Sensor and Simulation Notes

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Differential Switched Oscillators and Associated Antennas, Part 2

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Abstract

Building on previous results, switched oscillators and associated antennas are extended to new variations Differential systems are considered with in-line differential oscillators near the reflector focus for the purpose of increasing the voltage delivered to the antenna and thereby the far field. This leads to the concept of a separated reflector with two ground planes, two separated reflector foci, and a space between the ground planes for placing pulse-power equipment.

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1. Introduction

The oscillator reflector antenna (ORA) has many design options [2, 3, 6-8]. The oscillator itself can be single-ended or differential. The antenna can be a full reflector or a half reflector (with ground plane). Quarter-wave transmission-line transformers can also be used to increase the voltage delivered to the antenna.

This paper considers some more options for the differential type. The differential switched oscillator is constructed in an in-line configuration for greater practicality. This raises the difficulty of having two exit positions spaced $\simeq \lambda_0 / 2$ apart (λ_0 = wavelength in oscillator transmission line). We then need appropriately to direct the two waves into the antenna. In such a configuration we also consider the inclusion of a quarter-wave transformer in the feed to the antenna.

2. In-Line Differential Switched Oscillator

In [3] techniques for making a differential switched oscillator were discussed. Here we consider an in-line configuration as illustrated in Fig. 2.1. In this case the outer conductor can be a single circular cylinder which can be quite strong for holding pressurized gas, if desired. The two halves of the center conductor are differentially charged (through high impedances, e.g., inductors at high frequency) to $\pm V_0$. The charge voltage is isolated from the antenna by blocking capacitors. The single closing switch (avoiding jitter in the case of two triggered switches) can be self breaking. It can also be centered on the cylinder axis for greater symmetry in the oscillator.

This source is to drive a full reflector of some type to be discussed later. Let Z_a represent the characteristic impedance of the conical-transmission-line feed of a half reflector, or $2Z_a$ the equivalent impedance for the feed of a full reflector. As discussed previously $Z_a >> Z_c$, the characteristic impedance of the switched-oscillator transmission line, to obtain the resonant waveform. In this scheme the effective voltage on the antenna is $2V_0$, almost doubled again to $4V_0$ by the impedance mismatch.

Now the switch spacing is increased from d to about $2d$ to handle the double voltage. This raises the switch inductance L to $2L$, but the load being driven is now $2Z_c$. So we have the L/R time as

$$\tau_1 = \frac{L}{Z_c} \quad \text{for single ended switch}$$

$$\tau_2 = \frac{2L}{2Z_c} = \tau_1 \quad \text{for differential switch} \tag{2.1}$$

The voltage and impedance have been doubled with the switch rise time staying about the same. The power has also been doubled [4].

