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Determining the Antenna Gain in the GHz Range

It is possible in the microwave range to measure antenna gain with a few, simple aids (transmitter, directional coupler, diode probe, voltmeter), and when one has two identical antennas available. The described method can be carried out indoors.

The free-space attenuation a_{fs} can be exactly calculated for line-of-sight propagation in the VHF, UHF, and GHz range:

$$a_{fs/dB} = 20 \lg (4\pi d/\lambda) \qquad (1)$$

where:

d = Distance between transmitter and receiver

λ = Wavelength of the transmit frequency

This equation is, however, only valid when an imaginary isotropic radiator is assumed. It shows the attenuation that is present due to the "waste" of transmit energy in all directions, and by not using it in the optimum means of concentrating the energy using a directional antenna.

Of course, radio amateurs use antennas that possess a certain gain (even a dipole has 2.2 dB gain over an isotropic radiator). In this case, one will obtain a different free-space attenuation a_{tr} between transmitter and receiver that takes the gain of the transmit antenna – $G_{1/dB}$ – and the gain of the receive antenna – $G_{2/dB}$ – into consideration which can be calculated as follows:

$$a_{tr/dB} = 20 \lg (4\pi d/\lambda) - G_1 - G_2 \qquad (2)$$

This loss can, in contrast to a_{fs}, be actually measured. The attenuation a_{fs} cannot be measured in practice, but only calculated, since the isotropic radiator is not realizable in practice. The attenuation a_{tr}, on the other hand, is obtained by measuring the tansmit power P_{tx} and the receive power P_{rx} and by use of logarithms:

$$a_{tr/dB} = 10 \lg (P_{tx}/P_{rx}) \qquad (3)$$

The principle of the antenna gain measurement is as follows:

The power levels of P_{tx} and P_{rx} are measured and one calculates then the attenuation a_{tr} according to equation (3). The first expression in (2) corresponds to the free-space loss a_{fs} in the case of isotropic radiators, and can be calculated according to (1). This leaves the sum of G_1 and G_2 if one converts equation (2):

$$G_1 + G_2 = a_{fs} - a_{tr} \qquad (4)$$

It is now important that the transmit and receive antennas are identical! In this case, G_1 is equal to G_2, and one will only need to divide the result of equation (4) by half to obtain the gain of one of the antennas.

A horn radiator was now measured according to the described method at 8 GHz and the result was as follows:

At 8 GHz, λ is 3.75 cm. The spacing between the two horn radiators amounted to d = 128 cm. The transmit power was measured to be 32 mW, and the receive energy was 0.32 mW. According to equation (4) the following will result:

$$G_1 + G_2 = 52.6\,dB - 20\,dB = 32.6\,dB$$

This means that each of the two antennas exhibits a gain of 16.3 dB.

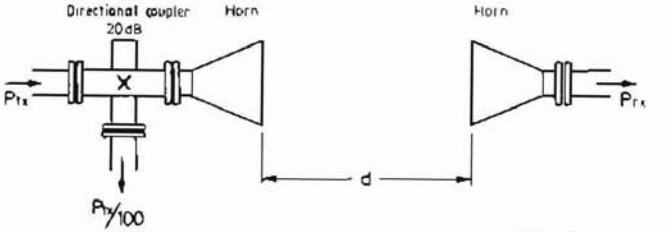

Fig. 1:
The distance d is selected so that $P_{rx} = P_{tx}/100$ in other words, that a_{tr} is exactly 20 dB.

The described measurement can also be carried out without absolute power measurement in a more elegant manner if a directional coupler is available. It is used to determine the transmit power. If, for instance, the directional coupler possesses a coupling attenuation of 20 dB, it is possible to select a_{tr} = 20 dB directly by placing the antennas only so far from another that the signal at the coupling output and at the output of the receive antenna are exactly equal. This is shown in **Figure** 1. The signals can be measured one after another using the same diode probe (test demodulator) and using the same operating point! This means that no power meter is required!

The accuracy of the measurement is dependent on the exact knowledge of the couple attenuation of the directional coupler. The distance 'd' is not given, but measured after determining the correct attenuation between transmitter and receiver. The given result coincides well with the data-sheet specifications of the antenna manufacturer. The gain measured in this manner is referred to an isotropic radiator, and not against a dipole, as is usually the case with professional, amateur, and other antennas.