

## ANTENNA TEMPERATURE

Antenna Temperature ( $T_A$ ) is a parameter that describes how much noise an antenna produces in a given environment. This temperature is not the physical temperature of the antenna. Moreover, an antenna does not have an intrinsic "antenna temperature" associated with it; rather the temperature depends on its gain pattern and the thermal environment that it is placed in. Antenna temperature is also sometimes referred to as Antenna Noise Temperature.

To define the environment, we'll introduce a temperature distribution - this is the temperature in every direction away from the antenna in spherical coordinates. For instance, the night sky is roughly 4 Kelvin; the value of the temperature pattern in the direction of the Earth's ground is the physical temperature of the Earth's ground. This temperature distribution will be written as  $T(\theta, \phi)$ . Hence, an antenna's temperature will vary depending on whether it is directional and pointed into space or staring into the sun.

For an antenna with a radiation pattern given by  $R(\theta, \phi)$ , the noise temperature is mathematically defined as:

$$T_A = \frac{1}{4\pi} \int_0^{2\pi} \int_0^{\pi} R(\theta, \phi) T(\theta, \phi) \sin \theta d\theta d\phi$$

This states that the temperature surrounding the antenna is integrated over the entire sphere, and weighted by the antenna's radiation pattern. Hence, an isotropic antenna would have a noise temperature that is the average of all temperatures around the antenna; for a perfectly directional antenna (with a pencil beam), the antenna temperature will only depend on the temperature in which the antenna is "looking".

The noise power received from an antenna at temperature  $T_A$  can be expressed in terms of the bandwidth ( $B$ ) the antenna (and its receiver) are operating over:

$$P_{TA} = KT_A B$$

In the above,  $K$  is Boltzmann's constant ( $1.38 \times 10^{-23}$  [Joules/Kelvin = J/K]). The receiver also has a temperature associated with it ( $T_R$ ), and the total system temperature (antenna plus receiver) has a combined temperature given by  $T_{\text{sys}} = T_A + T_R$ . This temperature can be used in the above equation to find the total noise power of the system. These concepts begin to illustrate how antenna engineers must understand receivers and the associated electronics, because the resulting systems very much depend on each other.

A parameter often encountered in specification sheets for antennas that operate in certain environments is the ratio of gain of the antenna divided by the antenna temperature (or system temperature if a receiver is specified). This parameter is written as G/T, and has units of dB/Kelvin [dB/K].

This refers to the positional dependence of the electromagnetic field in the near-field, or Fresnel region of the source. The near-field pattern is most commonly defined over a plane placed in front of the source, or over a cylindrical or spherical surface enclosing it. The far-field pattern of an antenna may be determined experimentally at an antenna range, or alternatively, the near-field pattern may be found using a near-field scanner, and the radiation pattern deduced from it by computation. The far-field radiation pattern can also be calculated from the antenna shape by computer programs such as NEC. Other software, like HFSS can also compute the near field.

Radiation pattern is one of the important characteristic of an antenna as tells the spatial relative distribution of the electromagnetic wave generated by the antenna. The radiation pattern is a plot of the magnitude of the radiation field as a function of direction ( $\theta, \phi$ ). The radiation pattern is essentially a 3-D surface. In the field of antenna design the term radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. Particularly in the fields of fiber optics, lasers, and integrated optics, the term radiation pattern, or near-field radiation pattern, may also be used as a synonym for the near-field pattern or Fresnel pattern.

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