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RADIATION CHARACTERISTIC OF BUILT-IN TYPE ANTENNA USING A SWITCHABLE PARASITIC SLOT

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1 Introduction

It is advantageous for cellular phones or Wireless LAN terminals that their antennas have variable radiation patterns when they are used in various situations. For examle, a radiation pattern forming toward a normal to a desk is suitable when they are put on it, and an isotropic pattern is suitable when they are held in a user's hand. Most conventional antennas, such as reactively controlled directive arrays[1], ESPAR antenna[2] etc. are composed of multiple elements of identical shape to resolve the above-mentioned issues. This paper proposes a novel variable radiation pattern antenna consisting of an inverted-F antenna and a parasitic slot with an electrical switch, and shows its fundamental characteristics and the appropriateness of its parameter optimization with GA.

2 Proposed antenna and principles

Figure 1 shows the proposed antenna configuration designed for 800MHz. An almost 0.4 wavelength slot is mounted on a 200mm□ conductive plate as a finite ground plane. The slot is switched by a PIN-diode bridged transversely at the center for the longitudinal direction of the slot. A matching circuit connected at the feed point of the inverted-F antenna suppresses a mismatching caused by PIN-diode switching.

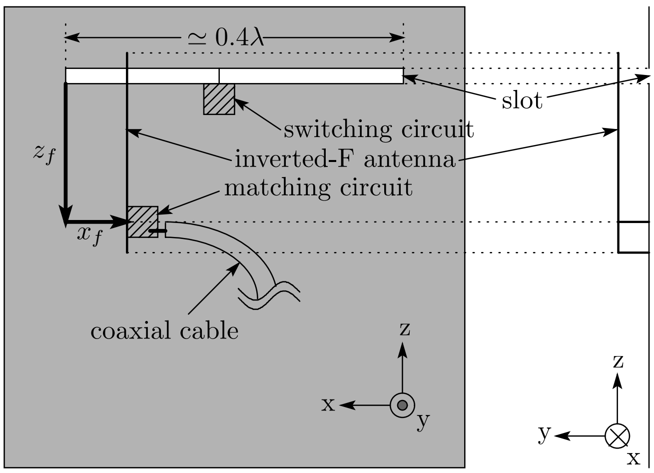

Figure 1: The proposed antenna configuration

An inverted-F antenna mounted on the conductive plate couples with the slot electromagnetically. Switching OFF the PIN-diode, the slot is transversely opened at the center for the longitudinal direction of the slot, and a magnetic current occurs on the slot. As a result, radiation pattern is formed toward the both sides of the conductive plate. Conversely, switching ON the PIN-diode, the slot is transversely shorted at the center for the longitudinal direction of the slot, and the magnetic current is suppressed. Conclusively, radiation pattern has a directivity toward +y direction due to the electrical current distribution on the inverted-F antenna and the conductive plate. These radiation patterns are advantageous when a terminal is put on a conductive desk and when it's held in a user's hand, for example.

The design method for this proposed antenna is discussed on section 4.

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3 Calculated and measured results

Figure 2 shows the measured VSWR of the proposed antenna. The reference plane for input impedance is at the junction of the matching circuit and the coaxial cable. It is matched nearby at the design frequency of 800MHz, and relative bandwidth at a center frequency of 800MHz with the VSWR below 3.0 is about 1.8% in the worst case when switch is OFF and ON.

