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# USEFUL FUTURE EXPERIMENTS FOR HPM RADIATION SYSTEMS

## I. Introduction

The purpose of this memo is to identify and document certain experimental studies that are useful in fabricating HPM radiation systems. The following list of experiments, although it may not be exhaustive, is considered as an useful set of experiments prior to building an optimal HPM radiation system.

1) electrical breakdown in evacuated waveguides at HPM frequencies, power levels and pulse widths

2) antenna pattern measurements to optimize feed arrays consisting of electromagnetic horns of various shapes

3) design of relativistic klystrons that operate well into the dominant rectangular waveguide mode

4) optimization of source arrays to achieve even higher power levels

5) phase shifting at high power levels

6) an experimental study of novel mechanical steering methods for reflector antennas

7) experimental optimization of the entire feed system

The above listed experiments are briefly discussed in the following section.

## II. Brief Description of Experimental Studies

In this section, we briefly describe the experimental studies. It is not the intent here to carry out the detailed design of the experiments, but merely point out the salient features.

### *1) Electrical breakdown in waveguides*

As an example, a peak power of 1.8 GW has been carried in the dominant mode of a WR-650 rectangular waveguide at an operating frequency of 1.1 GHz [1]. This corresponds to a peak electric field of 13.32 MV/m [2]. If one were to optimize the waveguide by using WR-975, 2 GW of peak power or 1 GW of average power corresponds to a peak electric field of 7.86 MV/m. This is easily sustained in WR-975, in comparison to what has been achieved in WR-650 waveguide. The ultimate physical limit of power carrying capacity of a waveguide is caused by field emission from the walls of the waveguide. However, practical engineering limitations will come into play before physical limits are reached. Carefully designed experiments of power handling capacity of rectangular waveguides (e.g. WR-975

*4) Optimization of source arrays*

The purpose here is to design optimal arrays of HPM sources by the use of symmetry concepts [4]. For efficient use of power, N number of HPM sources need to operate essentially as identical phase-locked sources. Symmetry is helpful in operating the N sources under identical conditions of voltage, current etc. One such symmetry group is the point symmetry group (rotation and reflection). Besides having all the sources operate at the same frequency, the relative phases are to be controlled so that signals from various sources can be combined appropriately. This concept has been implemented in the case of phase- locked relativistic magnetrons and may be explored further in future optimization studies.

*5) Phase shifting at high power levels*

Hansen[5] has pointed out that, at high power levels (in the range of a GW or higher), phase shifting can be produced by a) changing the length of a transmission line or b) the use of switched lines. They consist of using a trombone and gas or semi-conductor switched high power transmission lines. Some experimental studies are available [6] and further experimentation will be useful.

*6) Mechanical steering methods*

A dual reflector antenna system (e.g., Cassegrain antenna) permits certain flexibility in steering. The larger reflector is fixed, while the smaller hyperboloidal reflector may be moved to obtain a limited amount of scanning. Typically the amount of scanning is about 10 to 20 times the beam width. The steering mechanisms that were initially developed in the 1940s , over the years gave way to electronic steering , which is adequate at lower power levels. However, at the present high power levels, additional experimental studies in optimizing the scanning capabilities by mechanical means are considered useful.

*7) Feed system optimization*

The entire feed system has been designed for operation at high power levels as required. However, starting with these designs, one can experimentally optimize the feed system. This could consist of optimizing the sizes and shapes of various dielectric interfaces ( vacuum to SF6, SF6 to air etc.). The use of resistively loaded metallic slats in the horn - air interface needs experimental refinement for example. Yet another example is the optimization of side wall bi-directional couplers for power measurement.

Successful deployment of HPM radiating systems depend on optimizing various components of the system, both individually and collectively .

## References


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