Second lecture of Topic 4: Noise Temperature, Antenna Gains, Friis' Formula and Link Budget

February 28, 2018

Noise Temperature

Pozar, Ch. 14, pp. 668.

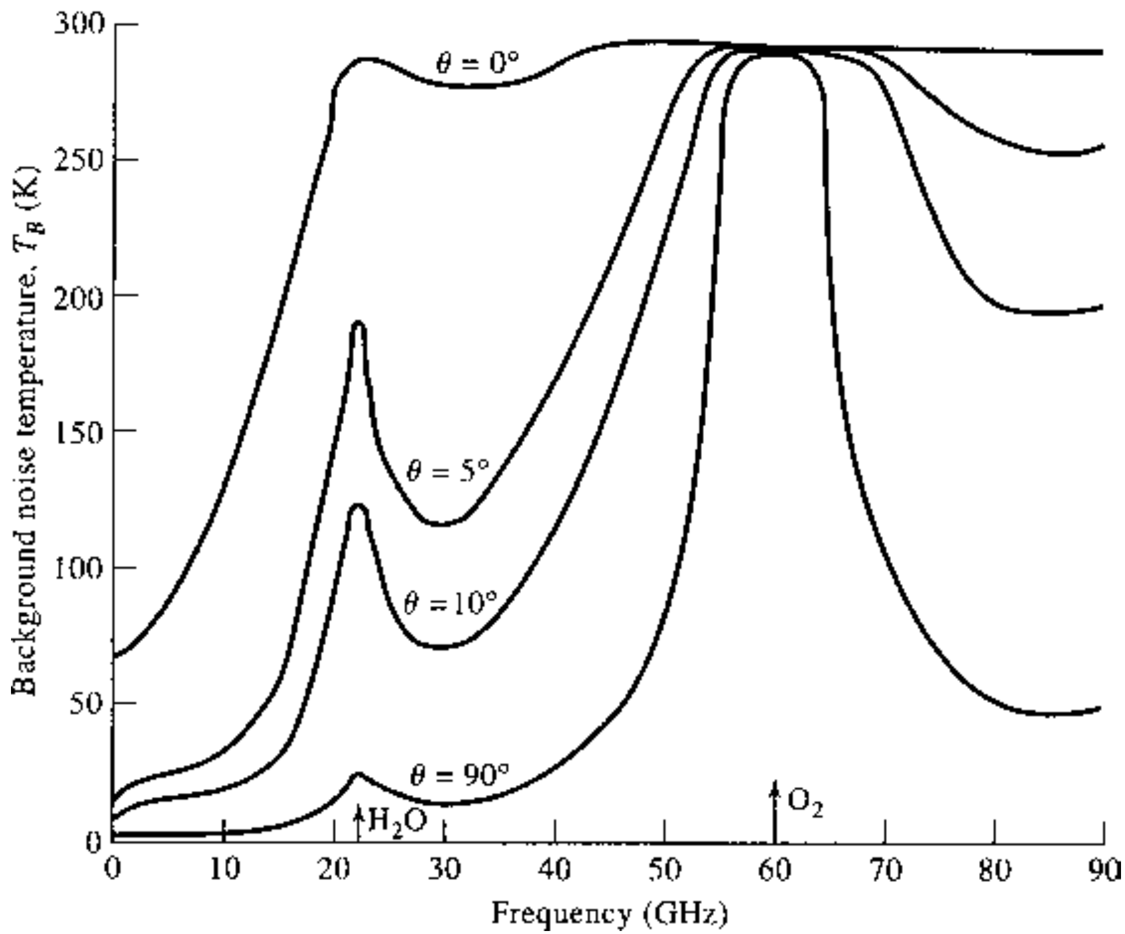


FIGURE 14.6 Background noise temperature of sky versus frequency. θ is elevation angle measured from the horizon. Data are for sea level, with surface temperature of 15° C and surface water vapor density of 7.5 gm/m^3.

Second Pre-Task for Topic 4

Watch a YouTube video and read Pozar Chapter 14.1 “System aspects of antennas”, keeping in mind the following questions. After watching the video and reading the chapter, answer the questions.

- Where does this mentioned noise floor of -174 dBm/Hz come from?
- Why the noise temperature of the antenna in the video is 150K? What is the corresponding noise floor (dBm/Hz)?
- What happens to the noise floor if we point the directive antenna to the sky?
- How would the situation change if the radiation pattern of the antenna was non-directive, i.e., omnidirectional?

