Design and analysis of radio antenna monopole arrays in the military world

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Abstract. The analysis and design of the proposed antennas is designated for receiving voice signals from Radio in general are out-of-prominent antennas and smaller indoor antennas, in this research, the authors aim to design and analyse an antenna with a simple design, a small dimension efficient, very easy installation, cheap and meet the antenna characteristics to support the movement in combat training within the Army. The antenna to be discussed is a monopole antenna Arra with a minimalist shape that works at frequencies between 350MHz - 480MHz by adjusting the length of the horizontal elemental Active distance between the outer and inner to get the impedance matching. In order to obtain a unidirectional pattern, a metallic plane reflector is placed at a distance of about λ/ 4 from the array board: predicted gain (11 dB for 5 × 1 array and 15 dB for 9 × 1 array) and bandwidth (around 600 MHz) are larger than for conventional micro strip patch arrays having similar board dimensions. the proposed antenna has been numerically analysed for wireless communication systems.

1. Introduction

Array antennas are usually used in wireless communication base stations that currently face the challenges of wider bandwidth and higher profits for increasing channel capacity with materials that are easily searchable in the market. Compact arrays can consist of print antennas featuring a variety of designs, for example: patch antenna [1], dipole antenna designed [2], monopole antenna printed and its variants (eg, Inverted-F) [3,4]. The disadvantage of patch antennas is the narrow bandwidth, which prevents their use in many applications. Instead, the design of the printed monopoles is very flexible and the bandwidth is medium to wide (350MHz to 480GHz). Impedance matching can be achieved [3,4], therefore, micro strip monopoles have been widely adopted in wireless communication systems [5,6]. According to the principles of Theory of Pictures, the monopole and mirror image in relation to the ground plane will form a dipole antenna [7]. However, the antenna is mounted above the ground plane, whose size and shape can affect the resonance frequency and radiation pattern. In this paper, we present two planar arrangements of monopoles printed with their feeding tissues; as can be seen in figure 1, this array is formed from N (= 2 and 4) active monopoles and N +1 (= 3 and 5) parasitic monopoles. Only active monopoles are fed directly, while parasitic radiators are fed through currents induced by active monopoles and by currents passing through the ground, because there is no balun in the input port. To obtain a wide pattern and maximize directivity it is necessary to select the magnitude and phase of the attractive current for each isotropic micro strip radiator. We numerically show that, by using a winding line capable of delaying active monopoles feeding flows, a radiation pattern leaflet can be
obtained with a gain value that approaches the standard $2N + 1 (= 5$ and $9)$ array of active elements. The dimension of the rectangular microstrip patch antenna has substantial parameter such as resonant frequency ($fr$), dielectric permittivity constant of the substrate ($\epsilon_r$), and height or thickness of the substrate ($h$) [8].

2. Antenna structure

An array of radiating elements is present on both faces of a standard FR4 substrate: active elements are made at the front of the substrate, while parasitic elements are made behind the same substrate. The proposed array is illustrated in Figure 1. The expected length of monopoles is a quarter wavelength, but this value must be set by numerical simulations because the resonance conditions are influenced by the relatively small size of the soil (i.e. large rectangular fields above the rear substrate). As shown in Figure 1 (a), the key concept of our design is to place symmetrically on both sides of each active monopole (at a distance of about $\lambda = 4$) two parasitic metallic strips which are protrusions from the ground plane. The tortuous line is inserted between the feed microstrip line and the active monopoles and acts as a phase-delay line for currently feeding active monopoles. Microstrip network between input Progress in the Research Electromagnetics Research Symposium.

![Diagram](image1)

**Figure 1.** Drawing of the microstrip monopole arrays: (a) $5 \times 1$ array, (b) $9 \times 1$ array. The feeding network, the meanders and the active monopoles are on the substrate front face, whereas the ground plane and the parasitic elements are on the substrate back face.
Port and the active elements allows for a wide bandwidth impedance matching. In the case of the 5 × 1 array (Figure 1(a)), the input 50-Ohm microstrip is split into two 100-Ohm lines, which are followed by 70-Ohm quarter wave transformers connected to the 50-Ohm microstrips feeding the meanders. Numerical simulations performed by means of CST Microwave Studio show that the current densities on the parasitic strips are mainly induced by the driven monopoles. In our design only an unbalanced waveguide like the micro strip is requested; this choice implies that some current passes across the ground plane and reaches the parasitic elements, but the same current is useful to achieve impedance matching on a wider band.

