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Compact Electric Antennas

Carl E. Baum
University of New Mexico
Department of Electrical and Computer Engineering
Albuquerque New Mexico 87131

Abstract

This paper explores some of the design concepts and parameters of electric-dipole antennas driven by high-voltage pulsers, producing mesoband resonant radiating waveforms.

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1. Introduction

A recent paper [2] introduced the concept of a low-impedance segmented-loop antenna designed to fill (in some sense) a given volume, chosen as a rectangular parallelpiped. Further considerations concerning how to drive this antenna are discussed in [3].

A logical question, related to the above, concerns what might be called the dual source. This would be some kind of electric antenna (electrically small up to about first resonance) designed to fit in the same volume. Such is the subject of this paper.

2. Confined Electric Dipole

Let us first consider the antenna. As is well known, an electrically small electric antenna radiates predominantly as an electric dipole. Not until the half wavelength $\lambda/2$ approaches the antenna dimensions, or less, do other multipole modes become significant for the far field. So let us consider filling the antenna volume in Fig. 2.1 by some kind of electric-dipole antenna.

This kind of antenna is roughly given by two conductors spaced far apart to give the maximum charge separation, and, hence, effective height, while making the conductors as large as possible in the transverse direction to maximize the capacitance, and, hence, the charge separated by this distance. Furthermore, one needs to create an antenna port (pair of terminals) somewhere between these conductors with electrical connections to these conductors. Then one has an antenna geometry something like that in Fig. 2.2. While the illustration has $b > a$, it could also have $b < a$. Which orientation one chooses depends on various factors.

Note that this type of antenna is topologically two conductors separated by the source. This is quite different topologically from a loop which connects the two source terminals.

In this type of antenna, if electrically small, the extreme ends should be conducting rectangles to maximize both effective height and capacitance. Here rectangular conducting cones are assumed to connect from the antenna port to the conducting rectangles. This also gives the good high-frequency performance of a biconical antenna (now electrically large). Of course, various other conductor geometries are possible for connections from the antenna port to the conducting rectangles. Here the antenna port is taken at the coordinate origin, $\vec{r} = (x, y, z) = \vec{0}$, for symmetry, giving three symmetry planes: $x = 0$, $y = 0$, $z = 0$. However, offset positions can also be considered if other considerations warrant.