Q1a: Choose an **incorrect explanation** about noise temperature. Choose 5. if you do not know what to choose.

1. When efficiency of the antenna is 1, the antenna noise temperature is averaged background noise temperature.
2. Antenna noise temperature is always around 290 K in a room temperature.
3. When the efficiency of the antenna is 0, antenna noise temperature is temperature of the antenna.
4. Background noise temperature peaks at 22 and 60 GHz, where water and oxygen absorption presents.
5. I do not know which explanation is incorrect.

Q1b: Choose an **incorrect explanation** about noise temperature.

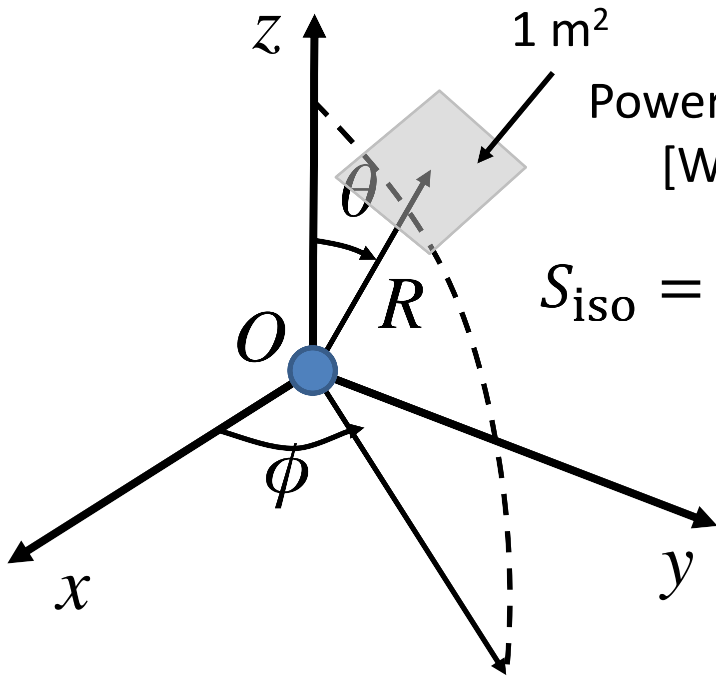
1. When efficiency of the antenna is 1, the antenna noise temperature is averaged background noise temperature.
2. Antenna noise temperature is always around 290 K in a room temperature.
3. When the efficiency of the antenna is 0, antenna noise temperature is temperature of the antenna.
4. Background noise temperature peaks at 22 and 60 GHz, where water and oxygen absorption presents.

Antenna Gains

- … are normalized radiated power density wrt that of an isotropic antenna

$$G(\varphi,\theta) = \frac{S_{\mathrm{AUT}}}{S_{\mathrm{iso}}}$$

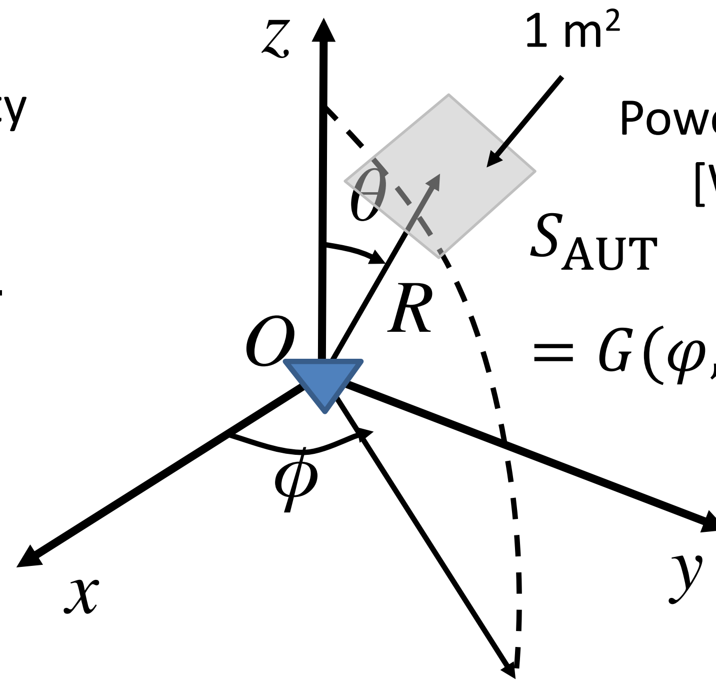
Reference: isotropic antenna with the same efficiency as antenna under test



Power density [W/m²]

$$S_{\mathrm{iso}} = \frac{P_{\mathrm{feed}}}{4\pi R^2}$$

Antenna under test



Power density [W/m²]

$$S_{\mathrm{AUT}} = G(\varphi,\theta)\frac{P_{\mathrm{feed}}}{4\pi R^2}$$

Q2a: Choose a side to the following statement; choose 3. if you do not know which side to choose.

