Antenna at top of tower.} \]

\[ \text{Earth.} \]

Tower height has nothing to do with size of antenna for 100 MHz. It is used to overcome line of sight problems on a curved Earth.
\[ \lambda = 2(6.46) = 1.3 \text{ km} \]

\[ v = f \lambda \]

\[ (3 \times 10^8) = f \left(1.3 \times 10^3\right) \]

\[ f \approx 230 \text{ kHz} \]

They actually used 227 and 225 kHz.
9) A) \( v = f \lambda \)

\[
3 \times 10^8 = 600 \times 10^6 \lambda
\]

\( \lambda = \frac{1}{2} \text{ m} \)

\( \frac{\lambda}{2} = \frac{1}{4} \text{ m} \)

250 cm \( \cong \) 10 inches

B) \[ d \approx \sqrt{2rh} \]

\( r \approx 6.4 \times 10^6 \text{ m} \)

\( h \approx 628 \text{ m} \)

\[ d \approx \sqrt{90 \text{ km}} \cong 56 \text{ miles} \]
\[ d \approx \sqrt{2rh} \]
\[ r \approx 6.4 \times 10^6 \text{ m} \]
\[ h \approx 50' \approx 15 \text{ m} \]
\[ d \approx 14 \text{ km} \]

**Total Distance**

\[ 90 + 14 \approx 104 \text{ km} \]
\[ d \approx \sqrt{2 rh} \]

\[ r \approx 6.4 \times 10^6 \text{ m} \]

\[ h \approx 25,000 \text{'} \approx 7.6 \text{ km} \]

\[ d \approx 312 \text{ km} \approx 200 \text{ miles} \]
\[ d \approx \sqrt{2rh} \]
\[ r = 6.4 \times 10^6 \text{ m} \]
\[ h = 192 \]
\[ d \approx 50 \text{ km} \approx 30 \text{ miles} \]

Web page shows coverage to about 60 miles. Bending of EM wave in atmosphere is significant - and extends range.
12) 1) vertical monopole.

\[ \text{[Diagram]} \]

Good for Sat. at any horizon - not good for Sat. overhead.

2) vertical dipole.

\[ \text{[Diagram]} \]

Same answers as 1/4 wave monopole.
3) North/South Dipole

SIDE VIEW

Good -> Bad

OTHER SIDE VIEW

Good -> Good

Antenna works well for all Sat overhead, and those near East and West horizons - But not for Sat near North and South horizons.
4) Same answer as Part 3 - but interchange North with East and South with West.
\( d \approx \sqrt{2rh} \)

\( r \approx 6.4 \times 10^6 \text{ km} \)

\( h \approx 40,000 \text{'} \approx 12,200 \text{ m} \)

\( d \approx 400 \text{ km} \).

Hawaii to San Diego \( \approx 4,200 \text{ km} \).

\[ \frac{4,200}{400} \approx 10.5 \text{ or } 10.5 \text{d} \]
We need 6 drones

\[ 12d \geq 10.5d \]

5 drones would only give us 10d.
\( \lambda = (2)(3.5 \times 10^6) = 7 \times 10^6 \text{ m} \)

\( f = \frac{3 \times 10^8}{\lambda} \approx \sqrt{43} \approx 6.5 \)
Pikes Peak
14,000' elevation.
or 9,000' HAAT

Eastern Colorado
about 5,000' elevation.

\[ d = \sqrt{2 \cdot r \cdot h} \]
\[ r = 6.4 \times 10^6 \text{ m} \]
\[ h = 9000' \approx 2.7 \text{ km} \]
\[ d \approx \sqrt{180 \text{ km}} \approx 110 \text{ miles} \]
16) Antenna needs to be
\[ \frac{\lambda}{2} \approx 20 \text{ meters long.} \]

Best orientation is NW to SE
or NWW to SSE

Misses Pacific NW.

Misses Los Angeles and SW US.


Catches Rolla.

Misses Florida.
17) Signal should hit Europe to the East and Australia to the West.

Europe should be easiest to hear shortly after sunset in Rolle, when Atlantic Ocean is in darkness.

Australia should be easiest to pick up just before sunrise in Rolle, when it is night over the Pacific Ocean.