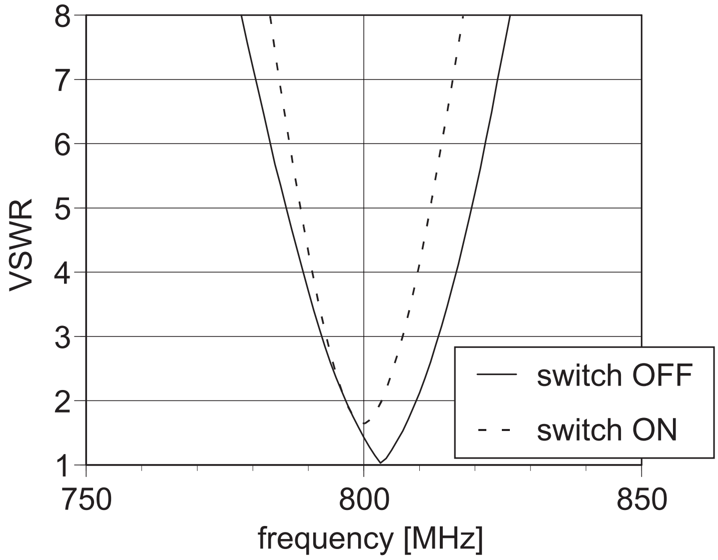
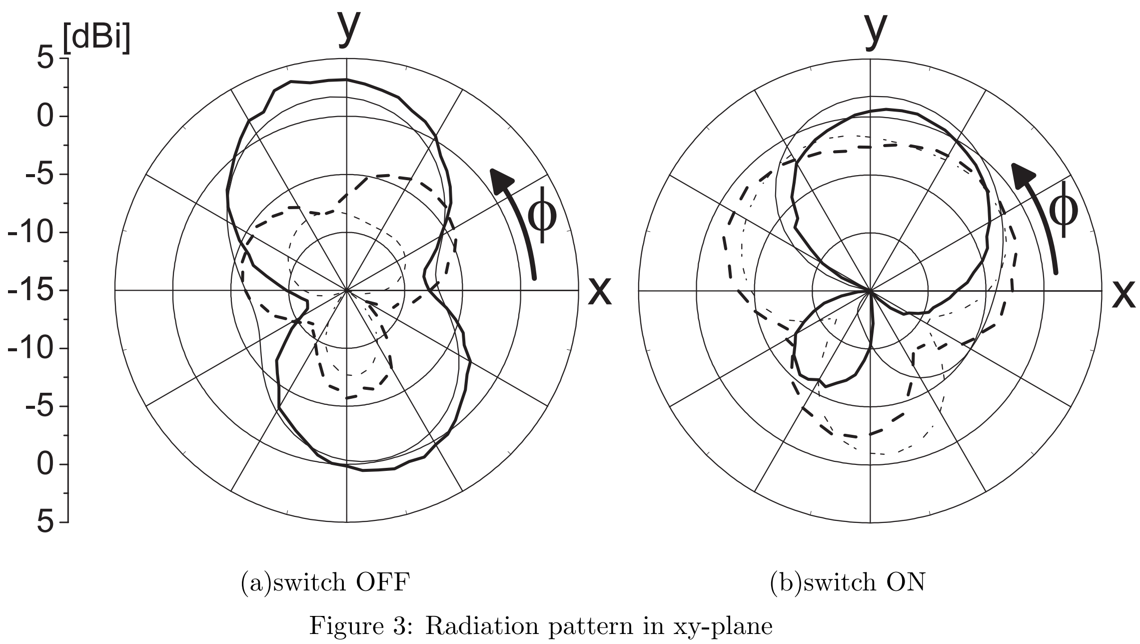


Figure 2: VSWR characteristic for frequency

Figure 3 shows the calculated and measured radiation pattern in xy-plane. The moment method is adopted to calculate antenna characteristics. The radiation pattern when switch is OFF shown in (a) is formed toward the both sides ($\phi = 90°, 270°$) of the conductive plate (zx-plane). On the contrary, the radiation pattern when switch is ON shown in (b) is formed toward the one side ($\phi = 90°$). The above means that radiation pattern is varied as PIN-diode is switched.