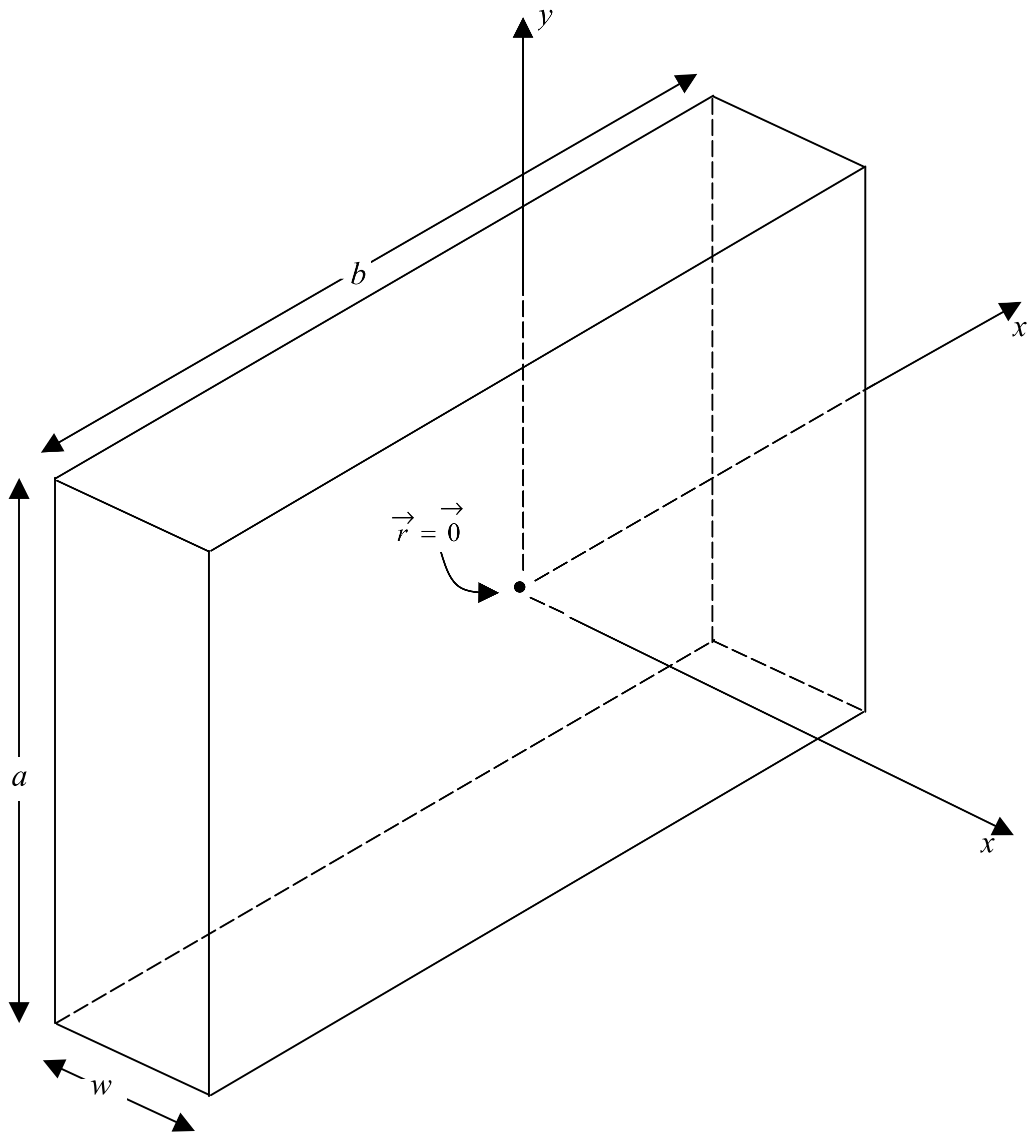
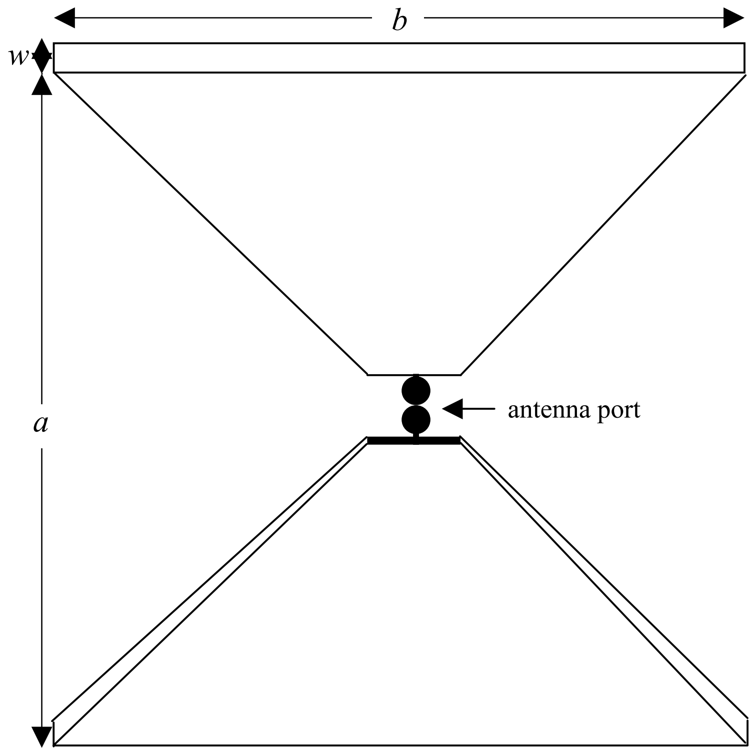


Fig. 2.1. Rectangular-Parallelepiped Antenna Volume.



