Building and Characterizing a Ferromagnetic Electrosurgical Pencil

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ABSTRACT

Monopolar electrosurgical pencils cut and coagulate tissue by delivering current from an active electrode, through the patient, and into a dispersive pad placed on the upper thigh. This modality generates an electric field, interfering with implanted medical devices and risking thermal injury at the exit site [1]. This project explores using ferromagnetism as an alternative energy modality to monopolar devices. Ferromagnetism sends a radio-frequency alternating current through a ferromagnetic material to maintain a stabilized temperature called the Curie point, delivering pure heat to the surgical site while maintaining electrical silence [2].

INTRODUCTION

Electrosurgical pencils use an active electrode and return electrode pad to cut (200 - 400 °C) and cauterize (60 - 80 °C) tissue to maintain hemostasis [3]. The generator sends a current through the patient from the monopolar active electrode, interfering with implanted devices. Ferromagnetic energy uses a radio-frequency alternating current coupled with a ferromagnetic material to operate at the specific Curie temperature, and unlike monopolar, does not require a return electrode [2]. At the Curie point, the material transitions from ferromagnetic to paramagnetic and the temperature stabilizes within seconds.

Using a high-frequency alternating current through the ferromagnetic material creates a real resistance and reactive impedance that opposes the direction of the generated current. An impedance-matching circuit creates a conjugate impedance to maximize the power delivery and minimize reflected power.

METHODS

Must deliver between 10 and 25 Watts of power to the ferromagnetic wire with a Voltage Standing Wave Ratio (VSWR) of less than or equal to 1.5 Watts at 10 MHz to reach and maintain the Curie point.

- Estimate the impedance of the Anomet A52 wire to get a range of values needed for impedance matching
- Design and simulate different impedance matching circuits using LTSpice
- Test the designed impedance matching circuits by implementing adjustable capacitors
  - Match the circuit such that the reflected power is less than 1W
- Perform preliminary tests in reflected power by submerging the ferromagnetic wire in a saltwater bath
- Redesign circuits and repeat tests

REFERENCES


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RESULTS

- Determine the relationship between variation in power levels and the time to reach 315 °C
- Standardized in a U-Loop configuration, at 10MHz, matched under 1W

FUTURE WORK

- Hybrid design with lower Curie point ferromagnetic materials
- Feedback loop + thermocouple for heat regulation under Curie
- Investigate thermal spread
- Analyze smoke production of monopolar vs ferromagnetism

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