(a)switch OFF (b)switch ON

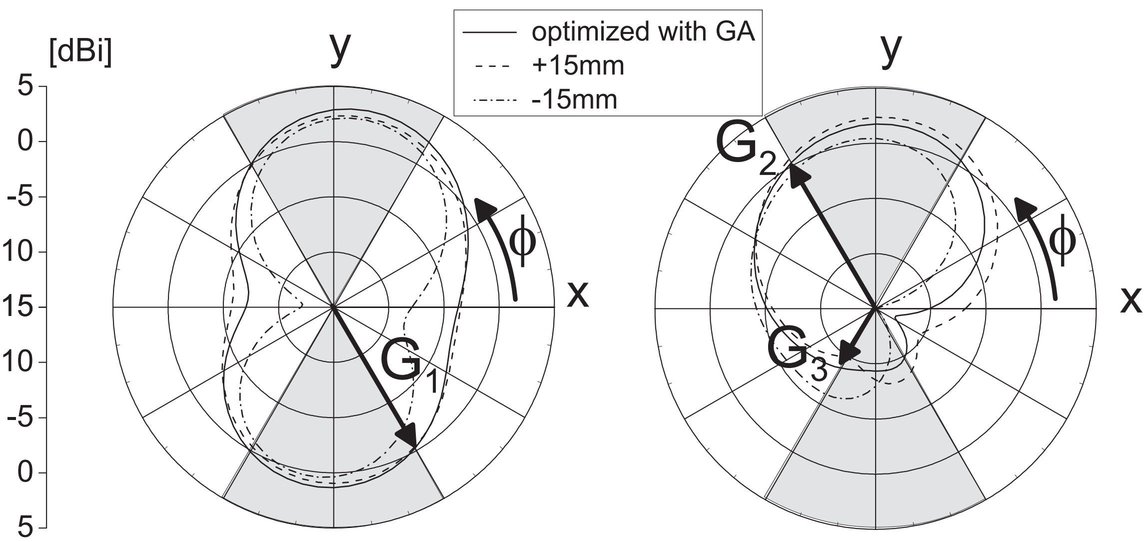
Figure 3: Radiation pattern in xy-plane
(thick:exp, thin:cal, solid:E_θ, broken:E_ϕ)

GA (Genetic Algorithm) is adopted as the method of optimization for the design of the proposed antenna, because the antenna has too many design parameters and evaluation values. GA optimizes the figure of the inverted-F antenna and the slot in order to maximize or minimize 6 evaluation values; power transmission coefficient and gain toward ±y for switch ON/OFF, respectively. It is unclear, however, what design parameters are required in order to realize the best performance. Therefore it is necessary to validate the appropriateness of optimization with GA.

4 Validation of GA's appropriateness

The proposed antenna is designed by optimization with GA. This section shows the validation of this method. GA optimizes all parameters of the antenna except for the size of the ground plane, with the directivity(G) and power transmission coefficiency(T) at feeding point as evaluation functions $E = G - T$. First, this section shows the directivity for the inverted-F antenna's feeding position displacement $(\Delta x, \Delta z)$ from the point (x_f, z_f). (x_f, z_f) is the optimum point designed with GA. Secondly, the power transmission coefficient is discussed. (ref. Figure 1)

Figure 4 shows the radiation pattern for Δx. Solid, broken, dotted and dot-dash lines indicate the radiation pattern at Δx=0, +15 and −15mm respectively. Figure 4 shows the directivity when the parameters are optimized with GA is confirmed to have a maximum $G = G_1 + G_2 - G_3$; G_1 is the lowest directivity within $\phi = 60° \sim 120°$ and $240° \sim 300°$ when switch is OFF (Figure 4(a)), G_2 is the lowest directivity within $\phi = 60° \sim 120°$ when switch is ON (Figure 4(b)) and G_3 is the highest directivity within $\phi = 240° \sim 300°$ when switch is ON.



(a)switch OFF (b)switch ON

Figure 4: The radiation pattern for Δx
(G_1, G_2 and G_3 point the gain when optimized with GA.)