N.B. Top and bottom rectangular surfaces (b x w) are conducting like the two rectangular cones.

Fig. 2.2. Electric-Dipole Antenna Filling Rectangular Parallelepiped.

3. Inclusion of Pulse Power

Now we need to drive this antenna somehow. We want high voltage and a ringing waveform for a high-power mesoband radiator.

Consider, first, where to place the pulse power such as a Marx generator or resonant transformer. As shown in Fig. 3.1, if the dipole conductors form closed volumes, we have these volumes, which are not used for the antenna, as volumes in which to place other things such as high-voltage sources, pulse forming networks, batteries, etc. So this antenna topology has another advantage. Of course, the pulse power feeds through a hole to the opposite antenna conductor. If desired, a high-impedance connection between the two antenna conductors can also be included. Any additional conductors (such as trigger cables, power lines, etc.) going between the two antennas conductors should be isolated by means of chokes along the connection path(s).

Instead of the single-ended source in Fig. 3.1, one can have a differential source as in Fig. 3.2. The two high-voltage sources have opposite polarities, doubling up the voltage on the antenna. Now we need an isolated trigger-signal connection between the two antenna conductors (optical or highly impedance-loaded conductors) to fire the two pulsers at the same time.

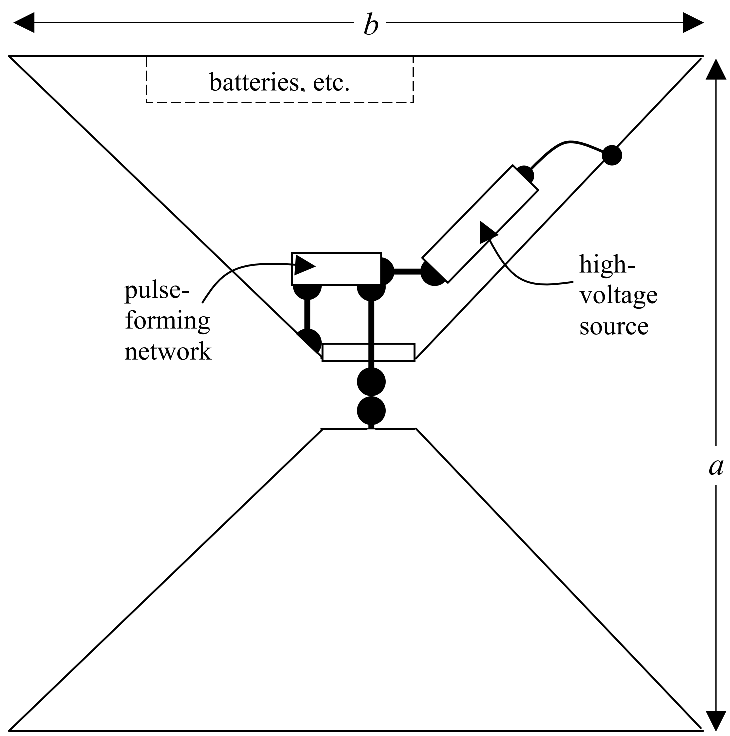


Fig. 3.1. Single-Ended Pulser Included Inside One of the Antenna Conductors.

