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Antenna Radiation Polarization Configuration by Controlling Feeding Power Ratio Based on Digital Phase-Shifter Excited 90-degree Hybrid Directional Coupler

Hsi-Tseng Chou*(1), Heng-Tung Hsu(2), and Yi-Fan Tsao (2)
(1) Graduate Institute of Communication Engineering, National Taiwan University, Taipei 10617, Taiwan. (e-mail: chouht@ntu.edu.tw)
(2) International College of Semiconductor Technology, National Yang-Ming Chiao Tung University, Hsinchu 300, Taiwan. (e-mail: hthsu@nycu.edu.tw)
(3) Industry Academia Innovation School, National Yang-Ming Chiao Tung University, Hsinchu 300, Taiwan. (e-mail: elle1352@nycu.edu.tw)

Antenna polarization is important in wireless communications, where linear polarizations (LPs) are popularly employed in terrestrial networks. For a moving terminal, especially when the movement involves orientation changes, polarization mismatch appears to increase the polarization loss factor (PLF) [7]-[9] and significantly degrades the signal strength at the receiving systems. Such behaviors can be seen in the UAV and ship communication scenario, where the fast-floating movement of the UAV/ship changes the antenna polarization dynamically. In some cases, they must also choose between linear and circular polarizations (LP and CP) because both polarizations are used in satellite communications. A polarization reconfiguration is required to facilitate the polarization match for good communication links to mitigate such polarization and change issues.

For most mobile communications, conventional approaches implement dual-LPs on the base transceiver systems (BTS) to minimize the polarization mismatch effects when the user terminals (UTs) change dynamically in locations and orientations, where the maximum loss is 50% when the UT's polarization is at 45 degrees to the two orthogonal LPs, in addition to the degrade the maximum achievable EIRP. Dual-CP antennas have drawbacks of narrower bandwidths than dual-LP antennas because the directions of LPs are generally fixed and frequency-independent in symmetric structures. At the same time, CPs need to retain a good phase difference of 90 degrees between the two principal LP directions, which is highly frequency-dependent. Second, most works cannot retain their original CP radiations when the dual-CPs are used to reconfigure an LP. It is difficult to extract the power split functionality as in the unequal power divider in the previous paragraph.

In this paper, applicable methodologies of LP reconfiguration are investigated, and their characteristics are explained, where the LP reconfigurations are controlled by a digitally discrete phase shifter (DPS) for fast alignment. These DPSs are naturally available in commercial beamforming integrated circuits (BFICs) to excite antenna elements in an active array system. The BFICs generally include power amplifiers (PAs), low noise amplifiers (LNAs), RF attenuators, and DPSs. As a result, the proposed work remains the architecture of the original array design. The studies use the two CP antennas to perform the reconfiguration. Afterward, the dual-LP antennas are investigated using individual DPSs to excite the two LP ports to create the two CPs. In particular, we have proposed to use a 90-degree hybrid directional coupler for broadband operation, which provides the advantage of low power loss. This passive directional coupler is inserted between the BFIC and antenna elements without altering the RF circuit layouts. It overcomes the drawbacks of conventional approaches discussed earlier with the potential of dual-band operations. First, the dual-LP directions of antennas are frequency-independent for broadband operations. Second, any polarization can be reconfigured because the directional coupler has an inter-port transformation matrix to adjust the dual polarization weightings by controlling the BFIC's DPSs and attenuators. This transformation enables the integrated antenna structure to operate in a broadband for practical applications. This integrated antenna particularly benefits LP reconfiguration by feeding the directional coupler's two input ports with the same power from the BFIC. In this case, the DPSs can control the directional coupler to split power in any ratio with the same phases and deliver all powers provided by the PAs to maximize EIRP. Third, the directional coupler can behave as an RF switch when all power is delivered to one of its ports.

This paper will first present the basic mechanisms behind the reconfigurable power division by considering mathematic deviation based on a domain transformation to show the power ratio control by phase shifting. System architectures will be presented to show the operation. Numerical and experimental results will be shown step-by-step to demonstrate the implementation procedure and validate the concepts.