Evaluation of Power Spectrum of 2-element Dipole Antenna with Periodically Variable Antenna Pattern

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***Abstract*—We derive a periodic time reactance sequence of a parasitic element for 2-element dipole antenna which makes the antenna pattern biased sinusoidal, i.e., without undesired harmonic components. The characteristics can construct two branches for diversity and MIMO reception by the antenna with single RF front-end. Through analysis of the antenna patterns for various interelement distances we can obtain a desirable antenna pattern for the distance of $\lambda/32$ in terms of receiver diversity.**

***Index Terms*—Periodically time variable antenna pattern, diversity, MIMO receiver.**

1. Introduction

Recently, MIMO(Multiple-Input Multiple-Output) technology is expected. But, it is dificult to bulid many antenna in actual. One approach to solving the problem, we have considered about MIMO reception by using antenna with periodically variable directivity [1]. This antenna generate diversity branches by time variable antenna pattern. However, we have confirmed to include harmonic component in the time variation of the antenna pattern [2]. Accordingly, we have shown that it is possible to generate antenna pattern without harmonic components [3].

In this study, we analyze time variation of antenna pattern for 2-elment antenna, and compare analysis result with received power in each distance between the active and parasitic element. Also we explain that the harmonic components are not included in the antenna patterns and study antenna patterns when varying distance between the active and parasitic element.

2. Analysis of Time-Variable Antenna Pattern

We assume that both an active and a parasitic antenna elements are dipoles. To analyze the antenna pattern of the antenna, we use equivalent weight vector method [4].

The admittance matrix Y of 2-port network is shown as

$$Y = \begin{bmatrix} y_{00} & y_{01} \\ y_{10} & y_{11} \end{bmatrix} \tag{1}$$

where y_{00} and y_{11} are self admittance and y_{01} and y_{10} are multual admittance. Equivalent weight vectors of active element $w_0\left(x\right)$ and parasitic element $w_1\left(x\right)$ can be expressed for given reactance of the parasitic element x as 2

$$\begin{bmatrix} w_0\left(x\right) \\ w_1\left(x\right) \end{bmatrix} = 2z_s \left(Y^{-1} + \begin{bmatrix} 2z_s & 0 \\ 0 & j2x \end{bmatrix} \right)^{-1} \begin{bmatrix} v_s \\ 0 \end{bmatrix} \tag{2}$$

TABLE I
ANTENNA PARAMETERS.

Parameters	Values
Target Frequency f_c	500 MHz
Radius of element $r = \lambda/300$	0.0020 m
Length of active and parasitic element $l = \lambda/2$	0.3000 m
Self admittance y_{00}, y_{11} $d = \lambda/4$	5.7650e-03 - j4.2931e-03 S
Mutual admittance y_{01}, y_{10} $d = \lambda/4$	1.8143e-03 - j4.0584e-03 S
Self admittance y_{00}, y_{11} $d = \lambda/8$	4.3839e-03 - j8.5425e-03 S
Mutual admittance y_{01}, y_{10} $d = \lambda/8$	1.2446e-03 - j7.6863e-03 S
Self admittance y_{00}, y_{11} $d = \lambda/16$	3.7196e-03 - j1.6281e-02 S
Mutual admittance y_{01}, y_{10} $d = \lambda/16$	1.0503e-03 - j1.5024e-02 S
Self admittance y_{00}, y_{11} $d = \lambda/32$	3.4047e-03 - j3.1763e-02 S
Mutual admittance y_{01}, y_{10} $d = \lambda/32$	9.2773e-04 - j3.0218e-02 S
Output impedance z_s	50 + j0 Ω
Inner Voltage v_s	1.0 + j0 V
Frequency of applied sinusoidal voltage f_s	30 MHz

where z_s is the output impedance and v_s is the inner voltage. The array factor of the antenna $D(\phi, x)$ for azimuth ϕ and reactance x can be shown as

$$D\left(\phi, x\right) = \begin{bmatrix} 1 & \mathrm{e}^{\left(j\frac{2\pi d}{\lambda}\cos\phi\right)} \end{bmatrix} \begin{bmatrix} w_0\left(x\right) \\ w_1\left(x\right) \end{bmatrix} \tag{3}$$

where d is the distance between the active and parasitic elements and λ is the carrier frequency of the signal [2].

3. Derivation of Reactance Time Sequence

The parameter of antenna is listed in Table 1. We use the parameters of the antenna which are listed in Table I. First, we obtain antenna patterns $D\left(\phi, x\right)$ for $d = \lambda/32$ and reactance values in 5 Ω interval from $x = -2,500$ to $2,500$ Ω by (3). The resultant pattern is shown in Fig. 1. As we can see, the shapes of the patterns are circular for each azimuth ϕ. Although the step size of reactance is constant, the distribution of the values $D\left(\phi, x\right)$ is not uniform on the circle. Thus, when we change the reactance in such a constant manner, the corresponding time-variable antenna pattern might have undesired harmonic components.

