A Simple Reconfigurable Monopole for Multiband Public Safety Applications

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1 Introduction

This report documents the further development of the broadband monopole described in previous reports [1] and [2]. The monopole is part of an antenna system being developed as part of our project “Antenna Systems for Multiband Mobile & Portable Radio” [3]. As described in [1], the intent is to use the monopole with an antenna tuner to achieve a useful level of performance in each of the bands of interest; namely, VHF-Low (25–50 MHz), VHF-High (138–174 MHz), 220 MHz (220–222 MHz), UHF (406–512 MHz), and 800 MHz (764–862 MHz). The previous monopole was 23.5 cm long, and found to be suitable for the UHF and 800 MHz bands, but unacceptable for the VHF-Low through 220 MHz bands. In order to achieve a usable level of performance in the VHF-Low through 220 MHz bands, we consider a switchable extension to the monopole. When switched off, the extension is disconnected and the monopole is essentially identical to the original monopole. When switched on, the extension is connected, yielding a longer monopole. This appears to be the simplest method to remedy the limitations of the original monopole without a significant (hence, undesirable) change in form factor.

2 Design and Electromagnetic Analysis

The monopole consists of two elements. The base element is identical to the original monopole: 23.5 cm in length, 5 mm in radius. The extension element is 1.165 m long and 1 mm in radius, and begins at the top of the base element. Thus, the overall length is 1.4 m; the only difference between “high band” and “low band” operation is whether the two elements are disconnected (hence; separated by a small gap) or connected (probably by an electromechanical relay). Note that both the overall length and diameter are comparable to the dimensions of existing commercial monopole antennas for the VHF-Low band [4].

In this report, the antenna is analyzed using NEC-4.1 [5], which is an implementation of the method of moments. The following assumptions are made: The antenna elements are assumed to be perfectly conducting, and the ground plane is assumed to be both perfectly conducting and infinite in extent. An infinite ground plane (as opposed to a finite surface, such as the trunk of a car) is required in order to make the wideband (25–900 MHz) analysis tractable. We have performed some preliminary studies of the original monopole on a finite ground plane modeling the trunk of a car. These studies suggested very little impact on the self-impedance, however the effect on directivity was not evaluated. Thus, the results presented here should be considered preliminary. The segment length used in the NEC computations is 1.8 cm, independent of frequency.

3 System-Level Analysis

The system-level analysis follows almost exactly the same procedures described in [1], where are documented in greater detail (from a theoretical viewpoint) in [6]. All parameters, unless noted below, are identical to those used in [1]. A difference from [1] is that the incident electric field magnitude is taken to be \((4.8 \, \mu\text{V})/\lambda\), where \(\lambda\) is free space wavelength, as suggested in [7]. That is, the stimulus is allowed to be frequency-dependent, so that the results are in some sense referenced to a quarter-wavelength monopole resonant at each frequency considered. Both self-impedance and effective length are computed using the NEC model described above; effective length is obtained by integration over the computed current distribution.

Receive performance is summarized in Figures 1 and 2. Figure 1 shows the realized predetection S/N in the high- and low-band states. Note that even with no matching the low-band state meets the 6 dB criterion described in [1] throughout the VHF-Low and VHF-High bands, and also in portions of the UHF and 800 MHz bands. For additional insight, the signal and noise components represented in Figure 1 are shown separately in Figure 2. Here, it is interesting to note that the performance in the VHF-Low and -High bands is very nearly optimal; that is, even a small (1–2 dB)
improvement in the receiver noise figure \((N_R\), as indicated in Figure 2\), would result in external noise-dominated performance.

Transmit performance is summarized in Figures 3 and 4. Figure 3 shows transmit VSWR (i.e., VSWR looking into the antenna system from the transceiver output). Here we note that matching may not be necessary for VHF-Low with the antenna system in the low-band state; also we see that the antenna system is already reasonably well-matched (i.e., VSWR < 3) over large portions of the VHF-High, UHF, and 800 MHz bands. Figure 4 shows transmit efficiency \(\epsilon_T\) as well as the “antenna-modified” transmit efficiency \(\epsilon_{TA}\). Here we see that the low-band state yields a usable level of performance over much of the VHF-Low and -high bands, although clearly matching is required to make this competitive with resonant antennas. It is interesting to note that the unmatched low-band antenna is able to perform fairly well over much of the UHF and 800 MHz bands as well.

4 Summary

The proposed two-state reconfigurable monopole appears to remedy the performance limitations of the (non-reconfigurable) 23.5-cm monopole previously proposed. Of course, a complete evaluation requires assessment of performance as various matching states are employed, as described in [1].
Figure 1: Predetection S/N.
Figure 2: Signal and noise contributions to predetection S/N.
Figure 3: Transmit VSWR.
Figure 4: Transmit efficiency ($\epsilon_T$) and antenna-modified transmit efficiency ($\epsilon_{TA}$).
References