Statement: a passive antenna can amplify the total signal power (unit in Watt) inputted to a feed port, when it has a gain.

1. The statement is correct.
2. The statement is incorrect.
3. I do not know which side to choose.

Q2b: Choose a side to the following statement.

Statement: a passive antenna can amplify the total signal power (unit in Watt) inputted to a feed port, when it has a gain.

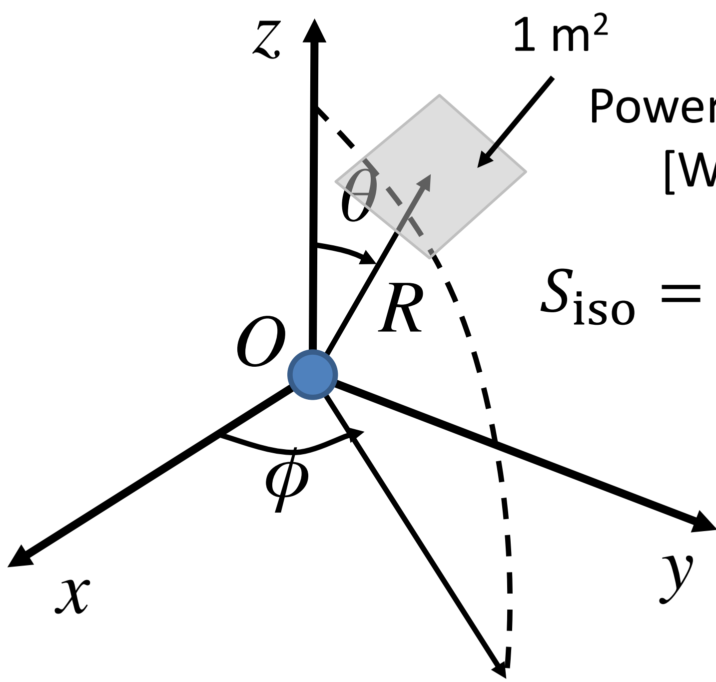
1. The statement is correct.
2. The statement is incorrect.

Antenna Gains

- … are normalized radiated power density wrt that of an isotropic antenna
  - And hence it is often quantified in dBi scale
  - Gain does NOT mean amplification of total power [W] at an antenna.
    - Total radiated power = power accepted by a lossless antenna.

$$G(\varphi, \theta) = \frac{S_{\mathrm{AUT}}}{S_{\mathrm{iso}}}$$

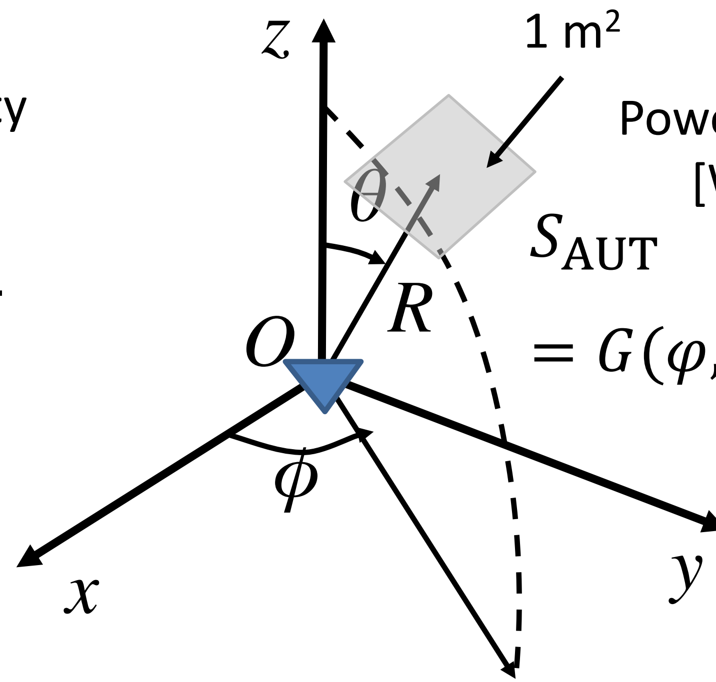
Reference: isotropic antenna with the same efficiency as antenna under test



