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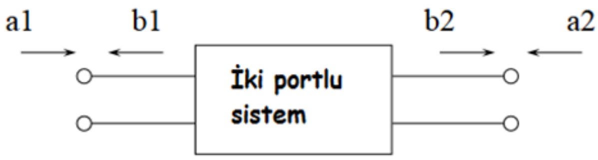
ANTENNA GAIN MEASUREMENT WITH A NETWORK ANALYZER

In this experiment, the use of a Network Analyzer will be examined, and it will be understood how antenna gain is obtained using S-parameters.

Preliminary Information :

S-parameters describe the input-output relationship between ports of a microwave system. For instance, in a two-port system, S_{21} represents the power transferred from Port 1 to Port 2.

$$b_1 = S_{11}a_1 + s_{12}a_2$$
$$b_2 = S_{21}a_1 + S_{22}a_2 \Rightarrow \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$



So, if we have a two-antenna communication system, there will be two connection points. S_{11} is the input reflection coefficient of antenna 1, and S_{22} is the input reflection coefficient of antenna 2. S_{21} is the ratio of the power at the ends of antenna 2 to the power at the ends of antenna 1. The S parameters are a function of frequency.

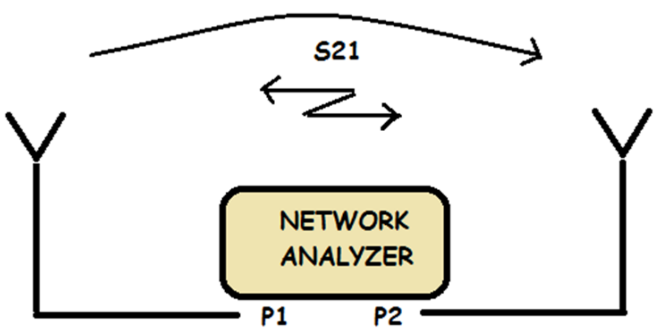


Figure-1 Antenna gain measurement using two ports

As an example, consider a two-port system. S_{21} represents the power received at antenna 2 relative to the power input to antenna 1. If S_{21}= 0 dB, it means all the power supplied to the input of antenna 1 has reached the terminals of antenna 2. If S_{21}=−3 dB, it means that if 1 Watt is sent to antenna 1, 0.5 Watts of power will be received at antenna 2.

If there is an amplifier in the circuit, S_{21} can show gain (i.e., $S_{21}>0$ dB). This would mean that for 1 W of power transmitted to Port 1, more than 1 W of power is received at Port 2.

Free-Space Path Loss :

$$L_{FS}\ (\mathrm{dB}) = 32.45 + 20\log(R) + 20\log(f) \qquad (1)$$

R : Distance between the transmitting and receiving antennas in meters (m).
f : Frequency in Gigahertz (GHz).

Antenna Gain:

If both antennas are identical, the antenna gain can be calculated with the following equation:

$$G = (S_{21} + L_{FS}) / 2 \qquad (2)$$

L_{FS} : Free-space path loss (dB).
G : Antenna gain (dB).

Experimental Procedure :

1. General Setup
1.1 Assemble the experimental setup as shown in Figure 2. Ensure that the Network Analyzer has been properly calibrated.
1.2 Place the horn antennas directly facing each other at an equal height.

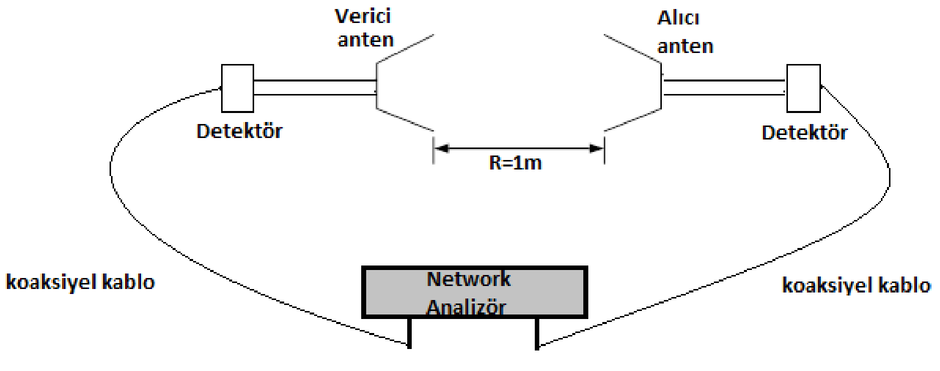


Figure 2: Antenna gain measurement setup with a transmitting antenna, receiving antenna, detectors, and a network analyzer connected via coaxial cables. The distance R is set to 1m.

2. Determining the Gain of the Horn Antenna

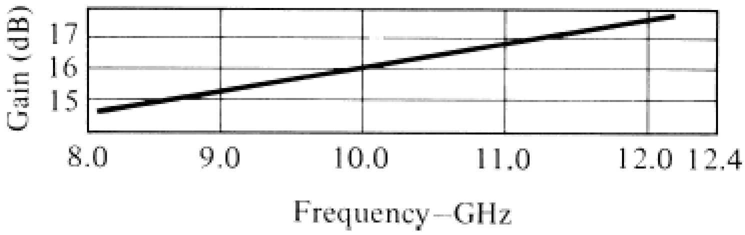
2.1 Set the distance between the antennas to the value specified in the figure (R=1m). Then, calculate the free-space path loss (L_{FS}) for this distance using equation (1).

2.2 Align the horn antennas as precisely as possible to ensure they are pointing directly at each other. Make fine adjustments (up/down, left/right) for each antenna while observing the Network Analyzer until the maximum amplitude for S_{21} is achieved. Antennas typically have sidelobes in addition to their main lobe. The purpose of aligning for maximum power is to ensure the gain is measured within this main lobe.

2.3 Using the Network Analyzer, read and record the S_{21} values for several frequencies within the 8.2-12.4 GHz range (X-band), for example, at 9, 10, 11, and 12 GHz.

2.4 For each frequency recorded, calculate the antenna gain using equation (2).

2.5 Compare your calculated results with the standard gain curve for an X-band horn antenna provided below and discuss your findings.



Questions

1. Explain how Equation (1) for free-space path loss is derived.
2. What other antenna characteristics can be measured using a Network Analyzer?
3. Why is the calibration of the Network Analyzer a critical step in this measurement?