Printed Dipole Array Fed with Parallel Stripline for Ku-band Applications

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Abstract-This paper presents the design procedure of a printed dipole antenna and 1D array configurations of the single dipole element in the Ku-Band with its metallic reflector plane parallel to the array plane. The proposed antenna has a natural beam tilt which is useful for some specific applications. Several array configurations in 1D are simulated and tested. The effect of mutual coupling among each array elements is also investigated. Required modifications on the individual array element and the feed structures due to the effect of mutual coupling are examined. The single dipole and array of dipole has measured VSWR values smaller than 2 in the Ku-Band with simulated gains of 5.7 dBi and 12 dBi, respectively. All the simulations are performed with ADS-2006A software and measurements are performed in an anechoic chamber.

1. INTRODUCTION

Recent studies are highly focused on antenna design in Ku-Band. Since the Ku-band has enough available bandwidth for satellite links, these systems are widely used in satellite communications, especially in the mobile antenna systems used in vehicles. There are also other application areas of Ku-band systems such as weather radars and fire detection radars. These systems need highly directive antennas with a very wide frequency band covering the entire Ku-Band to transmit signals to the receiver with equal power in the whole frequency range and an automatic tracking system to capture the maximum power incident from the satellite while the time and place of the receiver changed. In order to provide good tracking system, one can use digital phase shifter technology or mechanical systems to tilt the beam of the receiver both in azimuth and elevation to the specified direction which will increase the cost of the system or decrease the accuracy of the tracking system respectively, [1]. In this paper, printed dipole antenna configurations which operate in the Ku-Band with different gains and tilted beam positions are proposed. Since the proposed antennas have tilted beams in elevation, they can be used in mobile satellite communication systems to eliminate the mechanical hardware or digital circuit needs at least in one direction to tilt the beam of the system, [2]. Also, arrays of these printed dipoles will be investigated and the gain of the arrays will be both simulated and measured.

2. Ku BAND SYSTEMS and DIPOLE ANTENNAS

Most of the mobile antenna systems used in vehicles operates in Ku-band for satellite communications. The communication link works properly as the beam of the transmitter antenna (satellite) and the receiver antenna (mobile antenna o) see each other. During the journey of the moving vehicle, as the location and the time vary, the ground station cannot control the transmitter, thus the only way to prevent disconnection is to track the best incoming signal level from the satellite. Majority of the commercial mobile communication systems use either mechanical tracking systems or digital phase shifters to capture the maximum power incident from the satellite. Mechanical systems provide the coverage by rotating both in the azimuth and in the elevation planes which may not be that accurate and fast enough for signal tracking in [1],[3]. Digital/Analog phase shifters overcome the disadvantages of the mechanical systems by simply orienting the main beam of the antenna to the desired direction by adjusting the phase and amplitude of the array elements electronically without rotating the antenna. Unfortunately, this technology is too expensive to be used in civil applications. Digital/Analog phase shifters mostly used in military systems.

In this paper, a dipole antenna system is proposed which can provide full coverage by simply rotating the antenna system only 180 degrees in azimuth direction. In this system, there is no need for rotating the antennas in the elevation angle due to the images of the electric dipoles over perfect infinite conductor (PEC). The dipole itself and image of the dipole can be modeled as a two element array system. The array factor of the two element system directly depends on the distance between the dipole and its image. As the distance between the dipole and the PEC is varied, the array factor changes. Therefore, one can simply tilt the beam of the mobile antenna system by adjusting the height of the antenna from the vehicle which was studied for 1.5 GHz MSAT application in [2]. In addition to tilt of the main beam of the antenna, grating lobes (or scalloping of the main beam) are generated with the increased height between the dipole antennas and the ground plane, [4]. Here, it is assumed that the vehicle body is the ground plane of the dipole antennas. Thus, we eliminate mechanical rotation in elevation requirement by introducing the dipole antennas over the ground plane, and forming two beams through the proper design of the dipole arrays in the azimuth direction, only 180 degrees rotation is sufficient for the coverage of the entire 360 degree azimuth plane.

3. SIMULATION and MEASUREMENT RESULTS

In this section, simulation and measurement results of the three dipole antenna array configurations will be given, the antennas are single dipole element and 1x2 and 1x8 dipoles over PEC as shown in Figure 1. The distance between the antennas and the ground plane is 13 mm. The dipole element lengths are designed by considering the mutual couplings between the elements.