We derive a time sequence of reactance x which can make the antenna pattern rotate uniformly anticlockwise in a period $T_s = 1/f_s$ from the antenna pattern for $\phi = 0$ degree. The reactance sequence is obtained from the following equation derived from (3) and is shown in Fig. 2.

$$x = \frac{2v_s z_s (z_{00} - z_{10} e^{\left(j\frac{2\pi d}{\lambda}\cos\phi\right)}) - D(\phi, x)(|z_{00}|^2 - |z_{10}|^2 + 2z_s z_{00})}{j2\{D(\phi, x)(z_{00} + 2z_s) - 2v_s z_s\}} \tag{4}$$

The real and imaginary parts of the antenna pattern in time-domain for $\phi = 0$ are shown in Fig. 3. As we can see, the pattern can be sinusoidal with bias. The antenna patterns for

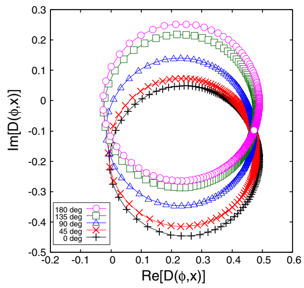

Fig. 1. The antenna patterns when the reactance is varied in 5Ω intervals from -2500Ω to 2500Ω.

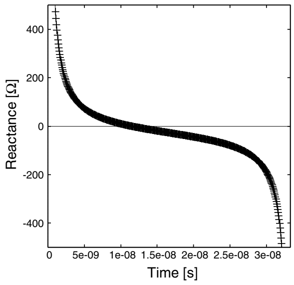

Fig. 2. Derived reactance sequence ($d = \lambda/32$).

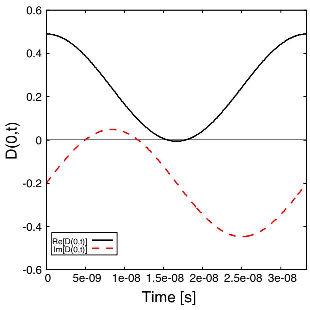

Fig. 3. Antenna patterns for time variation ($d = \lambda/32$).

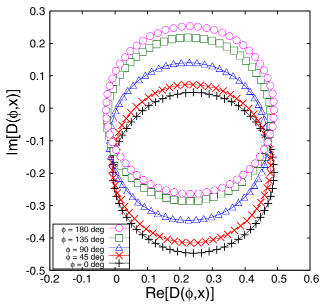

Fig. 4. Time variation of the antenna pattern generated by the derived reactance sequence ($d = \lambda/32$).

several azimuths ϕ generated by the same reactance sequence are shown in Gaussian plane in Fig. 4. The common sequence also can generate almost pure sinusoidal patterns.

4. Numerical Results

In this section, we analyze spectral components of the periodic antenna patterns derived in the previous section. The squared components (power) of antenna patterns for each azimuth ϕ are shown for distances between the active and the parasitic elements $d = \lambda/2$, $\lambda/4$, $\lambda/8$, $\lambda/16$, and $\lambda/32$ in Figs. 5, 6, 7, 8, and 9, respectively. Since the patterns in time domain are biased sinusoidal, the non-zero spectral power can be obtained only for DC (denoted as f_c) and frequency-shifted one (denoted as $f_c + f_s$). We find that the sum power of the two components can be achieved for $d = \lambda/8$. As for MIMO reception by the antenna, the difference between two components f_c and $f_c + f_s$ should be equivalnt to each other. We also find the distance $d = \lambda/32$ is the best from this perspective.

5. Conclusion

In this paper, we analyze the frequency components of the periodically time variable antenna pattern of 2-element dipole whose reactance varies with a particular reactance time sequence. By the derived reactance sequence we can obtain two diversity branches at the frequencies f_c and $f_c + f_s$ as well as suppress undesired harmonic components. For MIMO and diversity reception, We find that the distance between two elements of $d = \lambda/32$ can achieve the closest spectral power difference between dc and frequency-shifted components.

As future work, we would like to clarify the diversity gain obtained by the antenna patterns.

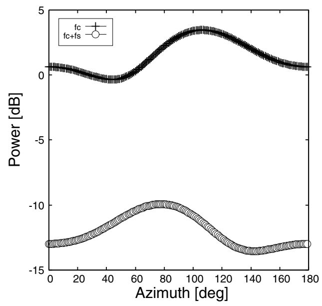

Fig. 5. Spectrum power of antenna pattern ($d = \lambda/2$).

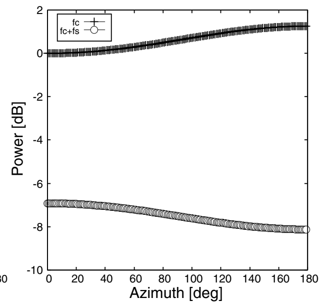

Fig. 6. Spectrum power of antenna pattern ($d = \lambda/4$).

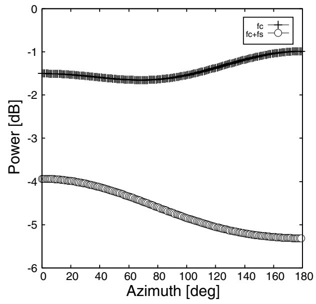

Fig. 7. Spectrum power of antenna pattern ($d = \lambda/8$).

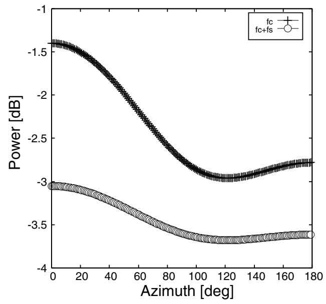

Fig. 8. Spectrum power of antenna pattern ($d = \lambda/16$).

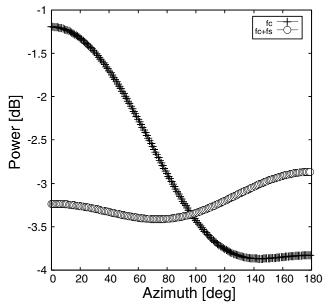

Fig. 9. Spectrum power of antenna pattern ($d = \lambda/32$).

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