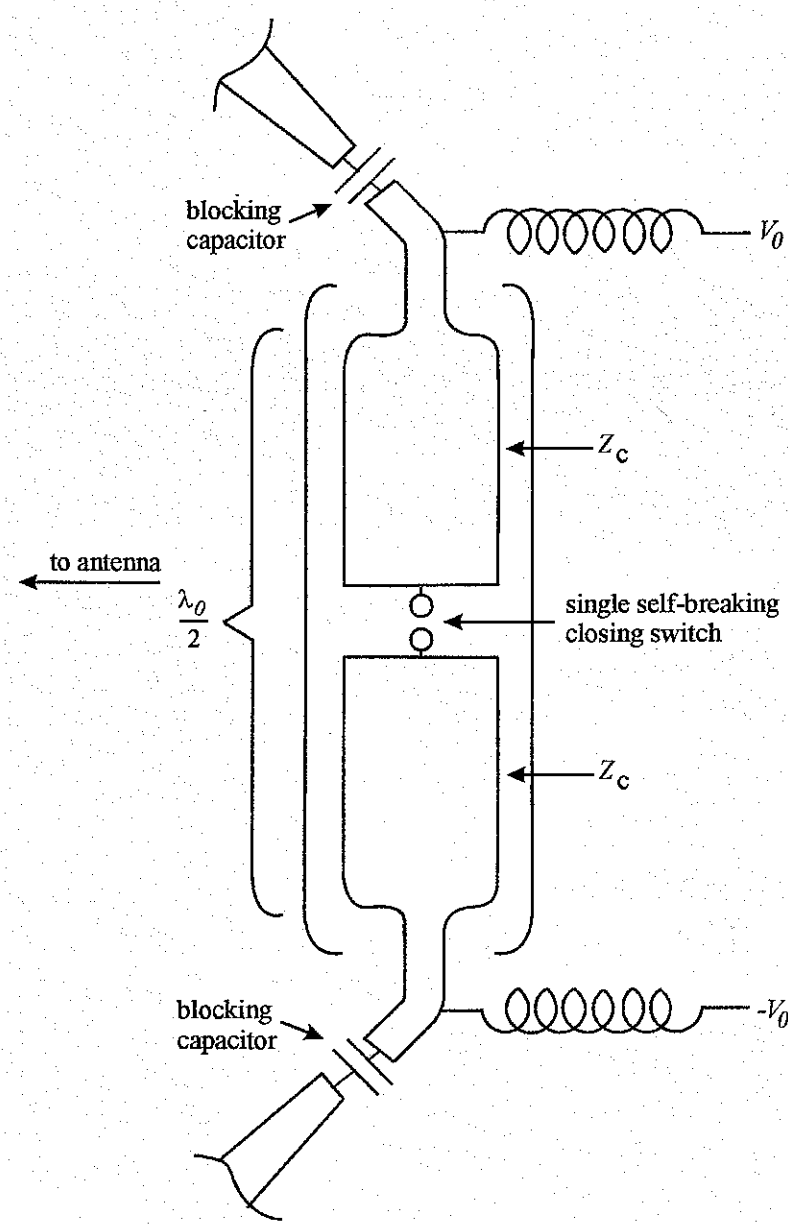


Fig. 2.1 In-Line Differential Switched Oscillator

3. Inclusion of Quarter-Wave Transmission-Line Transformer

Since the source is a resonant structure on a low-characteristic-impedance transmission line (say a few ohms), the voltage to the antenna can be increased by inserting a quarter-wave transmission-line transformer as discussed in [7]. In this case the characteristic impedance $Z_c^{(2)}$ of the transformer section is best chosen as a geometric mean

$$Z_c^{(2)} = [Z_c Z_a]^{1/2} \text{ positive square root)} \tag{3.1}$$

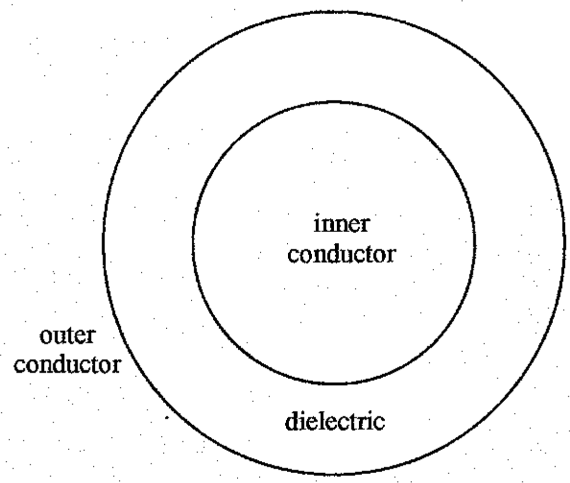
As an example, one might have

$$\begin{aligned} Z_c &= 4\Omega \quad , \quad Z_a = 100\,\Omega \\ Z_c^{(2)} &= 20\,\Omega \end{aligned} \tag{3.2}$$

