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Microwave Memos

Memo 10

The Dispatcher

Foreword

Dispatcher (or despatcher) (noun): one that dispatches

Dispatch (or despatch) (transitive verb): a: to put to death, b: kill

From: Webster's Third New International Dictionary of the English Language Unabridged, 1967

Damped
Intensive
Sinusoidal
Pulsed
Antenna,
Thereby
Creating
Highly
Energetic
Radiation

I Introduction

The Phaser was introduced as an HPM weapon in [4]. This is a narrow band device in that a hundred cycles or so of a single frequency are produced for each pulse. This is quite different from a disrupter [5] which is an HPM weapon [6], having a band ratio of a few decades.

Let us now consider something with a moderate bandwidth (still ultra-wideband by some definitions). This involves a transiently excited resonant structure with the resonance lasting several cycles (say to e^{-1} relative amplitude). The frequencies of interest lie in the few hundred MHz to several GHz range [1]. However, it may be easier to produce such transiently excited resonant structures at very high voltages in the lower part of this frequency range. Of course, we still need an antenna with significant gain to maximize the fields incident on a target [7]. Let us refer to this type of approximately damped-sinusoidal radiator as a dispatcher.

II EM Source (Oscillator)

One kind of oscillator is a charged transmission line with a shorting switch at one end as in Fig. 1. With a short at one end and a high impedance (100Ω or so of an antenna) at the other end, this is a quarter wave ($\lambda/4$) oscillator (with generally higher harmonics ($3\lambda/4$, etc.)). Note that we assume

$$Z_c << |Z_a|$$

$$Z_c = \text{transmission-line characteristic impedance} \quad (1)$$

$$Z_a = \text{antenna input impedance}$$

In order to simplify the subsequent discussion let us assume that Z_a can be approximated by a constant resistance. Also the high-voltage connection to the oscillator is assumed to be through a high impedance (e.g. inductor) near the oscillator in order to minimize the loading of the oscillator via this connection.

Following waves back and forth on the transmission line. Beginning with the switch closure, let it close in a time t_s, short compared to t_t, the transit time along the transmission line. For a quarter-wave resonator we have

$$f = \frac{\varpi}{2\pi} = \frac{4}{t_t} \quad (2)$$

for the principal resonance. A real switch will have some inductance (and resistance) which will modify the resonance somewhat. As an example 500 MHz corresponds to a quarter wavelength in transformer oil of 0.1 m, not very large. For a charge voltage V_0 in

