Array Antenna with Suppressed Side Lobe Level for Millimeter-Wave Applications

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Abstract – As millimeter-wave(mm-wave) band is attracted for 5G and autonomous driving technology, mm-wave band has become a commercial interest. In mm-wave radar applications, the suppression of the side lobe level has to be considered thoroughly. This paper proposes an array antenna structure that reduces the side lobe level by arranging the equal power divider in series from the uniform distribution structure. The beam patterns of the proposed 1x8 array antenna completely suppress the first side lobe. The level difference between a peak gain and side lobe level was 18.4dB. The proposed method provides an array antenna with low side lobe level for mm-wave radar applications such as motion sensing and security.

Index Terms — mm-wave applications, mm-wave array antenna, side lobe level suppression, amplitude tapering.

1. Introduction

The mm-wave band is limitedly used in defense and aerospace fields due to various technical problems of the high frequency band. As it is attracted for 5G and autonomous driving technology, mm-wave band has become a commercial interest. In addition, the mm-wave radar markets such as security, gesture recognition sensors, vehicle collision avoidance, anti-collision drones, and radar products for small robots are gradually expanding.

In radar system, one of the factors that improve the performance of the array antenna is the reduction of side lobe level. A beam synthesis technique utilizing various types of amplitude tapering distributions is used to lower the side lobe level of the array beam patterns. To obtain beam patterns with low side lobe level, antenna elements of the array antenna are required to have different weighting factors.

Un-equal power dividers are used to reduce the level of side lobes by obtaining different weight factors [1, 2]. An amplitude tapering methods were presented using unequal rectangular microstrip antenna elements to get different weight values [3]. However, these approaches tend to create sensitive electrical performance. In case of the power dividing ratio is large, the transmission lines with high characteristic impedance cause a risk of implementation due to the narrow line width.

This paper proposes an amplitude tapered array antenna for mm-wave radar applications. Based on the uniform distribution of corporate feeding network, a novel structure is proposed through changing of the placement of equal power dividers. This proposed method provides the design and implementation of an array antenna with low side lobe level for mm-wave radar applications.

2. Design of Low Side Lobe Levels Array Antenna

An array antenna structure is proposed to obtain different weighting coefficients by changing the arrangement of power divider in an antenna array. Fig. 1 shows an array antenna to reduce the side lobe level of undesired directions. The feeding network of proposed array antenna is composed of a number of equal power dividers. As the power divider is
connected in series, the amplitude of current fed to the antenna decreases farther away from the center. When power $P_T$ is applied to the 1x8 array antenna, the power is divided in half at each equal power divider. And the amount of power fed to each antenna is distributed $\frac{1}{16}P_T, \frac{1}{16}P_T, \frac{1}{8}P_T, \frac{1}{4}P_T, \frac{1}{4}P_T, \frac{1}{8}P_T, \frac{1}{16}P_T$. 

The design of proposed array antenna is described in Fig. 2. It is designed on Rogers 4350B ($\varepsilon_r = 3.66$, thickness = 0.254mm) and optimized antenna parameters are shown in Fig. 2. The array antenna operates at 24GHz and has a 0.5GHz bandwidth. The T-junction equal power divider is connected in series away from center, and the impedance is matched using the quarter-wavelength impedance transformer. The antenna spacing is $\lambda_g(=7.7mm)$ to feed in same phase. When an addition of antenna element is needed, it can be easily available by adding antenna element to the outermost side using the cascaded equal power divider.

3. Simulation Results

Since each antenna path of proposed antenna pass through the equal power divider in series, the transmission characteristics of the feeding network simulation result were [-12.2dB, -12.37dB, -9.46dB, -6.51dB, -9.46dB, -12.37dB, -12.2dB] at each antenna port.

Fig. 3 is comparing the proposed method with the uniform amplitude distribution in a 1x8 antenna array. The proposed array antenna to reduce the side lobe level has the following amplitude distribution that [0.25, 0.25, 0.354, 0.5, 0.5, 0.354, 0.25, 0.25]. That distribution is very similar to the Gaussian distribution with the variance of 2.1.

The radiation patterns of these cases are shown in Fig. 4. The radiation patterns of proposed array antenna completely suppressed the first side lobe as compared with the patterns of uniform distributions. The peak gain was 0.4dB less than the uniform distribution pattern, but the side lobe level was reduced by 5.44dB. The difference between the peak gain and side lobe level was 18.4dB.

4. Conclusion

This paper proposes an array antenna that reduce side lobe level by changing the arrangement of equal power divider in series based on the uniform distribution structure which is traditionally and generally used. The proposed structure includes amplitude tapering whose value is similar to the Gaussian distribution with a variance of 2.1. Proposed 1x8 array antenna suppresses the first side lobe compared to the uniform distribution. It achieves peak gain and side lobe level difference of 18.4dB. The proposed method can easily reduce the side lobe level of mm-wave system for effective motion sensing and crime prevention radar applications.

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References