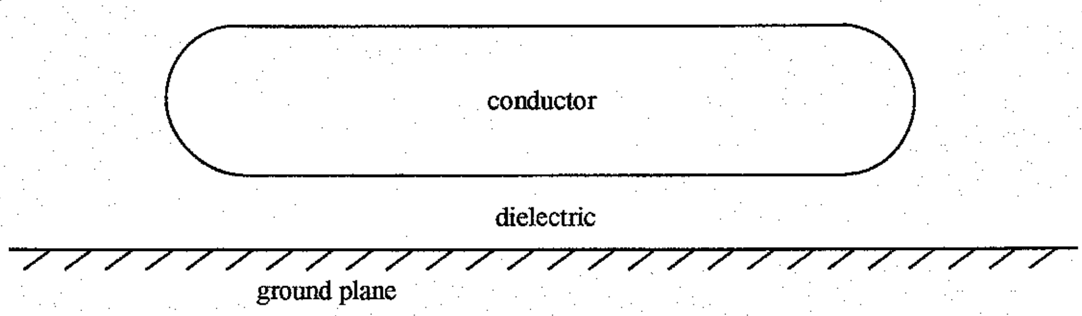
As discussed in [7], while the voltage is increased the decay time of the oscillation (or Q) is decreased. In a limiting sense the oscillation corresponds to a second-order pole in the complex frequency plane (including harmonics).

Physically the high-voltage transmission line comprising the transformer might have a cross section as indicated in Fig. 3.1. A coaxial geometry is the most compact, but one might also consider a strip-line geometry with rolled edges to minimize electric-field enhancement. A high-dielectric-strength insulating medium is required to minimize the cross-section dimensions (and thereby keep the transmission-line approximation accurate). The physical length of the transformer depends on the dielectric constant (e.g., $\varepsilon_r \simeq 2.25$ for transformer oil) for the insulating dielectric medium.

Of course, one can also use sequential quarter-wave transformers as discussed in [8]. An alternate approach is to have a smoothly increasing characteristic impedance of a sufficiently long nonuniform-transmission-line transformer as discussed in [5].



A. Coax



B. Strip line

Fig. 3.1 Transmission-Line Cross Section for Quarter-Wave Transformer

4. In-Line Differential Oscillator Feeding Reflector Antenna

There are various ways to feed a reflector antenna (full paraboloidal reflector with circular boundary) from a differential oscillator as discussed in [3]. If we want the oscillator located near the focus we might think of a geometry as in Fig. 4.1. In this case one might have a central ground plane (perpendicular to the electric field by symmetry) giving what might be called a split reflector.

One problem with such a configuration concerns the physical size of the oscillator. The waves leave the oscillator ends which are about $\lambda/4$ away from the ground plane, and hence from the usual focus. Of course one can bend the reflector to move the focus correspondingly. Then there is the problem that the ground plane, which guides the wave to the reflector, is displaced from the wave source. One can then place some metal tapers to more smoothly transition the wave to the ground plane and reduce the disturbance (local increase) of the conical-transmission-line characteristic impedance.

An alternate approach could have transmission lines feeding the oscillator outputs back to the central ground plane before launching the wave toward the reflector. These might also include transformer sections.