Each meandered delay line is composed of 5 segments with a width of 0.5 mm and a total length $l$ that must compensate for the phase delay among the active monopoles and the parasitic ones; a long optimization procedure gave the value $l = 2.86$ cm.

CST simulations confirm that the $2N + 1$ radiators are fed in phase and it must be underlined that the currents flowing in the parasitic elements are less intense than the ones in the active monopoles. Without the presence of the meanders the relevant gain enhancement due to the array factor of $2N + 1$ isotropic elements cannot be observed, even by significantly changing the radiating elements separation or optimizing the feeding network.

A thorough numerical optimization has led to the geometrical dimensions of the final designs displayed in Figure 1: the substrate total area is $13.9 \times 7.6$ cm$^2$ for the $5 \times 1$ array and $27.1 \times 9.2$ cm$^2$ for the $9 \times 1$ array, the area occupied by each meander is $2.25 \times 0.35$ cm$^2$ and the driven and parasitic microstrips have a width of 2.9 mm.

### 3. Results

Prototypes were milled on FR4 substrates (with thickness 1.58 mm, $\varepsilon_r = 4.5$, $\tan \delta = 0.025$) and measured in anechoic chamber by using a two port Agilent N5230 PNA-L network analyser. The simulated and measured reflection coefficients of the $5 \times 1$ and $9 \times 1$ arrays are shown in Figure 2(a) and 2(b), respectively. The 10 dB impedance matching bandwidth ranges from 2.2 GHz to 2.91 GHz for the $5 \times 1$ linear array, with a fractional bandwidth (FBW) of 0.28, and ranges from 2.2 GHz to 2.65 GHz (FBW = 0.17) for the $9 \times 1$ linear array. The simulated and measured return losses are in good agreement for the $5 \times 1$ linear array; considering the $9 \times 1$ linear array, we have almost the same −10 dB bandwidth, but the minima predicted by the numerical simulation are 15 dB smaller than the measured ones.

![Figure 2](image_url)

Figure 2. Computed (dashed lines) and measured (solid lines) reflection coefficients: (a) $5 \times 1$ array, (b) $9 \times 1$ array.
**Figure 3.** Radiation patterns of the $5 \times 1$ array at the frequency of 2.4 GHz: (a) plain array, (b) array with metallic plane reflector.

**Figure 4.** Radiation patterns of the $9 \times 1$ array at the frequency of 2.4 GHz: (a) plain array, (b) array with metallic plane reflector.

Figure 3 (a) shows the calculated 3D radiation pattern of the $5 \times 1$ array; as expected from basic array theory, there are two main lobes (tilted by 10° with respect to the normal to the board) and the gain is 7.3 dB. In order to obtain a unidirectional pattern, a metallic plane reflector ($18 \times 12$ cm$^2$) is placed at a distance of 3 cm from the array board and the resulting 3D pattern is shown in Figure 3(b); the main lobe is almost perpendicular to the board (the tilt is only 5° and the corresponding gain is 11.4 dB (the increase in gain is even larger than the 3 dB predicted by theory). The 3D radiation pattern of the $9 \times 1$ array exhibits a gain of 10.8 dB (see Figure 4 (a)), which can be augmented up to 14.6 dB when a metallic plane reflector ($31 \times 12$ cm$^2$) is placed at a distance of 3 cm (see Figure 4(b)). In the case of the $9 \times 1$ array, secondary lobes are present (with a side lobe level of $-10$ dB) and the main lobe is tilted of 20° irrespectively of the presence of the metal reflecting plane.
4. Conclusion
Two printed arrays with N active micro strip-fed element and N + 1 parasitic strips have been designed and characterized at 2.4 GHz: meanders are used to enforce a phase lag to the currents flowing in N of the radiating metallic strips and determine a broadside radiation. Simple fabrication techniques that are inexpensive can be employed to realize these structures and the feeding network is much more simple than those required by monopole arrays already reported in the literature [6]. The results of this study have shown that by adding N + 1 parasitic elements, we can obtain a broadside radiation gain value close to that one of a standard 2N + 1 isotropic element array and the bandwidth is significantly larger (> 600 MHz) than the one of conventional micro strip patch arrays [9]. In spite of the compact board areas, gains of 11 dB and 15 dB are achieved with a metallic plane reflector placed at a distance of about λ/4. In order to verify the array performance, prototypes have been fabricated and are currently under test. The proposed antennas may be suitable candidates for WLAN point to point operations.

Acknowledgments
The authors would like to express special thanks of gratitude to State Polytechnic of Malang for supporting this research.

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