VHF Antennas: Radiation Patterns

Introduction

As is well-known, the wireless transmission and reception of signals is caused by the propagation of an electromagnetic field from a source into the surrounding space. The process of radiation begins with high-frequency electromagnetic fields, which force external currents and charges to appear in the radiating system [1]. Currents and charges, in turn, move from the generator through the feeder path [2]. Thus, a system of electromagnetic field radiation requires an oscillation generator, a feeder, and a radiator. Also, in the context of radar design, it is important to note that all antennas follow the so-called principle of "duality", which implies that any antenna can be both transmitting (converting waves of the transmission line into diverging waves of the surrounding space) and receiving (performing the reverse conversion) [1]. All antennas are usually characterized by the following main parameters: radiation pattern (which includes directivity and gain), transmission line, load, weight, and dimensions [3].

Radiation Pattern and its Formation

Regardless of their type, implementation, and design, antennas consume energy and transmit it as a three-dimensional wave. This characteristic, which is common to all antenna, can be represented in the form of a radiation pattern. Radiation patterns include several auxiliary energy parameters, such as antenna gain and directivity. This, in turn determines the type of the antenna: omnidirectional, low directional or highly directional [4].

By its definition, the radiation pattern depends on the field strength created by an antenna at a sufficiently large distance and its observation angles. The formation of radiation pattern is a special case of filtering and can be used to separate the features of the desired signal and noise [5]. In the overwhelming majority of cases, this dependence is plotted in a spherical or polar coordinate system. However, for the convenience of engineering calculations, sometimes it can be represented in a rectangular coordinate system [4].

Directivity and Antenna Gain

As we have mentioned above, one of the key characteristics which determine an antenna’s design are directivity and gain. Although both of these values serve to describe similar concepts, and could be derived from the same principles, it is necessary to distinguish between them. Directivity is the ratio of the square of the field strength generated in the main direction to the mean of the square of the field strength in all directions [1]. In other words, it measures the degree to which the radiation emitted is concentrated in a single direction (power density).

Directivity does not consider losses presented in a system, such as the reflection of power flowing back into the feed line. This happens when input impedance is not exactly matched to the characteristic impedance of the line (since both the transmitting and receiving antennas are connected to the power line). That is why there will be an undesirable reflection of waves, and the presence of the latter always leads to a decrease in the radiated power and a source of additional interference (such as noises) [1].

The value which characterizes the directional properties of the antenna and takes into account its losses is called the gain. It is the ratio of the square of the field strength emitted by the antenna in the main lobe to the mean value of the square of the field strength emitted by the isotropic (ideal) antenna when both antennas are supplied with an equal amount of power [1]. The antenna gain is always smaller than the directivity, since the gain takes into account all of the losses of the system. In real antenna systems, the difference between the directivity and gain usually varies between 1.5 and 2.5 dB [6][7][8].

Radiation Pattern of Array Antenna

Array of antennas is one of the most widely used antenna system designs for radars. In such system, multiple antennas are arranged in a geometric grid pattern, and transmit the same, properly phased shifted signal. This setting allows us to achieve much higher directivity and gain levels (greater number of elements in array, greater the maximum transmitted power density) [8]. Also, with the proper electronics installed, such a system allows the simultaneous transmission and reception of multiple signals. At the same time, the low efficiency problem can be solved through varying excitation levels. Typically, when estimating performance of the system, it is assumed that the only difference between antennas in an array is a phase shift, and all of them are at the same excitation level. By allowing excitation level to vary between different elements, we can significantly improve overall performance of the system. Therefore, we decrease an amplitude of the signals fed to the certain elements of the system, performing a so-called thinning of the array [8].

Integration of Omnidirectional Antennas into Location System

The main advantage of omnidirectional antennas is their size. As an example, the Laird S9028PCR 9dBi patch 900MHz antenna has dimension of 259x259x33 mm and weight of 793g, while the Taoglas TG22 low-directivity antenna, which operates at the same frequency has dimensions of 48x6x0 mm and weight of 5.1g [2]. In addition to their smaller size, they have lower cost, broader angle coverage, and less phase center variation. All these advantages make integration of omnidirectional antennas into portable devices much easier, compared to the high-directivity antennas. However, because of an increased number of multi-paths and weaker line-of sight path, it becomes much harder to achieve accurate indoor ranging with omnidirectional antennas in indoor environment. One possible solution to this problem is to construct a system consisting of two arrays of 2-element omnidirectional antennas, which offer peak and average gain of 0.5 dB and -1.9 dB [2]. At the same time, it is important to note, that in the case of antennas, their dimensions are unambiguously related to the fundamental wavelength at which the antenna operates [3]. Generally, in antenna design there is no concept of "large" and "small" antenna. Therefore, their dimensions are usually characterized in wavelengths.

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