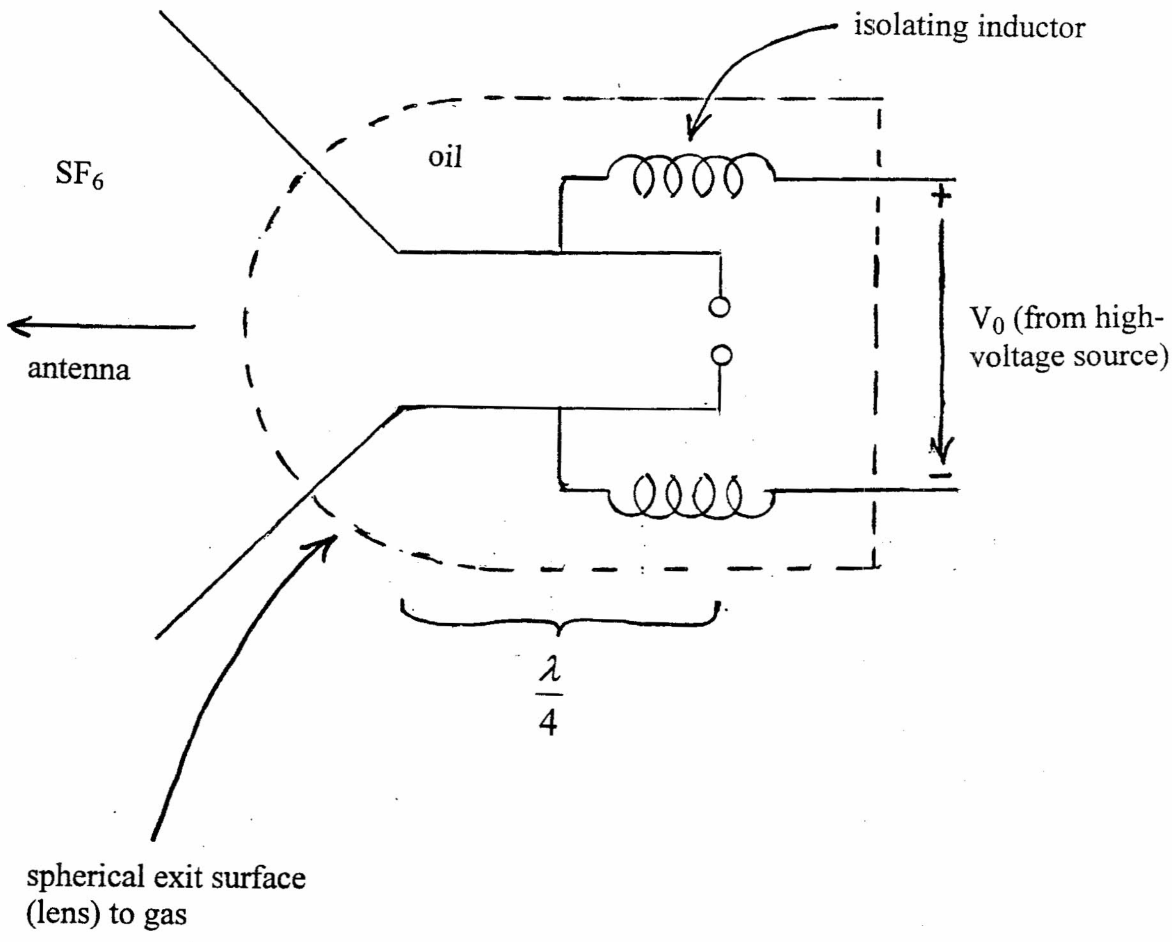

Figure 1. Low-Impedance, Quarter-Wave, Transmission-Line Oscillator Feeding High-Impedance Antenna

the 100s of kV one will need to make the switch closure time small compared to a t_t of 0.5 ns. The switch will also need to be physically small.

On closing the switch a wave (ideally a step function) of amplitude $-V_0$ propagates to the left (in Fig. 1), with nearly a +1 reflection coefficient, placing a transient voltage doubling is characteristic of a Blumlein and is advantageous in the present application. The reflection coefficient at the antenna is more accurately

$$p = \frac{1 - \dfrac{Z_c}{Z_a}}{1 + \dfrac{Z_c}{Z_a}} \cong 1 - 2\frac{Z_c}{Z_a} \tag{3}$$

Assuming an ideal reflection coefficient of -1 for the wave returning to the switch, then the second wave reaching the antenna reflects with amplitude ρ^2, etc. This is a geometric series with alternating signs, describing an exponential decay, the dominant frequency in this as in (2), but now more accurately described as a damped sinusoid. In N cycles the amplitude is reduced to ρ^{2N}. If we set this equal to e^{-1} we have

$$N = -\frac{1}{2\ell n(\rho)} \tag{4}$$

describing an effective number of cycles. With (3) we have for small damping

$$N \cong \frac{1}{4}\frac{Z_a}{Z_c} \tag{5}$$

An alternate source is the half-wave oscillator in Fig. 2 obtained by placing the switch in the center of the low-impedance transmission line. This doubles the length for a given oscillation frequency and increases the stored energy available to the antenna. However, in this case the switch needs to have some non-zero impedance to allow the energy to its right to propagate to the left, past the switch. This is but one example of a more sophisticated resonator design. The characteristic impedances of the left and right portions need not be the same. Variable transmission-line impedances (transmission-line transformer) are possible. Even non-transmission-line geometries are possible, and more general two- and three- dimensional oscillators are also possible. These will require more detailed calculations for optimization.