Power density [W/m²]

$$S_{\mathrm{iso}} = \frac{P_{\mathrm{feed}}}{4\pi R^2}$$

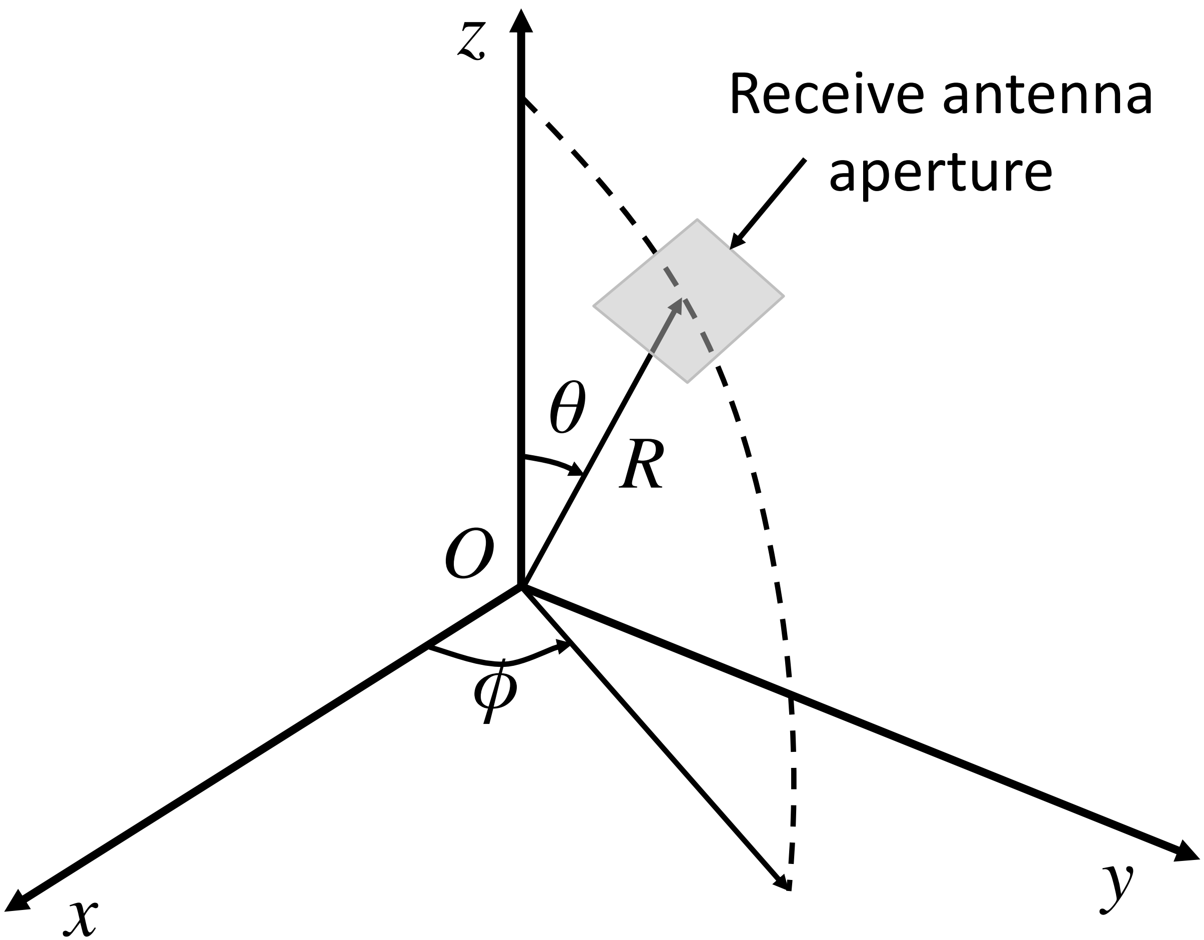
Antenna under test



Power density [W/m²]

$$S_{\mathrm{AUT}} = G(\varphi, \theta) \frac{P_{\mathrm{feed}}}{4\pi R^2}$$

Friis' Free-Space Transmission Formula



$$S_{\text{avg}} = \frac{P_{\text{t}}}{4\pi R^2}$$

$$G = 4\pi \frac{A_{\text{e}}}{\lambda^2}$$

$$P_{\text{r}} = S_{\text{avg}} A_{\text{e}}$$

$$= P_{\text{t}} G \left(\frac{\lambda}{4\pi R} \right)^2$$

Q3a: Choose a side to the following statement; choose 3. if you do not know which side to choose.