Figure 5 shows the value G for $(\Delta x, \Delta z)$. This chart has 2 peaks near points A and B. Point A designed with GA is on the one peak, but point B is on the another highest peak.

Power transmission coefficient $T = -6.37$dB at B is, however, vastly inferior to -1.83dB at A. Changing the parameters except for feeding position in order to improve matching at B, the value G decreases greatly before T rises above -1.83dB.

Figure 6 shows the value E for $(\Delta x, \Delta z)$, and E is higher at A than at B. This confirms that the optimization of directivity and matching simultaneously is necessary, and GA could optimize the parameters, taking both characteristics into consideration.

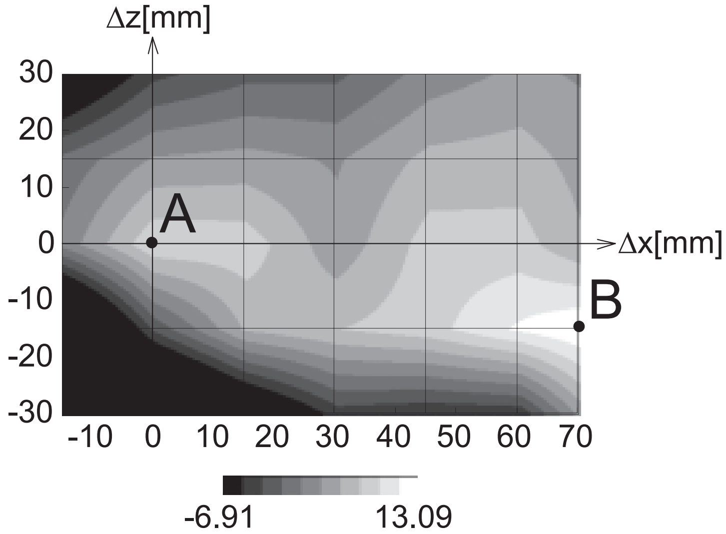


Figure 5: The value G for the feeding position displacement

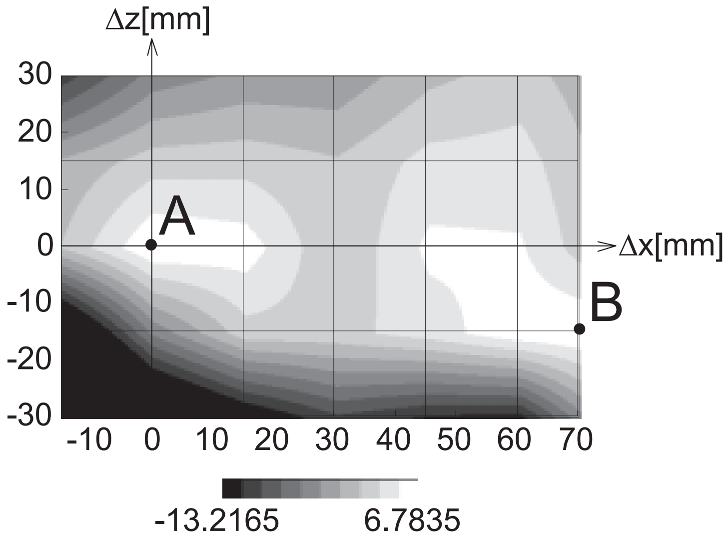


Figure 6: The value E for the feeding position displacement

5 Summary

The variable radiation pattern antenna has been proposed, and its fundamental characteristics have been confirmed with simulation and experiment. It is validated that the GA optimization of its parameters realize the best performance. In regard to application such as cellular phone or WLAN-AP, subjects for future work include miniaturization of the antenna, suppression of the cross-polarization in xy-plane, evaluation of radiation efficiency which is needed to take into account the loss of switch and broadening of the bandwidth.

References

[1] R. F. Harrington, "Reactively Controlled Directive Arrays," *IEEE Trans. Antennas Propagat.*, vol. AP-26, no. 3, pp. 390-395, May 1978

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