Experimental laboratory no. 3: Antenna radiation pattern

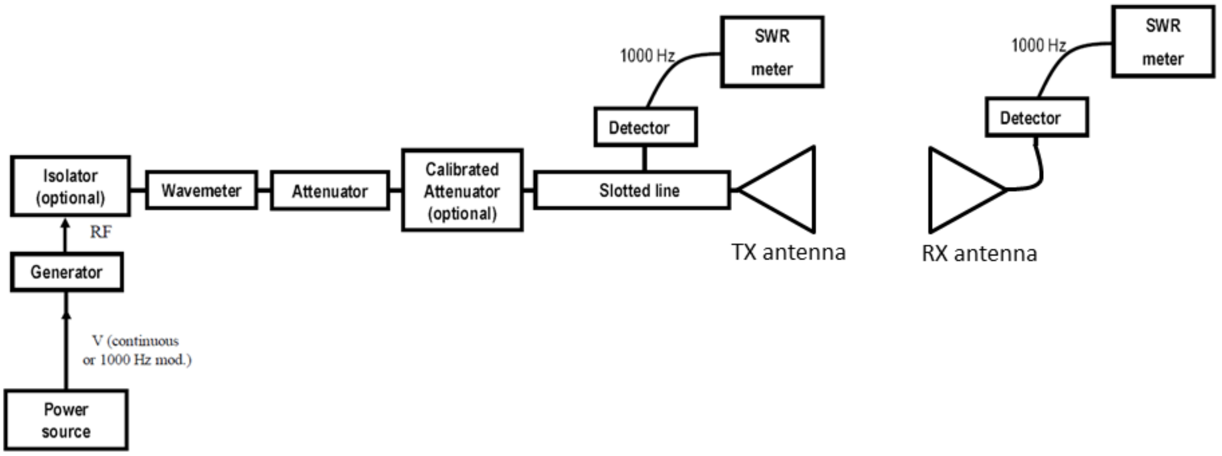
1. Measurement objective

Measurement of the normalized radiation pattern of an horn antenna in the two main planes (E plane and H plane), and measurement of the maximum gain of the antenna.

2. Technical data

- WR90 waveguide
- bandwidth: 6.2-12.4 GHz
- cut-off frequency for the fundamental mode TE10 (f_{c10}): 6.557 GHz
- maximum waveguide side *a*: 0.9 in (2.2286 cm)
- minimum waveguide side *b*: 0.4 in (1.016 cm)

3. Scheme of the test bench



4. Measurement procedure description

4.1 Frequency set up:

- Close the slotted waveguide with the matched load (to measure a constant signal with the SWR meter);
- set the frequency with the gunn generator to 9 GHz;
- connect the slotted waveguide with the SWR meter;
- switch on the power source and the SWR meter;
- check that moving the detector in the slotted waveguide the signal measured with the SWR meter is constant;
- set the resonant frequency of the wavemeter to 9 GHz (that corresponds to 4.863 if the wavemeter scale is in guided wavelength);

- move slowly the gunn generator around 9 GHz in order to measure a minimum signal with the SWR meter;
- keep in the gunn generator the position that corresponds to the minimum signal (the wavemeter is at the resonant frequency equal to 9 GHz);
- change the resonant frequency of the wavemeter (the measured signal should increase);
- switch off the power source.

Note: if a detector inside the wavemeter is available it is possible to detect a maximum inside the wavemeter instead of a minimum in the slotted waveguide.

4.2 Measurement of the antenna normalized radiation pattern:

- We recall that:

$$P_{RX} = P_{TX} \cdot g_{TX}(\vartheta) \cdot g_{RX}(\vartheta) \cdot A_{fs} \cdot \chi$$

  where P_{RX} is the received (available) power, P_{TX} is the input power, $g_{TX}(\vartheta)$ is the transmitting (TX) antenna gain in the direction ϑ, $g_{RX}(\vartheta)$ is the receiving (RX) antenna gain in the direction ϑ, $A_{fs} = \left(\frac{\lambda}{4\pi r}\right)^2$ is the free space attenuation (where r is the distance between the two antennas, and λ is the working wavelength), and χ is depolarization loss.
  In our test bench:
    - $P_{TX} = A \cdot P_g$ where P_g is the generator delivered power, and A the used attenuation (linear units);
    - $g_{TX,RX}(\vartheta = 0) = G$ maximum antenna gain;
    - $\chi = 1$ because the two antennas have the same polarization.
- Close the slotted waveguide with the TX antenna, and connect the RX antenna detector with the SWR meter;
- check that the TX and RX antennas are in far field condition ($r > \frac{2D^2}{\lambda}$, where D is the maximum dimension of the antenna aperture), and that they are aligned;
- set the calibrated attenuator to A_{1dB} (e.g. -20dB);
- switch on the power source;
- set the measured signal (P_{RX1}) to a reference value in one of the scales of the SWR meter;
- move the RX (or TX) antenna of an angle ϑ, and decrease the attenuation with the calibrated attenuator in order to set the measured signal (P_{RX2}) equal to the chosen reference value (P_{RX1});
- read the set attenuation (A_{2dB});
- considering that the two measured signals are the same ($P_{RX1} = P_{RX2}$) we get that:

$$A_1 \cdot P_g \cdot G \cdot G \cdot A_{fs} = A_2 \cdot P_g \cdot g_{TX}(\vartheta) \cdot G \cdot A_{fs}$$

  hence

$$g_{TXdB}(\vartheta) - G_{dB} = A_{1dB} - A_{2dB}$$

- Repeat the procedure for $0 < \vartheta \leq 20°$ with step 2.5° rotating the RX (or TX) antenna in both directions (left and right);
- repeat the procedure for both main planes (E plane and H plane);
- switch off the power source.

4.3 Measurement of the antenna maximum gain:

- Close the slotted waveguide with the TX antenna, connect the RX antenna detector with the SWR meter, and check that the two antennas are aligned;
- set the calibrated attenuator to A_{1dB} (e.g. 0dB);
- switch on the power source;
- set the measured signal (P_{RX1}) to a reference value in one of the scales of the SWR meter;
- switch off the power source;
- close the slotted waveguide with the RX antenna detector;
- switch on the power source;
- increase the attenuation with the calibrated attenuator in order to set the measured signal (P_{RX2}) equal to the chosen reference value (P_{RX1});
- read the set attenuation (A_{2dB});
- switch off the power source;
- considering that the two measured signals are the same ($P_{RX1} = P_{RX2}$) we get that:

$$A_1 \cdot P_g \cdot G \cdot G \cdot A_{fs} = A_2 \cdot P_g$$

hence

$$G_{dB} = \frac{1}{2}\left(A_{2dB} - A_{1dB} - A_{fsdB}\right) = \frac{1}{2}\left(A_{2dB} - A_{1dB} - 20\log_{10}\frac{\lambda}{4\pi r}\right)$$

that is the antenna (maximum) gain in dB unit.