Statement: when an isotropic antenna radiates fields and a receive antenna has <u>a constant effective aperture size over the frequency such as ideal horn antennas</u>, the receiving power from the antenna port depends on the frequency.

1. The statement is correct.
2. The statement is incorrect.
3. I do not know which side to choose.

$$S_{\mathrm{avg}} = \frac{P_{\mathrm{t}}}{4\pi R^2} \qquad P_{\mathrm{r}} = S_{\mathrm{avg}} A_{\mathrm{e}}$$

$$G = 4\pi \frac{A_{\mathrm{e}}}{\lambda^2} \qquad = P_{\mathrm{t}} G \left(\frac{\lambda}{4\pi R} \right)^2$$

Q3b: Choose a side to the following statement.

Statement: when an isotropic antenna radiates fields and a receive antenna has <u>a constant effective aperture size over the frequency such as ideal horn antennas</u>, the receiving power from the antenna port depends on the frequency.

1. The statement is correct.
2. $\boxed{\text{The statement is incorrect.}}$

$$S_{\mathrm{avg}} = \frac{P_{\mathrm{t}}}{4\pi R^2} \qquad P_{\mathrm{r}} = S_{\mathrm{avg}} A_{\mathrm{e}}$$

$$G = 4\pi \frac{A_{\mathrm{e}}}{\lambda^2} \qquad = P_{\mathrm{t}} G \left(\frac{\lambda}{4\pi R} \right)^2$$

Q4a: Choose a side to the following statement; choose 3. if you do not know which side to choose.

Statement: when an isotropic antenna radiates fields and a receive antenna has <u>a constant gain over the frequency such as dipoles</u>, the receiving power from the antenna port depends on the frequency.

1. The statement is correct.
2. The statement is incorrect.
3. I do not know which side to choose.

$$S_{\mathrm{avg}} = \frac{P_{\mathrm{t}}}{4\pi R^2} \qquad P_{\mathrm{r}} = S_{\mathrm{avg}} A_{\mathrm{e}}$$

$$G = 4\pi \frac{A_{\mathrm{e}}}{\lambda^2} \qquad = P_{\mathrm{t}} G \left(\frac{\lambda}{4\pi R} \right)^2$$

Q4b: Choose a side to the following statement.

Statement: when an isotropic antenna radiates fields and a receive antenna has <u>a constant gain over the frequency such as dipoles</u>, the receiving power from the antenna port depends on the frequency.

1. The statement is correct.
2. The statement is incorrect.

$$S_{\mathrm{avg}} = \frac{P_{\mathrm{t}}}{4\pi R^2} \qquad P_{\mathrm{r}} = S_{\mathrm{avg}} A_{\mathrm{e}}$$

$$G = 4\pi \frac{A_{\mathrm{e}}}{\lambda^2} \qquad = P_{\mathrm{t}} G \left(\frac{\lambda}{4\pi R} \right)^2$$

Q5a: Choose a side to the following statement; choose 3. if you do not know which side to choose.

Statement: Radio systems operating at 28 GHz carrier frequency is always inferior to those at 2 GHz in receiving powers at a mobile, when line-of-sight exists between base and mobile stations.

1. The statement is correct.
2. The statement is incorrect.
3. I do not know which side to choose.

$$S_{\mathrm{avg}} = \frac{P_{\mathrm{t}}}{4\pi R^2} \qquad P_{\mathrm{r}} = S_{\mathrm{avg}} A_{\mathrm{e}}$$

$$G = 4\pi \frac{A_{\mathrm{e}}}{\lambda^2} \qquad = P_{\mathrm{t}} G \left(\frac{\lambda}{4\pi R} \right)^2$$

Q5b: Choose a side to the following statement.

Statement: Radio systems operating at 28 GHz carrier frequency is always inferior to those at 2 GHz in receiving powers at a mobile, when line-of-sight exists between base and mobile stations.

