Bandwidth Enhanced Folded Unipole Antenna for VLF Measurements

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***Abstract*—folded unipole antennas have been used in AM radio communications since mid-90s. These antennas are capable of operating within a large bandwidth. Despite the history, large bandwidth and wide usage rigorous mathematical analysis and simulation results are not widely available for this antenna configuration. In this work, we present mathematical analysis and simulation results for a bandwidth enhanced folded unipole antenna which can be used effectively in the Very Low Frequency (VLF: 3 – 30 kHz) range, while keeping the antenna dimensions feasible.**

I. INTRODUCTION

The folded unipole or the ruffled skirt antenna was used since 1940's for AM radio communications [1-2]. The basic configuration consists of a monopole mounted on the ground plane, with metal cables connecting the top of the monopole back to the ground plane 'folding' the monopole. Figure 1 shows the equivalent circuit diagram for a folded unipole antenna. Although this configuration was being used for about 80 years, rigorous mathematical analysis are hardly found in the published literature.

Folded unipole antennas have several advantages, most notably a large bandwidth compared to other antenna designs of similar size [1-3]. Additionally, folded unipole antennas are capable of delivering a higher input resistance than other designs when the antenna must be less than a quarter wavelength in height [3]. Because of the higher resistance, these antennas can be much shorter than their monopole counterparts. Therefore this design is mostly used for Medium wave communication, which in North America is the spectrum between 520 kHz and 1710 KHz [3].

Given the capabilities of this antenna configuration, in this work we present bandwidth enhanced folded unipole antenna design for Very Low Frequency (VLF: 3 - 30 kHz) measurements. VLF waves have significantly high wavelengths (>10 km), making the dimensions of the antennas in the km range. Therefore, it was considered practically impossible to capture these waves with electrical antennas. Currently, magnetic loop antennas are used to capture VLF waves [4]. Therefore, we propose an antenna design which allows capturing VLF waves using the electric field, while keeping the dimensions of the antenna feasible.

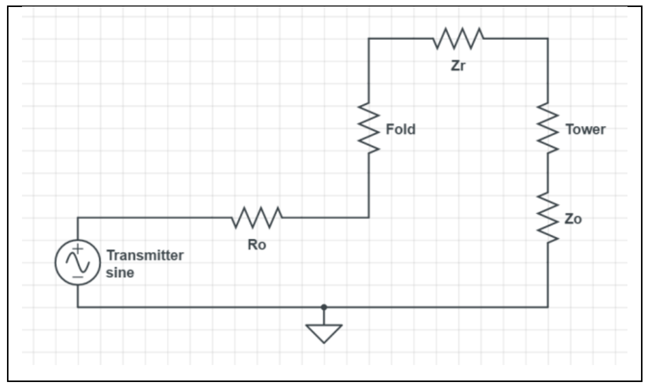

Fig. 1. Equivalent circuit of a folded unipole antenna.

II. TECHNICAL APPROACH

There are two modes of operation that are specific to this antenna. The common mode occurs when the current in the fold and the current in the tower are in-phase. Despite its name, this mode is not frequently used in practice [5]. The differential mode occurs when the current in the fold and the current in the tower are 180° out of phase with each other. This is the most common mode in practice, and the total current as shown in Equation (1).

$$I_d(z) = I_0 e^{-jkz} + I_0 e^{+jkz} \qquad (1)$$

The radiation pattern of the folded unipole antenna is given by Equation (2),

$$E_\theta = \frac{j\eta e^{-jkr} sin\theta\, F(\theta)}{4\pi r} \qquad (2)$$

Where;

$$F(\theta) = \int_{kl} I(z) e^{+jkzcos\theta} d(kz) \qquad (3)$$

In the above equations $I(z)$ is the current of the elements, k is the wave number, l is the length of the current element, η is the free space impedance (377Ω) and r is the radial distance from the antenna.

Given that the direction of the current for the fold and the tower are in opposite directions, the radiation pattern of a single folded unipole is similar to a dipole antenna, as shown in Figure 2.

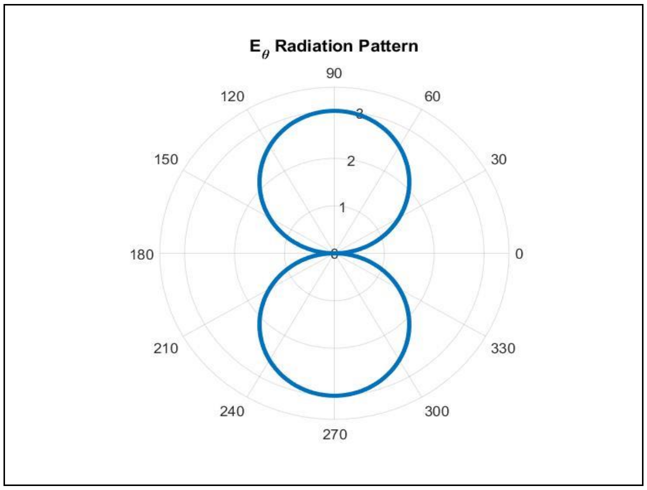

Fig. 2. Radiation pattern of a folded unipole antenna with a single fold and a tower.

III. Initial Design

The preliminary model is shown with 4 cables surrounding the center pole in Figure 3 is designed on FEKO for a frequency F_0 of 1.5 kHz.

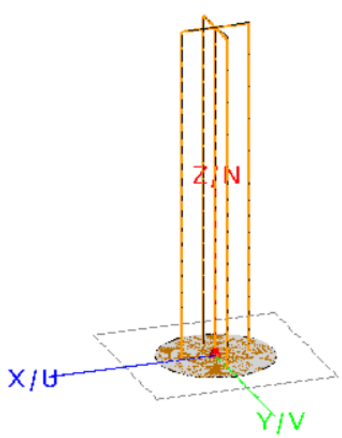

Fig. 3. Preliminary model with 4 cables using CADFEKO

Further optimization using FEKO will be performed after the submission of this paper, which will be intended to show the large bandwidth of folded monopole antennas.

References

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