

A New Microwave Source for Cardiac Therapy

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Abstract- Microwave technology shows promise in cardiac applications for microwave assisted balloon angioplasty and microwave cardiac ablation. Traditional microwave energy sources used in these procedures have poor efficiency, are large size requiring them to be located far from the patient, and require coaxial cables to deliver power resulting in loss and heat generation causing potential safety issues. Artisan Laboratories Corporation has developed a new microwave energy source that has demonstrated 80 % efficiency compared with less than 20 % efficiency in classic microwave amplifiers. This source will significantly reduce the size of microwave generators, improve efficiency, reduce heat generation, and allow for the generator to be controlled through an optical fiber improving flexibility and ease of use.

I. INTRODUCTION

Stroke and heart disease reign as two of the most important causes of morbidity and mortality in the American population [1]. Atherosclerotic narrowing of the vasculature remains one of the keys to the underlying pathophysiology of these illnesses. Microwave technology is currently being used in cardiac surgery for microwave assisted balloon angioplasty and microwave cardiac ablation. While angioplasty has become one of the most commonly performed major cardiac operations in the United States, microwave assisted balloon angioplasty has become popular because of the ability to heat plaque without overheating surrounding tissue [2]. In an animal model, microwave assistance substantially improved both immediate and short term follow-up outcomes of vascular patency relative to balloon angioplasty without such assistance [3]. The underlying mechanism appears to include direct thermal injury to the media and intima with decreased proliferation in animals so treated. Microwave cardiac ablation is now also used in treatments of cardiac arrhythmia [4]. In cardiac surgery patients, use of microwave ablation for atrial fibrillation reduced mortality from common complications [5]. These arrhythmias arise from regions in the heart of abnormal impulse conduction or formation. The goal of effective cardiac ablation is to create a localized injury that will effectively remove the arrhythmia without injuring the surrounding tissue [6]. Microwaves are best suited for ventricular tachycardia which requires heating at larger depths and across larger volumes [7].

Microwave energy sources for cardiac surgery must be capable of delivering up to 80 Watts at 2.54 GHz. The primary technology for these sources is vacuum-tube

technology such as a Magnetron. In addition, they must be digitally controlled to set power levels and delivery times.

While tube and solid state technologies are common they have several limitations including poor efficiency and large size. Because the source is located outside the surgical field, a long coaxial cable is needed to transfer the power from the source to the radiating element at the surgical site. Losses on the order of 6 dB can be found in medical grade coaxial cable causing the cable to heat up and presenting a safety hazard to the patient. If a higher efficiency, smaller size microwave source can be developed then improved surgical performance can be achieved.

Traditional solid state devices or monolithic circuits are smaller than conventional tube technology; however they are not efficient and therefore generate heat. New microwave source designs are required to improve efficiency and ultimately allow for the placement of the microwave energy source near or within the patient, reducing the need for coaxial cables.

In this paper we describe a new high efficiency microwave source that has the potential to reduce the size of the source, eliminating the need for long coaxial cable and potentially allowing for the source to be located at the heating site. In addition the digital control and distribution of the microwave energy can be delivery by a fiber optic cable improving flexibility, eliminating heat found in coaxial cable, and isolating the patient from the microwave generator thus improving safety.

II. MICROWAVE ENERGY GENERATOR CONCEPT

Artisan Laboratories Corporation has developed a new microwave source called Ultralight Microwave Energy Source [8] for generating, amplifying, distributing and controlling high power microwave energy for cardiac surgery. We have demonstrated an amplifier efficiency of 80% and a power added efficiency of 55% which we believe is state-of-the-art. In addition our concept allows for the use of optical fiber for distribution of control signals. Using a fiber optic cable for signal distribution has many benefits over coaxial cables including: low loss, high isolation, small size, improved flexibility.