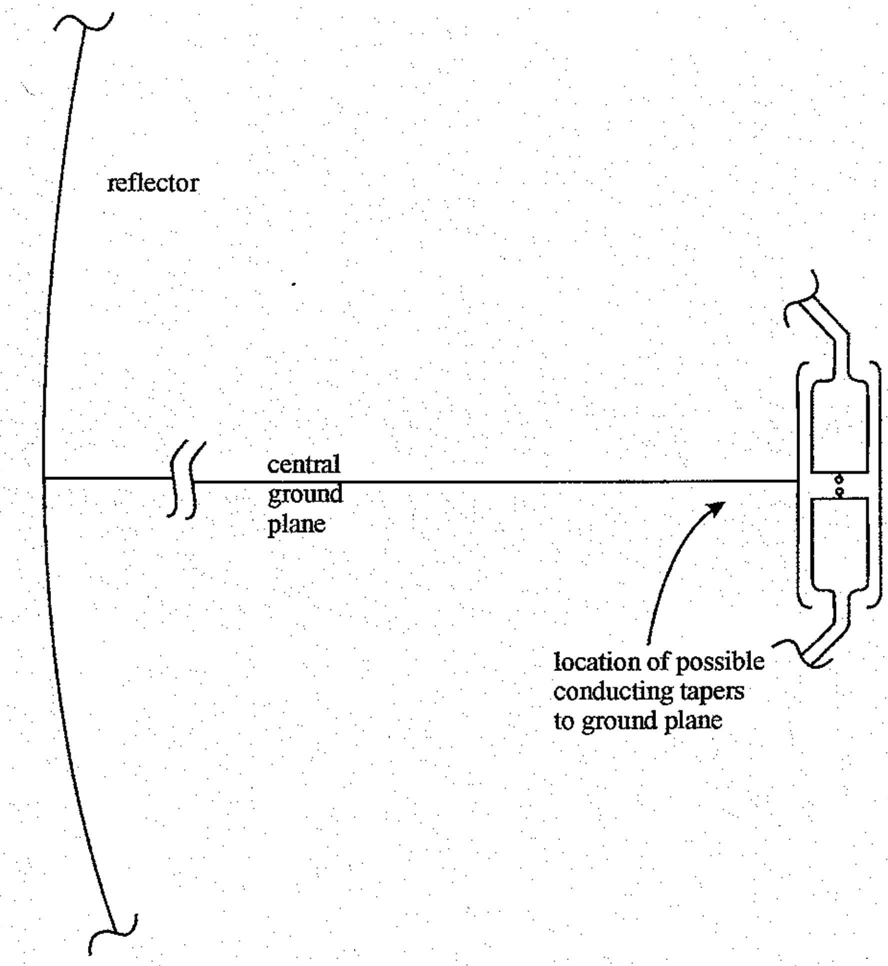


Fig. 4.1 Differential Oscillator Feeding Full Split Reflector Antenna

5. Separated Reflector Antenna

Another interesting geometry is shown in Fig. 5.1. In this case there are two parallel ground planes matched to the two outputs of the differential oscillator. The reflector is separated into two halves separated by the length w (about $\lambda_0/2$ or a little more) of the oscillator, each half being conductively bonded to the respective ground planes (also separated w). There are now two foci for the two half-reflectors, each located on the respective ground planes at the apices of the two conical-transmission-line feeds.

Note now that the space between the ground planes is available for other high-voltage equipment. As discussed in [1] one can have a half IRA (impulse radiating antenna) where the ground plane separates the antenna space (for the half-reflector plus feed) from the pulse-power space. In the present context we can consider that two half ORAs (oscillator reflector antennas) are joined with a space in between giving what might be termed a separated ORA. How much space for pulse-power equipment is available depends on w, and hence the frequency of the oscillator. Lower frequencies give larger w.

An added feature is what might be called a diffraction suppresser to join the two ground planes. In this case instead of abruptly joining the ground planes near the oscillator (and high-voltage feeds through the ground planes) a smoother transition for joining the two waves is constructed. The conducting wedge shape has a slant distance ℓ_1 larger than ℓ_0, the distance parallel to the wave-launching direction. In this case we have

$$\begin{aligned}\ell_1 &= \left[\ell_0^2 + \left[\frac{w}{2}\right]^2\right]^{1/2} = \ell_0\left[1 + \left[\frac{w}{2\ell_0}\right]^2\right]^{1/2} \\ &= \ell_0\left[1 + \frac{w^2}{8\ell_0^2} + O\left(\left[\frac{w}{\ell_0}\right]^4\right)\right] \quad \text{as} \quad \frac{w}{\ell_0} \to 0 \\ \ell_1 - \ell_0 &\sim \frac{w^2}{8\ell_0^2} \quad \text{for small} \quad \frac{w}{2\ell_0}\end{aligned} \tag{5.1}$$

One can constrain

$$\ell_1 - \ell_0 < \lambda\!\!\!^{-} \text{ (radian wavelength)} \tag{5.2}$$

to minimize the resulting phase variation over the antenna aperture.