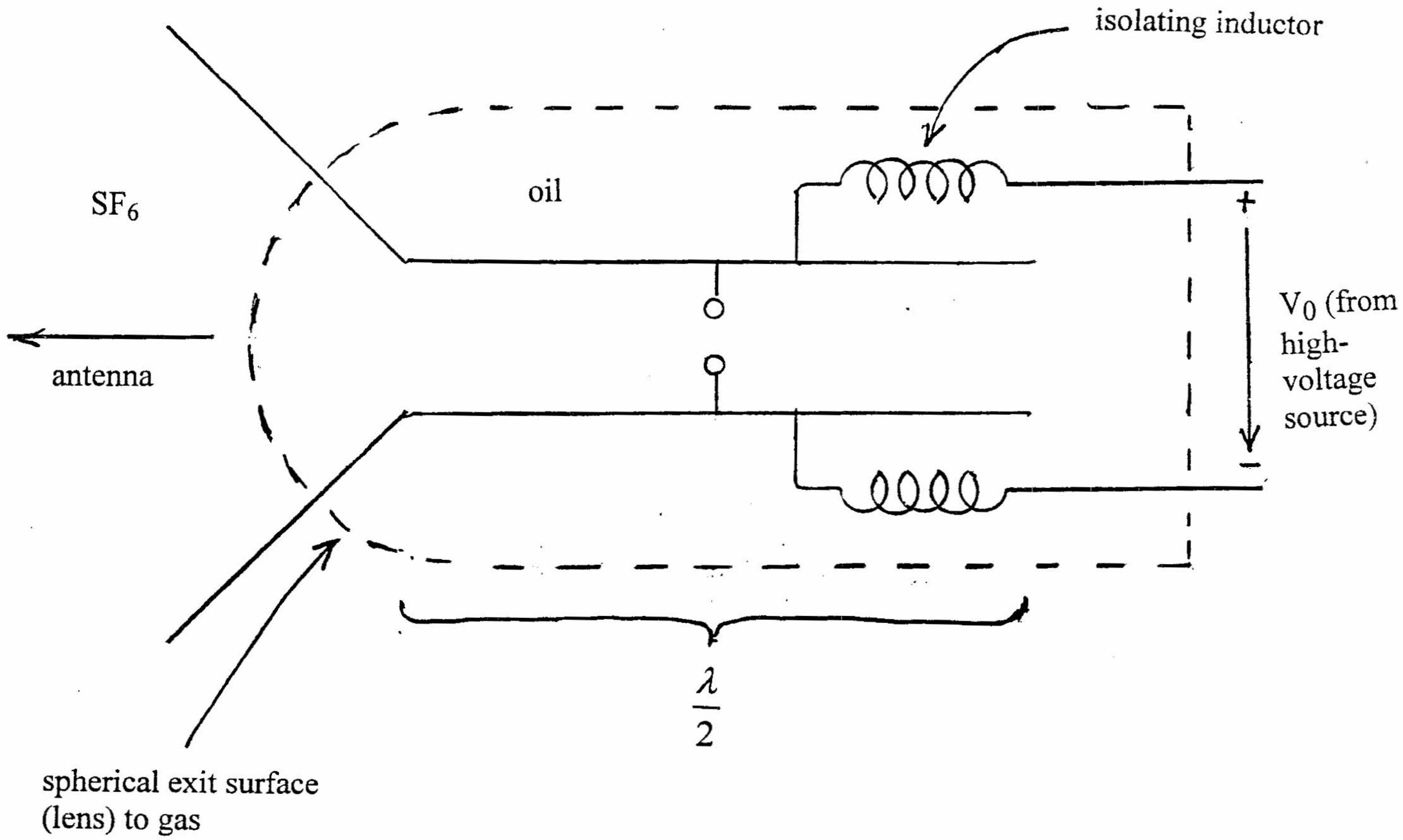

Figure 2. Low-Impedance, Half-Wave, Transmission-Line Oscillator Feeding High-Impudence Antenna

III High-Voltage Charging Source Integrated Into Antenna Geometry

Now let us consider some of the ways of charging the oscillator to initial voltage V_0 (voltage at time of switch closure). The type of antenna used has some influence on this.

Figure 3 shows the case of a high-voltage feed through the feed arms such as are used in a reflector IRA [2]. The high-voltage source is behind the reflector producing a differential $\pm V_0/2$, perhaps allowing a higher effective source voltage V_0. The feed arms are then part of the antenna, and one has choices of connecting the high voltage to two or four arms (typical) as desired. Where the feed arms approach the reflector rim one may wish to place some network there to allow termination of the high frequency wave propagating along the feed arms. This may involve not only terminating resistors, but blocking capacitors (D.C.) and inductors (high frequency). One will have to trade off the benefits of termination against the extra energy required from the high-voltage source.

An alternate configuration for the high-voltage feed involves bringing high-voltage leads separate from the feed arms which launch a wave toward the reflector, such as done in some reflector IRAs [8]. In this case the high-voltage leads follow paths on (or near) a symmetry plane which is perpendicular to the electric field produced by the antenna. This allows the feed arms which launch the wave toward the reflector to be replaced by a TEM horn of appropriate dimensions.

Figure 4 shows another geometry utilizing a ground plane, below which the high-voltage source is placed [3]. In this case the source feeds a TEM horn which has less capacitance to be charged by V_0 than does the long feed arms in Fig. 3. The required length of the horn is proportional to the wavelength at which one is operating. One can radiate directly from this horn, or for higher gain this horn can feed a paraboloidal reflector as indicated.

