A Concept of a Mesoband Source Combining a Reflectarray Antenna and a Switched Oscillator

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***Abstract*— We present in this paper the concept of a Mesoband radiating system, combining a quarter-wave switched oscillator source and a TEM-fed reflectarray antenna.**

I. INTRODUCTION

Mesoband radiators based on the SWO were originally proposed by C. Baum in [1]. These sources can produce a high amplitude signal with a fractional bandwidth $1\% < br < 100\%$ [2]. They have generally been reported operating at sub GHz frequencies with charging voltages in the 10's of kV [3]–[5]. Several antennas have been proposed for this device, namely helical [3], [6], [7], discone [4], HIRA [8], patch [9], among others [10].

The use of an aperture antenna, such as the HIRA, represents a clear advantage due to its gain and high impedance. However, in certain applications, antennas based on parabolic dish reflectors represent a mechanical and operational challenge. We propose in this paper to emulate the behavior of the HIRA using a printed reflectarray (RA) illuminated by a set of TEM feeders connected to an SWO. The main characteristics of the proposed RA are described in Section II. The SWO is presented in Section III, and the proposed assembly SWO+RA is described in Section III.

II. REFLECT ARRAY

The Reflectarray Antenna (RA) is a class of aperture antenna that utilizes a discrete two-dimensional array of elements implementing phase compensation to steer the antenna pattern in a selected direction [11].

Numerous unit cell geometries can be considered for the case; Figure 1 shows some examples that can be manufactured using PCB technology.

A plane wavefront can be obtained if the cells produce a phase compensation as follows [12]:

$$\begin{aligned} \Delta L_{m,n} &= L_{m,n} + L_{0,0} \\ \Delta \Phi_{m,n} &= \left(\Delta L_{m,n} / \lambda_0 - \text{integer}\left(\Delta L_{m,n} / \lambda_0 \right) \right) \cdot 360^{\circ} \end{aligned} \tag{1}$$

where $L_{0,0}$ and $L_{m,n}$ are the feed-to-RA center, and feed-to-mn^{th} cell distances, respectively. λ_0 is the wavelength at the center frequency, and $\Delta\Phi_{mn}$ is the phase difference, in degrees, to be compensated by the mn^{th} cell.

The required $\Delta\Phi_{mn}$ depends on the geometry and size of the particular cell and can be calculated via electromagnetic simulation, assuming periodic surface condition [12]. Since $\Delta\Phi_{mn}$ is highly dependent on frequency, the unit cells will be tuned to give phase agility around the central frequency of the SWO.

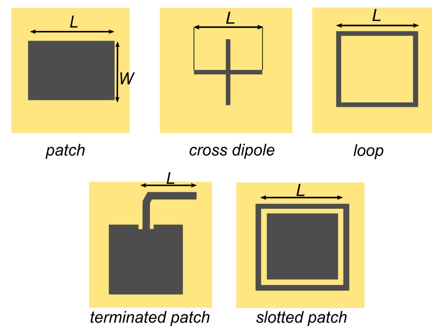

Figure 1 Tipycal RA unit cell geometries.

III. SWITCHED OSCILLATOR

The coaxial quarter-wave SWO consists of a low impedance, a coaxial transmission line with one end connected to a high impedance antenna, and the remaining end terminated at a spark gap switch. The line is slowly charged by an external HV source, through a high impedance connection. Once the breakdown voltage is reached, the spark gap closes, and a voltage wave travels up to the antenna end, where part of the energy is transmitted into space. However, due to the mismatch, most of the energy is reflected back to the coaxial and travels up to the short circuit formed by the spark gap. The energy is re-reflected, this time with negative sign, traveling again towards the antenna. This creates a damped sinusoidal-like waveform, whose central frequency (f_0) is close to:

$$f_0 = \frac{4}{v_p L_e k} \tag{2}$$

where v_p is the propagation velocity in the coaxial line, L_e is the electrical length of the coaxial section, and $k \geq 1$ is a constant associated with the length of the radial transmission line formed by the electrodes.

Inset in Figure 2 shows an example of a coaxial SWO [13]. This unit, manufactured by the authors, can be charged up to 60 kV and is designed to resonate at 433 MHz.

IV. Description of the Assembly SWO + RA

The Mesoband source here proposed consists of a SWO connected to a couple of TEM coplanar feeders over a ground plane. The spherical wavefront, transported by the feeders, illuminates the reflectarray. Each unitary cell reflects the signal with a specific phase, producing a combined quasi planar wavefront. A suitable RA for this application consists of a lattice of 5x10 slotted patches printed over FR4 substrate; see Figure 2 as a reference.

The aperture angles of the feeders can be designed using the classical approach for the HIRA. Blocking capacitors, added between the SWO and the feeders, prevent circulating DC currents in the antenna. The feeders are terminated at their characteristic impedance, preventing reflections of the voltage wave.

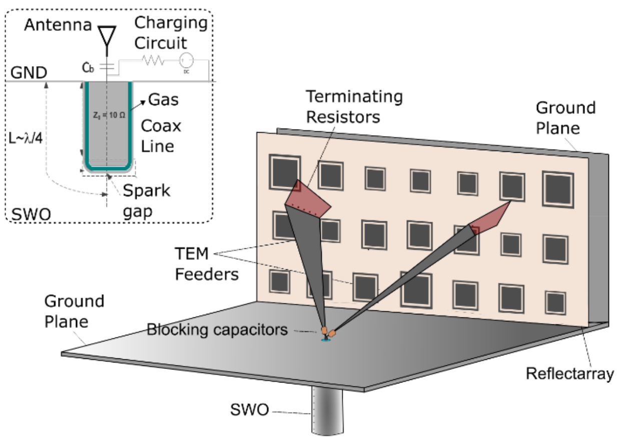

Figure 2 Sketch of the assembly SWO+RA.

The radiated signal can be calculated as:

$$E(f) = V_{SG} \frac{T_{SWO}(f)}{L_{eff}(f)} \tag{3}$$

where: $L_{eff}(f)$ is the effective length of the RA, $V_{SG}(f)$ is the Fourier transform of the voltage pulse waveform at the spark gap, and $T_{SWO}(f)$ is the frequency-dependent transfer function between the voltage at the antenna end and $V_{SG}(f)$, including the losses at the gap:

$$T_{SWO} = \frac{Z_A(f)}{A(f)Z_A(f) + B(f)} \tag{4}$$

V. Conclusions

We presented the concept of a mesoband radiator integrating a coaxial SWO and a printed reflectarray illuminated by TEM feeders. This design combines the high impedance of a HIRA type antenna and the advantages of a planar reflector.

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