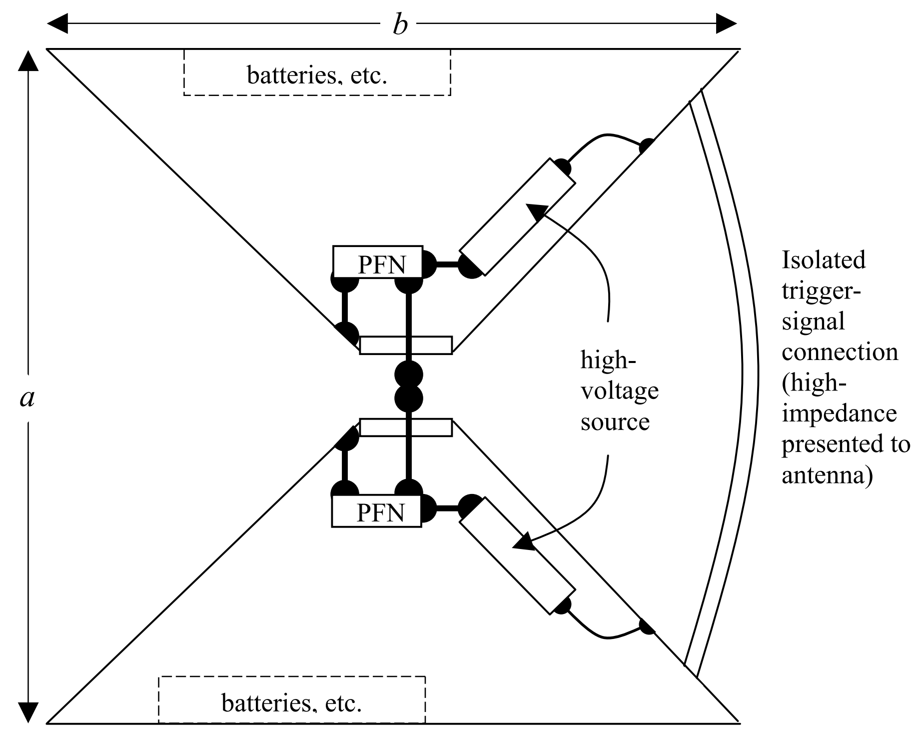


Fig. 3.2. Differential Pulser Included Inside Both of the antenna conductors.

4. Pulse-Forming Networks (PFNs)

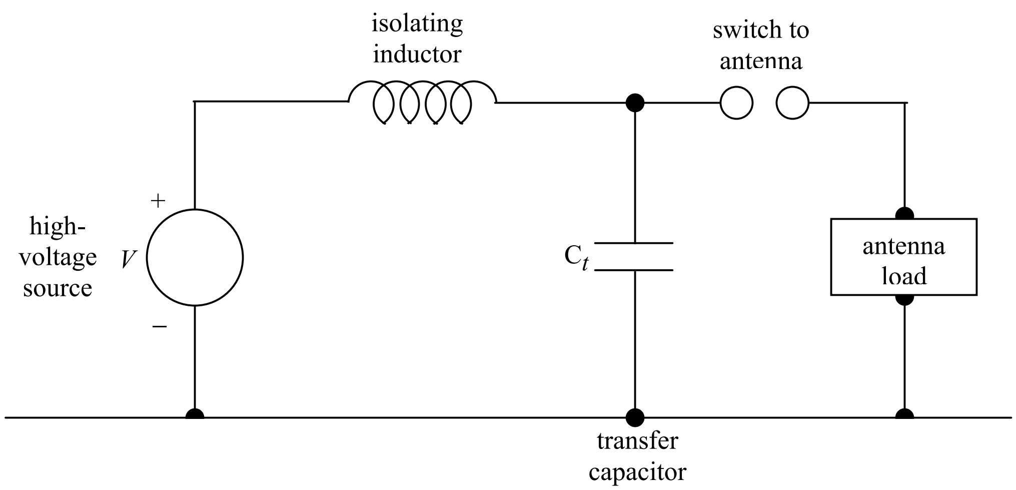
In order to achieve a desired mesoband ringing waveform (approximate damped sinusoid) some kind of pulse forming network can be used to take the slowly rising output of the high-voltage source, and convert it to something faster.

A common technique uses a transfer capacitor as indicated in Fig. 4.1A. In this case a high-voltage source charges a transfer capacitor C_t. In turn a closing switch feeds the antenna. For a Marx generator an isolating inductor can be used to ring up the voltage on C_t to greater than V (ideally $2V$ if $C_t \ll C_M$ (Marx capacitance)). Of course, C_t also loads the antenna and must be taken into account in designing the resonance frequency. After pulsing, the antenna needs to be discharged (relatively slowly) to prepare for the next pulse. This is accomplished by a high-impedance resistive path between the two antenna conductors.