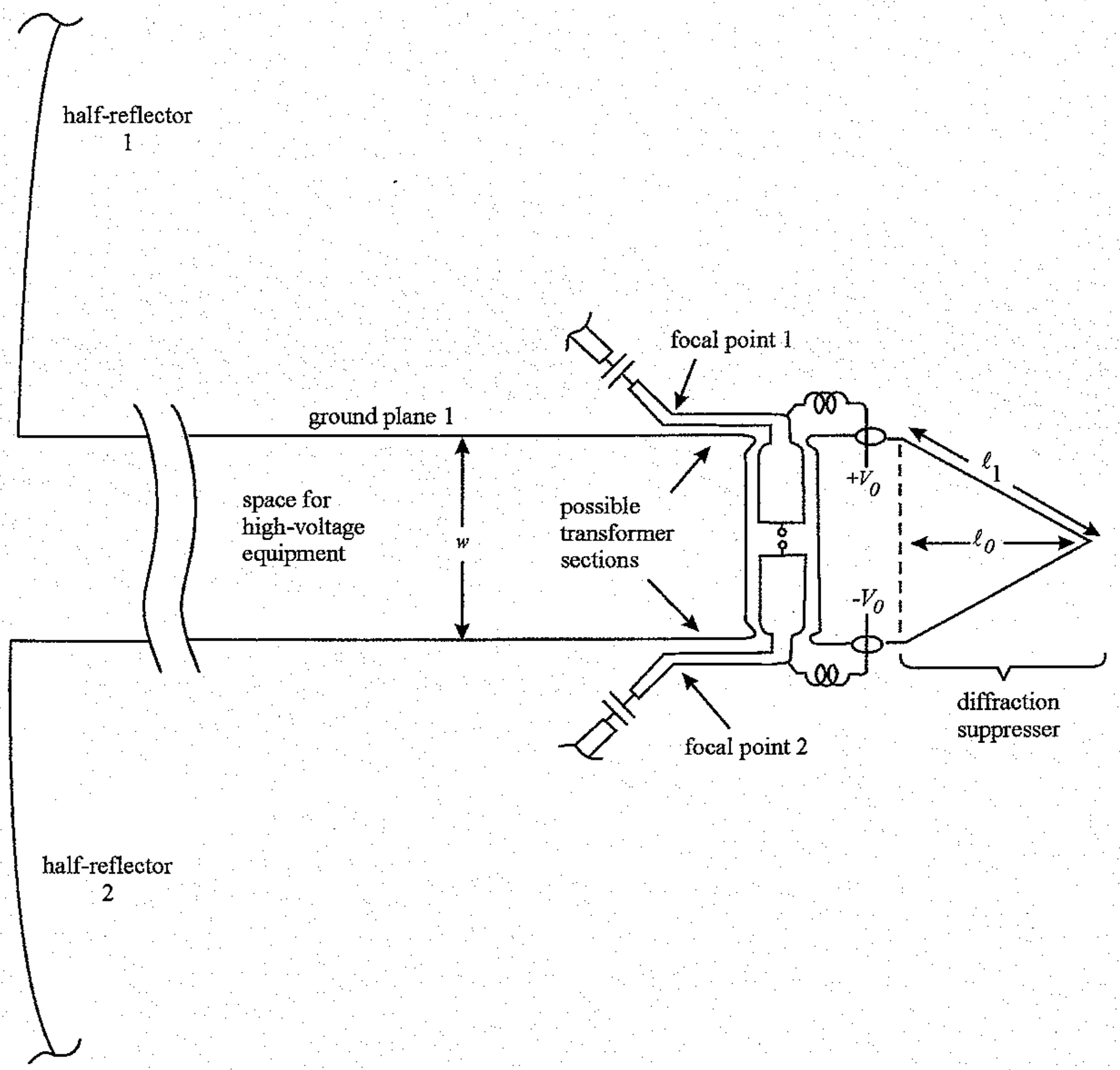


Fig. 5.1 Differential Oscillator Feeding Separated Reflector Antenna

6. Concluding Remarks

These design variations for the ORA now allow voltage doubling due to the differential system. Together with the separated reflector one can obtain larger far fields.

References

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