Trends in Narrowband High Power Microwaves

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Abstract— **Narrowband high power microwave (HPM) sources are coherent hypoband sources of electromagnetic radiation that have been under development for nearly 50 years. Such sources are intense, high perveance, relativistic electron beam-driven vacuum electron devices that follow a power-frequency scaling governed by Pf^2. This presentation reviews historical developments, describes the present state-of-the-art in the field, and suggests recent trends that are shaping the future direction in this field.**

Keywords-high power microwaves, hypoband sources, pulsed power

I. INTRODUCTION

Narrowband HPM sources [1,2] are hypoband coherent sources of electromagnetic radiation that have been under development for nearly 50 years. These sources are an outgrowth of the development of modern pulsed power [3]. Such sources are intense, high perveance, relativistic electron beam-driven vacuum electron devices that follow a power-frequency scaling governed by Pf^2 (power times frequency squared). The frequency range over which HPM sources are researched range from <1 GHz – 1 THz.

II. HISTORICAL OVERVIEW

HPM sources began to appear in the mid-to-late 1960's (see [4] for more details). They have two lines of genesis, one in the United States and one in the Soviet Union. The availability of high-current pulsed power accelerators led researchers, primarily plasma physicists, to revisit conventional electron beam-driven source concepts except this time using high-perveance electron beams. Plasma physicists led this line of research because these high-perveance relativistic electron beams have strong space charge fields, and plasma physicists are those who best understand particle-wave interactions under such extreme conditions, Fig. 1.

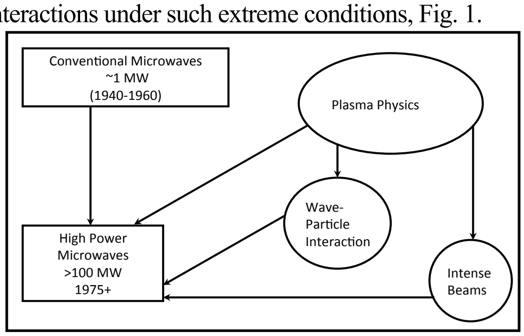

Figure 1. Plasma physicists dominated the development of HPM sources because of their understanding of particle-wave interaction when space charge is dominant [2].

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A. *The Early Years – The HPM Power Derby*

The early years (1960's to 1991) were dominated by a power derby between researchers in the United States and the Soviet Union. This was the era of big machines, exemplified by the Aurora machine at Harry Diamond Laboratories (Army Research Laboratory, Adelphi, MD) and the Gamma machine at the Institute of High Current Electronics, Tomsk, Soviet Union.

B. *Pulse Shortening and Virtual Prototyping*

The HPM power derby came to an end by the mid-1990's. At the time the goal of source researchers was 1 kJ of output energy. This was beyond what was achievable. Inevitably, plasmas generated within the electrodynamic interaction region limited the output pulse duration and pulse repetition rate.

At about the same time, virtual prototyping emerged as a revolutionary tool for designing HPM sources [5]. Prior to the early-mid 1990's experimentalists tinkered; modeling and simulation attempted to match experimental results. Absolute agreement was poor. Today, no metal will be cut until simulation demonstrates optimal performance! Particle-in-cell (PIC) codes have altered the paradigm of HPM source design.

III. RECENT TRENDS

The recent trends in the field are summarized in bullet form below.

- Multi-spectral sources
- Phase-coherent sources
- Metamaterial and metamaterial-like slow wave structures.

Multi-spectral sources pertains to single HPM sources that can concurrently generate two or more frequencies. Phase-coherent sources pertains to recent advances in driving two (N) or more sources using the same pulsed power driver. The phase coherence required to achieve an N^2 scaling in peak output power is <25°. Finally, metamaterials have recently been extensively studied for their use as slow wave structures in HPM sources [6]. This research frontier is at its nascent stage.

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