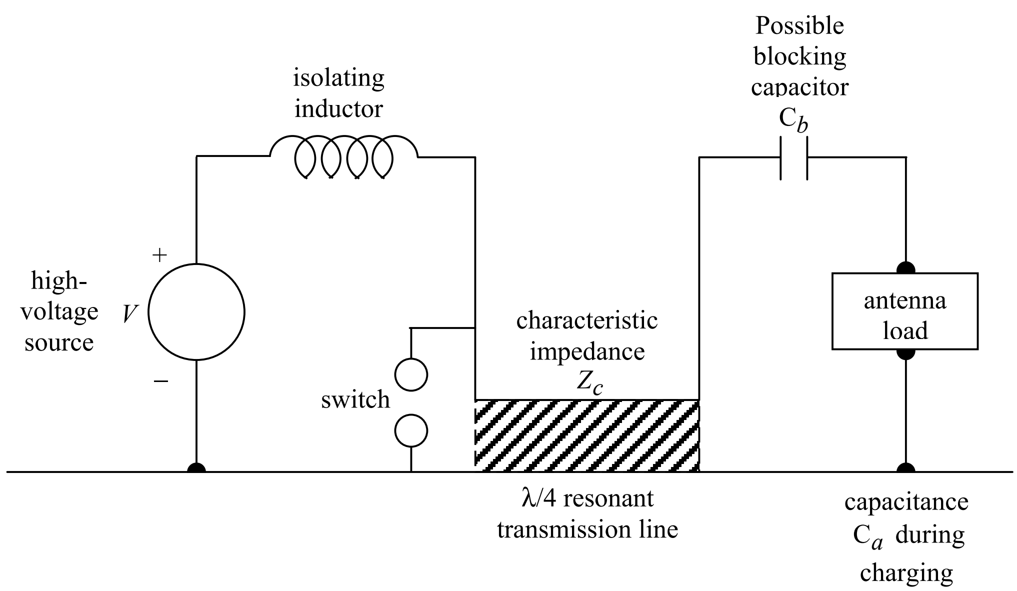
The transfer-capacitor scheme also works well for a differential pulser. The switch now connects between the *two* transfer capacitors so that only one closing switch is required to fire, discharging both transfer capacitors simultaneously.

An alternate type of PFN is the switched oscillator illustrated in Fig. 4.2. As a single-ended system this has much to offer. As discussed in [1, 4] a $\lambda/4$ low-impedance Z_a transmission line is charged by the high-voltage source (also possibly to greater than V). This requires some isolating capacitor during the charging cycle. This can be a blocking capacitor C_b as indicated (with high-resistance, late-time load), or just the antenna capacitance C_a itself (noting high voltage on the antenna during the charging cycle). Of course, C_a is just part of the antenna load. Noting the switch position at the back of the oscillator (away from the antenna port), the switch can self break, and the wave toward the antenna port reflects with a positive reflection coefficient near 1.0, giving a near doubling of the voltage onto the antenna [4]. This scheme is similar to one of the antenna configurations in [1].

For a differential switched oscillator in this type of antenna, the requirement for two closing switches, simultaneously fired, creates a problem, since both switches have to close with a time spread Δt, between the switch firings, small compared to a quarter period of the desired resonance. This, in turn, likely requires both switches to be triggered from a common trigger signal.



A. Transfer Capacitor



B. Switched Oscillator

Fig. 4.1. Pulse-Forming Networks

5. Concluding Remarks

This paper has laid out various physical considerations for a physically constrained electric-dipole antenna, driven by a high-voltage source, producing a resonant mesoband radiating waveform. This leaves many details to be considered, including detailed numerical modeling.

References

1. C. E. Baum, “Antennas for the Switched-Oscillator Source”, Sensor and Simulation Note 455, March 2001.

2. C. E. Baum, “Compact, Low-Impedance Magnetic Antennas”, Sensor and Simulation Note 470, December 2002.

3. C. E. Baum, “Symmetry in Low-Impedance Magnetic Antennas”, Sensor and Simulation Note 497, March 2005.

4. C. E. Baum, “Switched Oscillators”, Circuit and Electromagnetic System Design Note 45, September 2000.