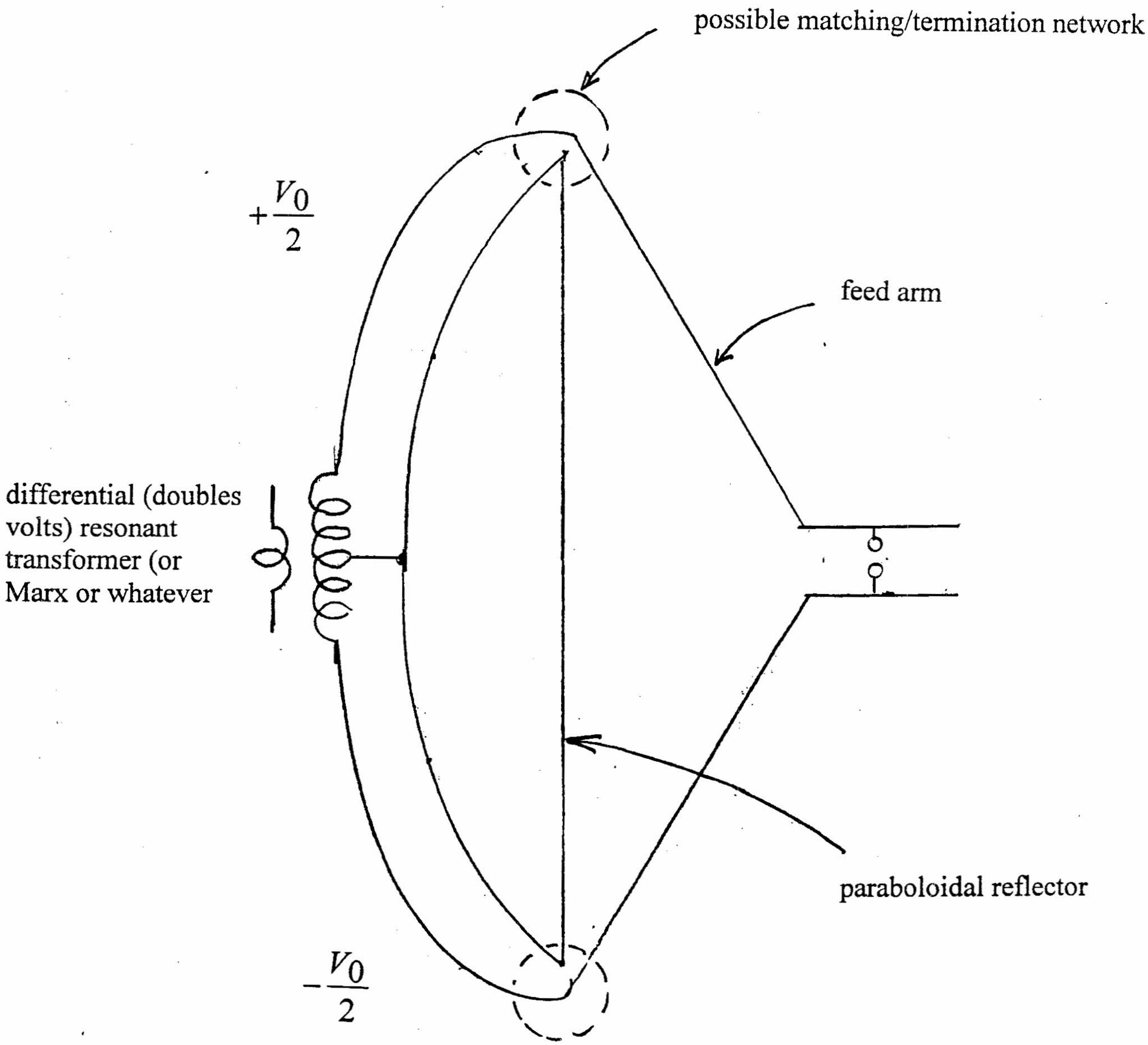

Figure 3. Differential High-Voltage Feed From Behind a Paraboloidal Reflector

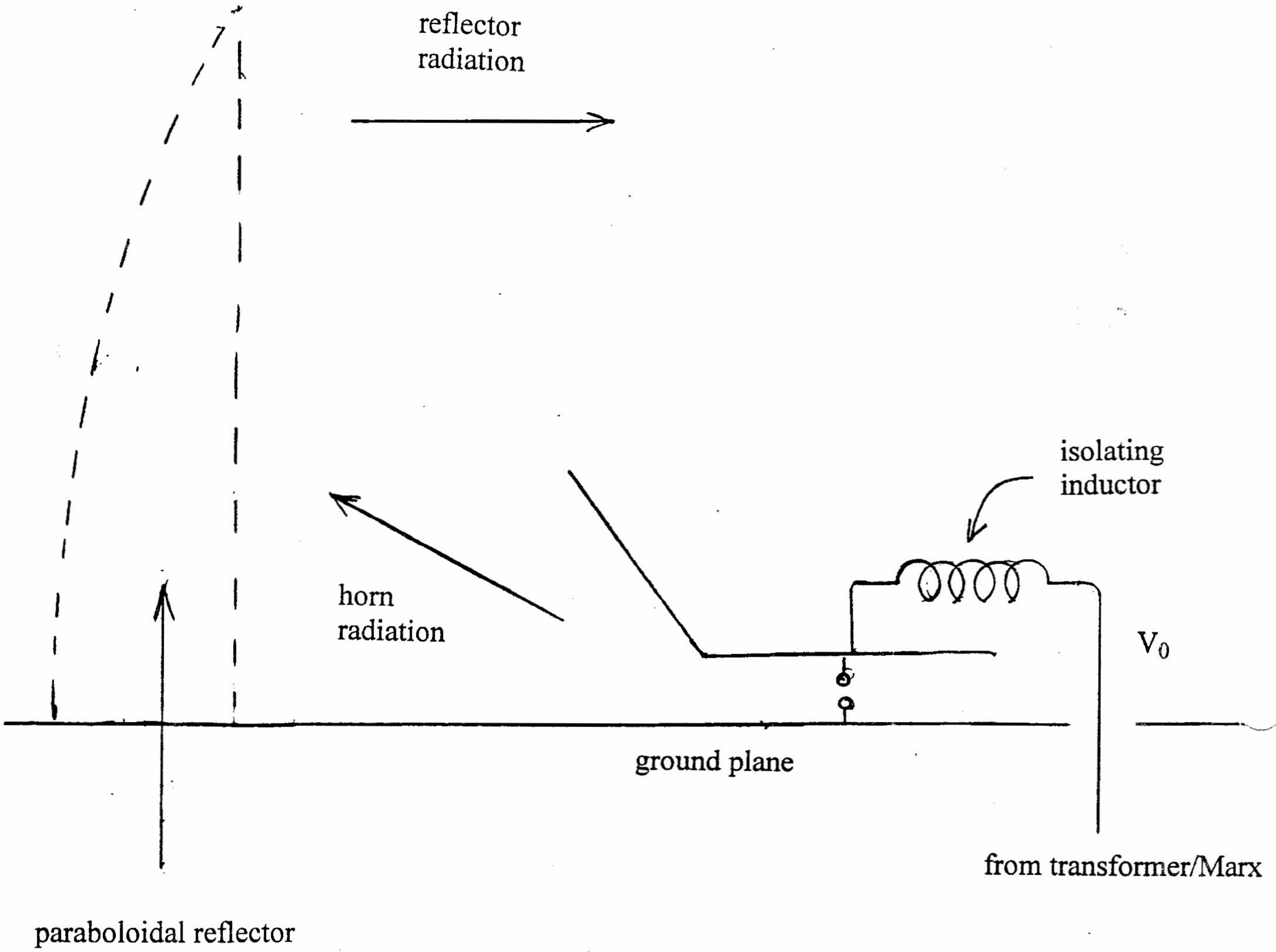

Figure 4. Single-Ended Feed From Below Ground Plane For Horn and/or Reflector Antenna

References:
1. C.E. Baum, Maximization of Electromagnetic Response at a Distance, Sensor and Simulation note 312, October 1988. IEEE Trans. EMC, 1992, pp. 148-153.

2. C.E. Baum, Configurations of TEM Feed for an IRA, Sensor and Simulation Note 327, April 1991.

3. C.E. Baum, Variations on the Impulse-Radiating-Antenna Theme, Sensor and Simulation Note 378, February 1995.

4. C.E. Baum, The Phaser, Microwave Memo 2, November 1988.

5. C.E. Baum, The Disrupter, Transient Radiating Antenna Memo 4, May 1998.

6. C.E. Baum, High-Power Impulse (HPI), Transient Radiating Antenna Memo 5, July 2000.

7. C.E. Baum, Figures of Merit for High-Power Electromagnetic Radiators, Transient Radiating Antenna Memo 6, July 2000.

8. D.V. Giri et al, Design, Fabrication, and Testing of a Paraboloidal Antenna and Pulser System for Impulse-Like Waveforms, IEEE Trans. Plasma Science, 1997, pp. 318-326.