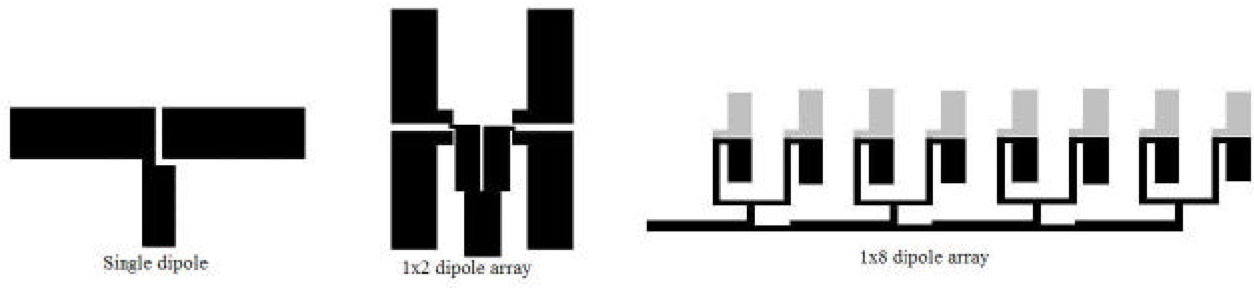

Figure 1 – Single dipole, 1x2 dipole, 1x8 dipole arrays (element length = 15 mm)

The antenna elements are simulated using the ADS-2006A Momentum simulation tool. The input return loss results are given in Figure 2. The single dipole element has S11 values less than -10 dB between 10.7 GHz – 13.1 GHz, while the 1x2 dipole antenna array has S11 values less than -10 dB between 10.4 GHz-12.2 GHz.

The 1x8 dipole antenna array has S11 of less than -10 dB between 11.3-12.3 GHz frequency range, and -5 dB return loss point is between 10 GHz and 13 GHz. As the more antenna elements are added, it is expected to have a narrower bandwidth operation, however, the antennas can still be used with a small return loss in the entire Ku bandwidth.

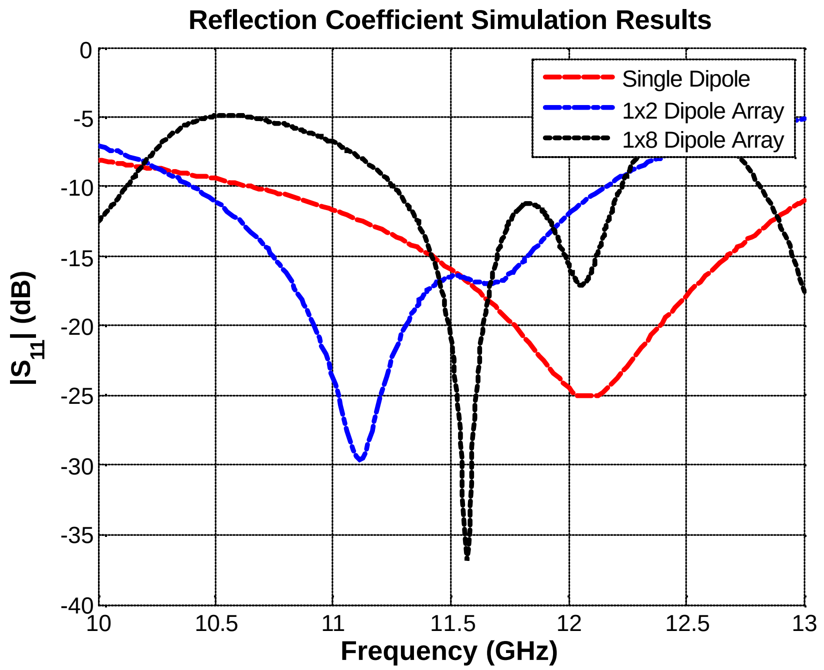

Figure 2 - The simulated return loss of single dipole, 1x2 dipole and 1x8 dipole arrays

After obtaining the input impedance results, antennas are simulated for the radiation pattern, and the simulated radiation patterns of the dipole antennas (E-plane) are obtained as shown in Figure 3. As the antenna height changes over the ground plane, the main beam of the antennas are tilted closer to the direction of the array. In Figure 3, for a specific antenna height of 13 mm from the PEC, the radiation patterns are plotted, and it can be seen that the pattern can be tilted even to 20 degrees with the direction of the array. Note that without the presence of the ground plane, the antennas would be radiating in their maximum direction of 90 degrees.