1. The statement is correct.
2. The statement is incorrect.

$$S_{\mathrm{avg}} = \frac{P_{\mathrm{t}}}{4\pi R^2} \qquad P_{\mathrm{r}} = S_{\mathrm{avg}} A_{\mathrm{e}}$$

$$G = 4\pi \frac{A_{\mathrm{e}}}{\lambda^2} \qquad = P_{\mathrm{t}} G \left(\frac{\lambda}{4\pi R} \right)^2$$

Friis' Formula in Practice

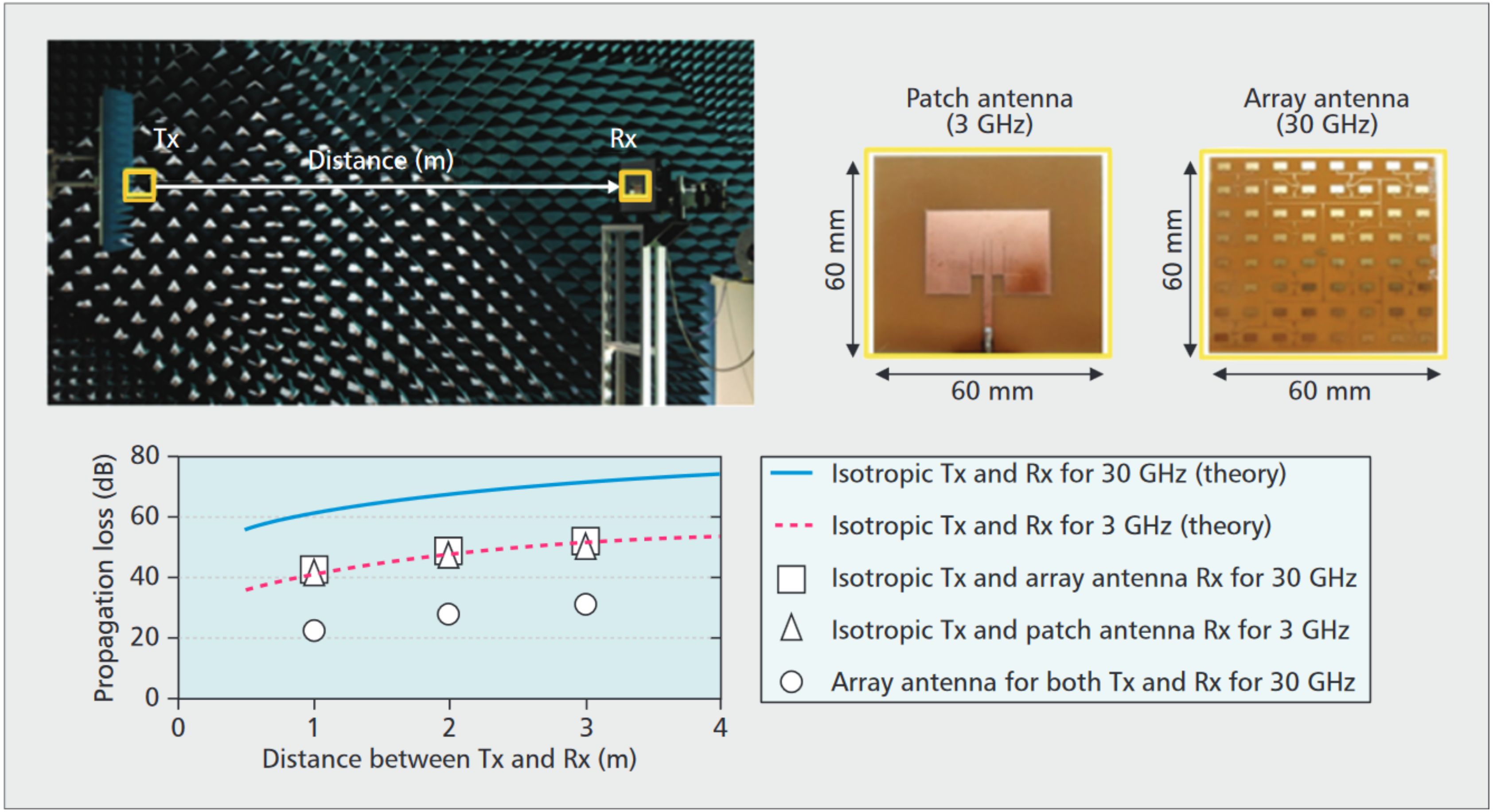
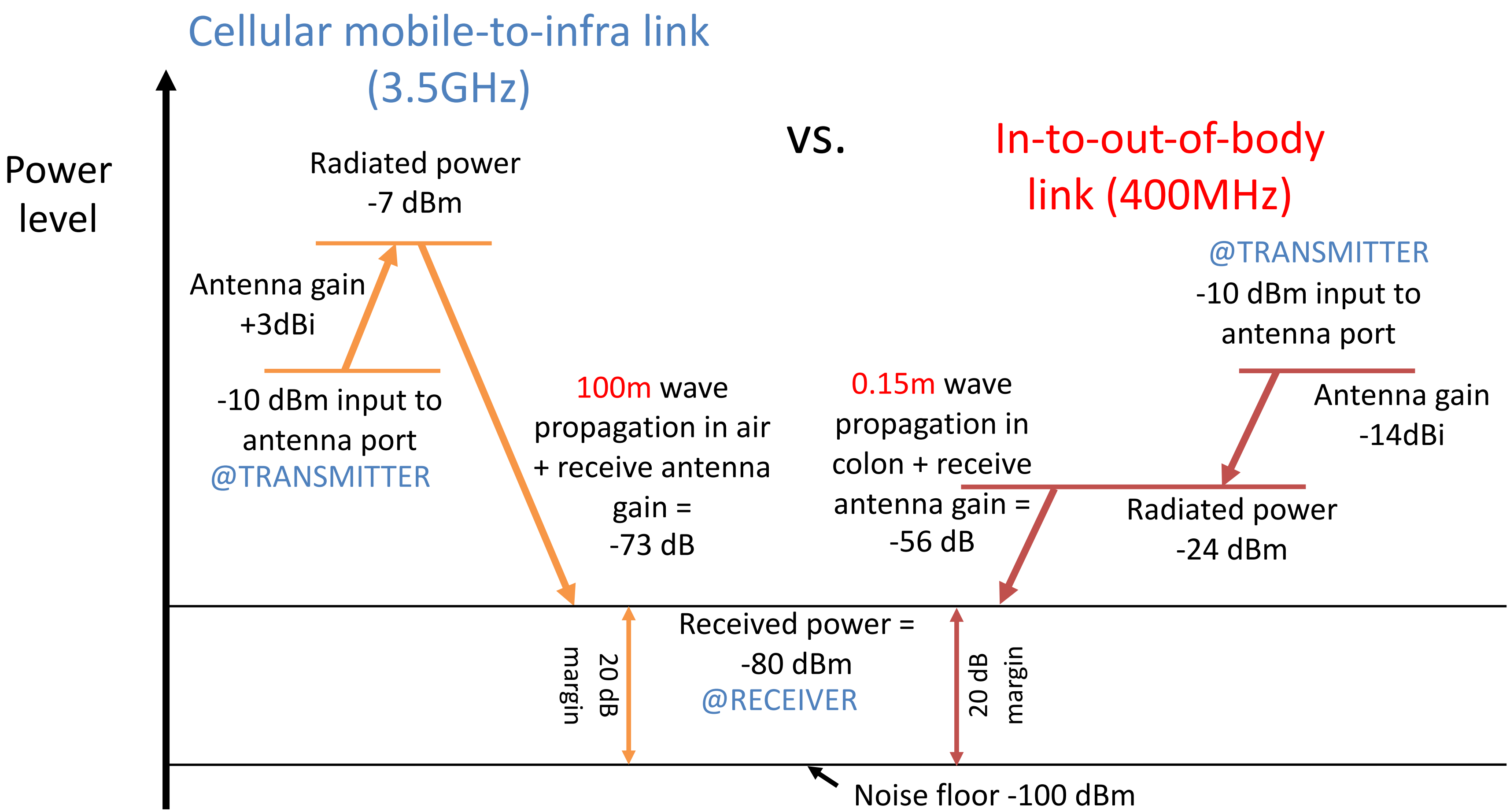


