Coplanar Multi-line Antenna Design for Thin Wireless Terminal

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To improve portability of wireless apparatus, recently their shapes have been required thinner and thinner. On the other hand, responding starts of several kinds of multi-media wireless services, ex. wireless LAN (WLAN), 2.5/3 G cellar phone, terrestrial digital TV and etc., it is necessary to provide multi-mode antennas. The coplanar line antenna (CPLA), which consists of finite a self ground and strip lines around it, is suitable for thin shape multi-mode antenna [1]. This antenna has been widely used as multi-mode WLAN antenna for mainly notebook PC application. CPLA can be designed using simple modified transmission line theory, which is obtained by replacing conventional line with new line having a complex transmission constant due to radiation loss [2]. For the purpose of applying CPLA to smaller and thinner wireless apparatus, i.e., handy phone, PDA, and pocket PC, we propose the coplanar multi-line antenna (CPMLA), which has multi-stacked strip lines around the self ground.

To realize CPMLA in the limited small space of smaller and thinner terminal, we must analyze more precise antenna pattern, which is made under 0.5–1 mm line and space rule in stead of 2–4 mm rule of conventional CPLA. Direct EM analysis by using numerical method, i.e., FEM, FDTD, and Method of Moment, consumes huge computational time. An antenna design with computer is equal to searching out the candidate structure by using suitable searching algorithm and fast EM calculation required too many times in its algorithm. To realize the actual computer design of CPMLA, we have developed a novel design method by using the modified transmission line theory.

The novel design method is based on conventional design method of coupling transmission lines. Since strip lines of CPMLA are arranged on one ideal plane, we approximately consider only a multiple coupling between neighbor two strip lines. Different relative locations of these lines cause different self impedance of them. Because the conventional method assumes the same self impedance and the same mutual impedance caused of the coupling between neighbor lines, the scattering matrix of a multi-line structure is derived analytically. To obtain a scattering matrix of a multi-line structure with different self impedances, we have developed a recursive algorithm for such a scattering matrix as follows.

$$\overline{Z} = \begin{bmatrix} \alpha_1 & \beta & 0 & 0 \\ \beta & \alpha_2 & \ddots & 0 \\ 0 & \ddots & \ddots & \beta \\ 0 & 0 & \beta & \alpha_N \end{bmatrix}, \quad \begin{vmatrix} \alpha_1 - \lambda_i & \beta & 0 & 0 \\ \beta & \alpha_2 - \lambda_i & \ddots & 0 \\ 0 & \ddots & \ddots & \beta \\ 0 & 0 & \beta & \alpha_N - \lambda_i \end{vmatrix} = 0, \quad \begin{array}{l} \alpha_1 x_1^i + \beta x_2^i = \lambda_i x_1^i \\ \beta x_1^i + \alpha_2 x_2^i + \beta x_3^i = \lambda_i x_2^i \\ \vdots \\ \beta x_{N-1}^i + \alpha_N x_N^i = \lambda_i x_N^i \end{array}$$

$$\overline{Z} = {}^t\overline{T}\,\overline{S}\,\overline{T} = \begin{bmatrix} x_1^1 & \cdots & x_N^1 \\ \vdots & \vdots & \vdots \\ x_1^N & \cdots & x_N^N \end{bmatrix} \begin{bmatrix} z_1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & z_N \end{bmatrix} \begin{bmatrix} x_1^1 & \cdots & x_1^N \\ \vdots & \cdots & \vdots \\ x_N^1 & \cdots & x_N^N \end{bmatrix}$$

The final equation shows that impedance matrix Z is converted into diagonal scattering matrix S. Therefore, dividing CPMLA structure along longitudinal direction of the strip line into a short period without discontinuity along this direction, EM performances can be calculated by the modified transmission line theory. Moreover, connecting each short period with the cascade matrix of conventional circuit theory according to the CPMLA topology, we can design a multi-mode antenna, ex. 800/1500/1900 MHz 3-mode antenna sized of $40 \times 50 \times 0.03$ mm.

REFERENCES

1. Japanese patent application 2001-085484.
2. Japanese patent application 2004-305873.