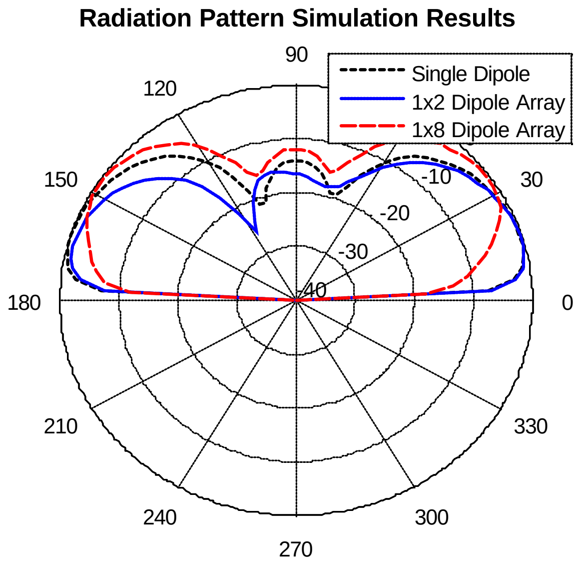

Figure 3- The simulated radiation patterns of single dipole, 1x2 dipole and 1x8 dipole arrays

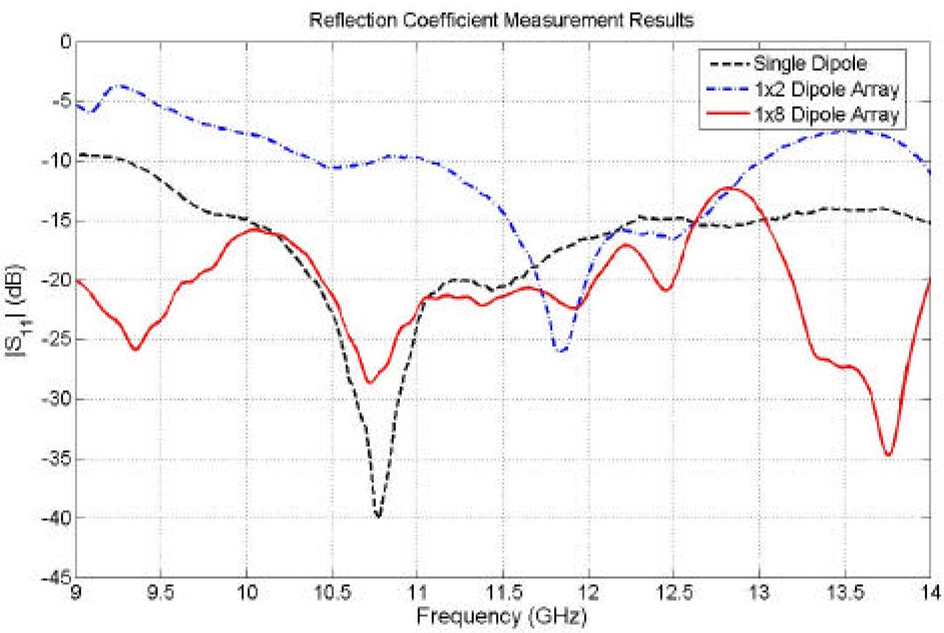

Figure 4 - The measured return loss of single dipole, 1x2 dipole and 1x8 dipole arrays

After simulations, the antennas are manufactured and S11 measurements are performed using Agilent Network Analyzer 8720ES for the three different antenna arrays without the presence of the ground plane. The single dipole antenna element has less than -15 dB return loss in 10.7-12.7 GHz band, the 1x2 dipole antenna has measured return loss of less than -10 dB in the 10.7-12.7 GHz frequency band, and 1x8 array has less than -12.7 dB return loss in the 10.7 -12.7 GHz frequency band. We have simulated the radiation patterns in ADS 2006A, and simulated gain changes between 10-12 dBi in the band of interest for the 1x8 dipole array.

4. CONCLUSION

Dipole antenna arrays with a beam tilt in elevation plane are proposed to be used in Ku band mobile communication systems. Due to ground plane, antenna beams are tilted, and the requirement for rotation in elevation is eliminated by adjusting the height between the antenna and the ground plane. Three antennas; single dipole, 1x2 dipole array and 1x8 dipole arrays are simulated and measured. Simulation and measurement results show that the return loss of the antennas are less than -10 dB in 10.7 -12.7 GHz band. The beam is tilted from the broadside direction such that only azimuth rotation is necessary for a mobile antenna system. Patterns are measured without the presence of the ground plane, as a future work, the antenna gains and radiation patterns will be measured with the ground plane.

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