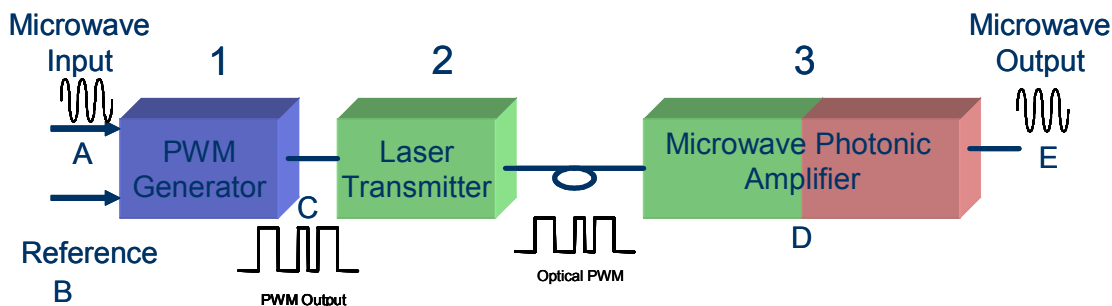


Figure 1. Block diagram of the Ultralight Microwave Energy Generator concept. The microwave input signal (A) is compared against a reference signal (B) in a PWM generator. The output (C) is a pulse-width modulated signal that drives an optical transmitter and is directed to a microwave photonic amplifier via a fiber optic cable. The optical PWM signal (D) is used to drive the high efficiency microwave photonic amplifier that converts the signal back to analog (E).

Conceptually, our approach to generating high power microwave signals is shown in Figure 1. Referring to Figure 1, the microwave input signal (A) is compared against a reference signal (B) in a pulse width modulator (PWM) generator. The output (C) is a pulse-width modulated signal that drives an optical transmitter and is directed to a microwave photonic amplifier via a fiber optic cable. The optical PWM signal (D) is used to drive the high efficiency microwave photonic amplifier that converts the signal back to microwaves (E).

III. EXPERIMENTAL RESULTS

The design and fabrication of the system consisted of building three main circuits: PWM Generator, Laser Transmitter and the Microwave Photonic amplifier. The PWM generator uses a high speed comparator to convert the analog or microwave signal to a PWM. The PWM output is used to modulate a laser transmitter and the resulting signal is transmitted over a fiber to the microwave photonic amplifier. We tested the completed system as a function of frequency. For this test the low level microwave signal is applied to one input of the

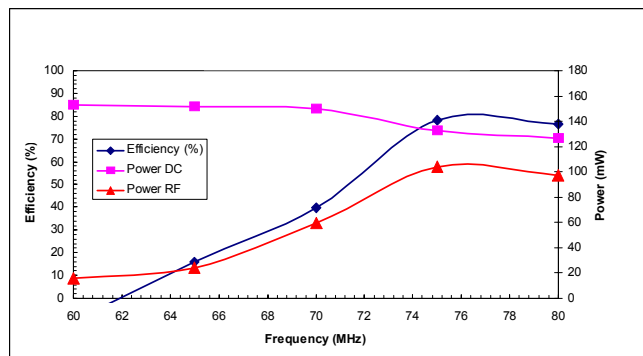


Figure 2. Summary of results of the *Ultralight Microwave Energy Generator*. This figure shows the RF power and efficiency as a function of frequency. We achieved 80 % maximum efficiency with 55 % power added efficiency at a level of 100 mW.

PWM generator; a reference signal is applied to the other input. The signal is transmitted over a fiber to the microwave photonic amplifier and converted to an electrical signal. The output power is measured and the efficiency is calculated. The results, as can be seen in Fig. 2, show the RF power and efficiency as a function of frequency. We achieved 80 % maximum efficiency with 55 % power added efficiency at a level of 100 mW.

IV. CONCLUSIONS

We have demonstrated what we believe is the first microwave photonic amplifier capable of delivering high efficiency and high power for cardiac applications. Although our results were developed at lower frequencies than traditional applications, we are encouraged by the results [9]. Changing the components in the design will allow us to go to higher frequencies and higher power.

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