Figure 1. *Results of verification measurements of propagation loss predicted by the Friis equation.*

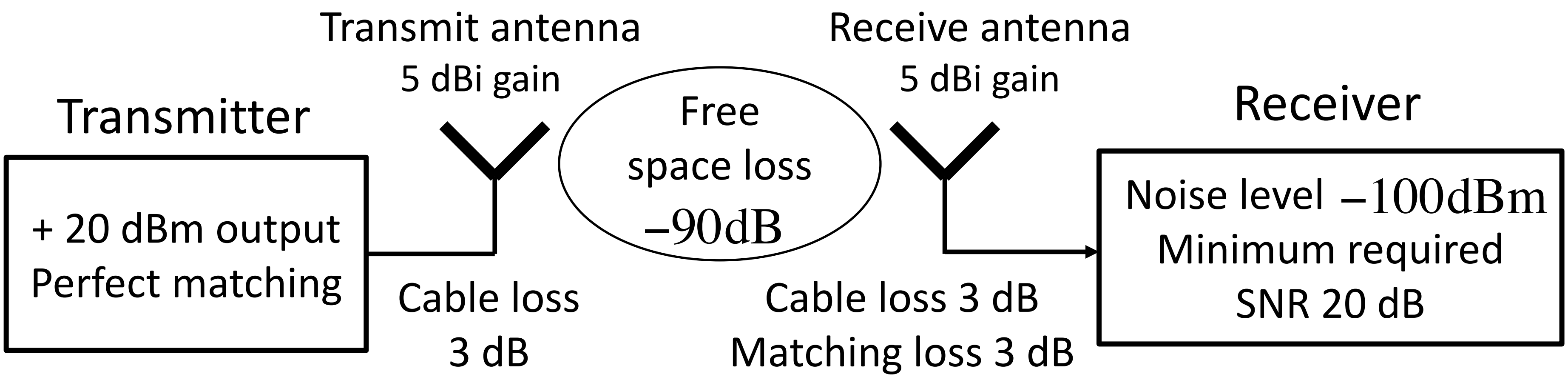
W. Roh et al., IEEE Commun. Mag. Feb. 2014.

Link Budget Analysis



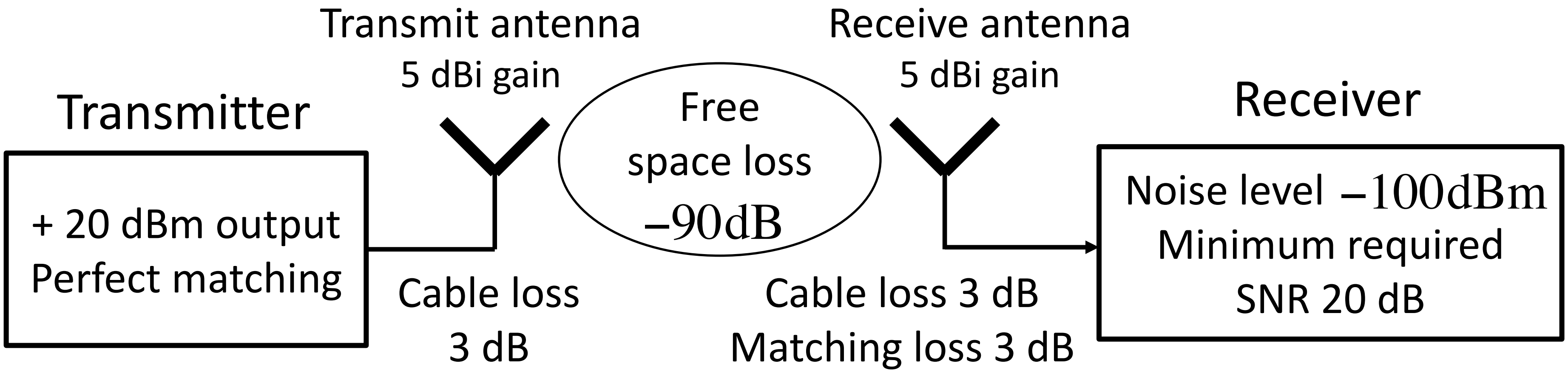
(Here, we assume the same input power to the antenna, and the same noise floor at the receiver)

Q6a: What is the link margin (dB) of the following radio link?



1. 7 dB.
2. 11 dB.
3. 15 dB.
4. 17 dB.
5. I do not know which one to choose.

Q6b: What is the link margin (dB) of the following radio link?



1. 7 dB.
2. 11 dB.
3. 15 dB.
4. 17 dB.

Topic 5 and Towards the End of the Course

- Monday, 4th March at 10:15 am
  - Exercise return session until noon
- Thursday, 7th March at 9:00 am
  - Deadline of pre-task for topic 5
- Thursday, 7th March at 9:15 am
  - Lecture for topic 5 (radio propagation)
- Monday, 11th March at 10:15 am
  - Exercise return session until noon
- Thursday, 14th March at 9:00 am
  - Online submission of exercise problems closes on MyCourses
- Thursday, 14th March at 9:15 am
  - The last exercise return session until noon
  - Please spare enough time to discuss with a teacher, as there may be longer queue on the day.