Bandwidth Extension of Dual-Polarized 1-D TCDA Antenna Using VMS

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ABSTRACT

In this paper, a wideband, low-profile, one-dimensional tightly coupled dipole array (1-D TCDA) antenna with vertical metal strips (VMSs) is proposed. The 1-D TCDA has a limited scan angle due to variations in vertical wavenumbers according to scan angle. Floquet theory and the electric field profile can be used to analyze the theory of a TCDA, obtaining scan-independent characteristic. Removing some metal strips from the side walls also improved the radiation efficiency. The overlapped impedance bandwidth (IBW) for dual polarization was 0.8-2.5 GHz (3.1:1) for VSWR < 3, and the maximum scan angle was ± 50°. The radiation efficiency was over 70% within the IBW and maximum scan angle. The measurement results show that the gain was 7.0-12.4 dB for vertical polarization and 7.3-15.4 dB for horizontal polarization within the IBW and maximum scan angle. Furthermore, the height of the antenna was 0.13 λ_{low} at the lowest operating frequency, and the overall dimension of the full array structure was 1.69 λ_{low} × 0.59 λ_{low} × 0.13 λ_{low}.

Key Words : TCDA, phased array antenna, wideband antenna, low-profile antenna, wide scannable antenna.

1. Introduction

The boundary condition of the extant 1-D TCDA [1] is imperfect, especially when scanning the beam. As scanning the beam, the impedance matching becomes poor. To have a wide scan-angle performance with light weight and low cost, there are many efforts [2]-[4]. Wide angle impedance matching (WAIM) was proposed in [2]. A high dielectric constant slab is placed over the antennas. However, to place the slab at a proper position, it inevitably becomes a high height and the bandwidth becomes narrower. An advanced version of WAIM with a metasurface was used in [3] to steer the beam more widely. However, it still has a high height and the bandwidth is narrow. By placing a frequency selective surface (FSS) on dipole antennas, [4] found that the beam can be steered up to ± 70°. However, the greatest disadvantage of FSS is that its height is high.

In this paper, the proposed antenna has been designed based on that described in a previous paper [1]. Compared with the 1-D TCDA in [1], it is clear that this work is better in terms of beam scanning and impedance matching property.

2. Wide angle impedance matching of the TCDA analyzing the equivalent circuit

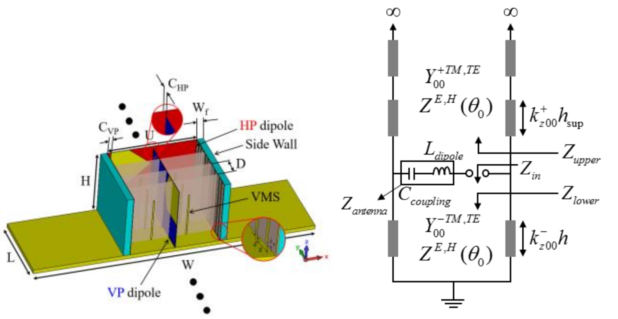

Fig. 1. Unit cell of the TCDA and the equivalent circuit of it.

$$Z_{in} = Z_{antenna} + Z_{upper} \parallel Z_{lower} \quad (1)$$

$$Z_{lower} = jZ^{E,H}(\theta_0)\tan(k^{-}_{z00}h)\Big|_{\varepsilon_r=1,\mu_r=1} \quad (2)$$

Fig. 1 shows the unit cell of a TCDA simulating a uniform current sheet and equivalent circuit of it. When scanning the beam, the impedance matching was poor because the impedance is matched when scanning to broadside. When scanning to the broadside, the propagation mode was the TEM mode, which means that the electric and magnetic fields were perpendicular to the z-axis. However, k^{-}_{z00} decreased when scanning to the other direction.

However, if VMS's are established at proper positions, the only transverse electric and magnetic field exists in the VMS region with $k^{-}_{z00} = k_0$ even when scanning the beam along the E-plane as explained in [5]. It means TM mode (not TE mode) incident on the VMS region is converted into the special transmission-like mode with $k^{-}_{z00} = k_0$ in VMS region as shown in Fig 2 so that the electrical length between the dipole and the ground plane is not a function of the scan angle. Also, $Z^E(\Theta_0)$ can be shown to be 377Ω with any scan angles. As a result, the array antenna with VMS can operate as a low-profile antenna since Eq. (2) is constant with scan angles.

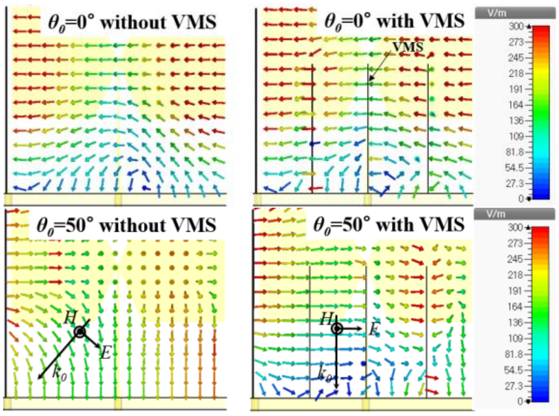

Fig. 2. Electric field profile without VMSs and with VMSs, both when scanning the beam at Θ_0 = 0˚. Electric field profile without VMSs and with VMSs, both when scanning the beam at Θ_0 = 50˚.

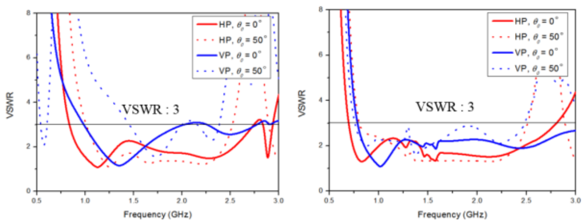

Fig. 3. Simulated VSWR of the antenna without VMSs and with VMSs.

Fig. 3 shows the simulated VSWR for both polarizations. At a low frequency band, the impedance matching without VMSs was very poor, but the impedance matching with VMSs improved significantly, even at other frequencies. As a result, the height was reduced from 0.24 λ_{low} to 0.13 λ_{low} when scanning up to 50° at the lowest operating frequency for VSWR < 3 within the overlapped band. Furthermore, the operating IBW was 0.8-2.5 GHz (3.1:1).

3. Conclusion

In this paper, we proposed a wideband, low-profile, 1-D TCDA antenna using VMSs. We employed Floquet theory to describe the main reason for impedance mismatching when scanning the beam. This was confirmed by the field profile between the dipole and the ground plane, but the VMSs did not change the field profile. As a result, IBW for VSWR < 3 was 0.8-2.5 GHz (3.1:1), and the antenna's height was reduced from 0.24 λ_{low} to 0.13 λ_{low}. The measurement results of the proposed array antenna were also in good agreement with the simulation results. This array antenna can be used in 1-D phased array antenna systems (e.g., base station array antennas or electronic warfare array antennas). This concept is expected to be used not only for array antennas but also for single vertical antennas with a ground plane, thus providing a low-profile characteristic.

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