PATENT APPLICATION

DELIVERY HARDWARE FOR RESONANT PROTEIN FOLDING MODULATION IN BIOLOGICAL CONTEXTS

PROVISIONAL PATENT APPLICATION

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Hardware components for delivering resonant microwave radiation at the molecular gate frequency (10–20 GHz) to biological samples, including specialized applicators (waveguide cuvettes, microfluidic chambers, near-field antennas, resonant cavities), electromagnetic shielding, calibration phantoms, and dosimetry systems.

CONFIDENTIAL — PATENT PENDING

Contents

ABSTRACT OF THE DISCLOSURE

Hardware components for delivering resonant microwave radiation at the molecular gate frequency (10–20 GHz, specifically ∼14.65 GHz for H_2O and ∼10.4 GHz for D_2O) to biological samples for protein folding modulation. The hardware comprises: (a) waveguide-coupled cuvette applicators for bench-top research; (b) microfluidic flow chambers for continuous processing and kinetic studies; (c) near-field antenna applicators for localized delivery to cells, tissues, or in-vivo applications; (d) resonant cavity applicators for high-efficiency bulk processing; (e) electromagnetic shielding enclosures to contain radiation and prevent interference; (f) calibration phantoms with defined dielectric properties for system verification; and (g) dosimetry systems for measuring and controlling delivered power. The hardware is specifically designed for the 10–20 GHz frequency range relevant to protein folding modulation, with features including optical access for fluorescence detection, temperature control integration, isotope-compatible materials, and modular construction for flexibility. Applications include laboratory research instruments, biopharmaceutical manufacturing equipment, and potential therapeutic delivery devices. All hardware maintains electromagnetic emission levels below regulatory limits while enabling efficient energy delivery to biological samples.

Keywords: microwave applicator, waveguide, microfluidic, near-field antenna, resonant cavity, shielding, calibration phantom, dosimetry, protein folding, 10–20 GHz

1 BACKGROUND OF THE INVENTION

1.1 Field of the Invention

The present invention relates generally to hardware for delivering electromagnetic radiation to biological samples, and more specifically to applicators, shielding, calibration, and dosimetry systems designed for the 10–20 GHz frequency range used in resonant protein folding modulation.

1.2 Description of Related Art

1.2.1 Existing Microwave Applicator Technology

Prior art microwave applicators are designed for different frequency ranges and applications:

Technology	Frequency	Application	Limitations for PFM
Domestic ovens	2.45 GHz	Heating	Wrong frequency, no precision
Industrial heating	915 MHz, 2.45 GHz	Processing	Wrong frequency
Diathermy	27 MHz, 2.45 GHz	Therapy	Wrong frequency
Hyperthermia	434 MHz, 915 MHz	Cancer	Wrong frequency
NMR/MRI	60–900 MHz	Imaging	Wrong frequency, different purpose
EPR	9–35 GHz	Spectroscopy	Designed for spin, not folding

Table 1: Existing microwave applicator technologies (PFM = protein folding modulation)

1.2.2 Limitations of Prior Art

(a) **Wrong frequency range:** Most applicators are designed for 2.45 GHz or lower; 10–20 GHz requires different waveguide sizes, materials, and design principles.

(b) **No optical access:** Prior applicators are designed for heating or imaging, not combined microwave-optical experiments.

(c) **Poor temperature control:** Prior applicators for biological samples often lack the precision temperature control (±0.1°C) needed for isothermal resonant modulation.

(d) **No isotope compatibility:** Prior applicators are not designed for switching between H_2O and D_2O samples with automatic frequency reconfiguration.

(e) **No folding-specific design:** Prior applicators do not account for the specific requirements of protein folding experiments (denaturant compatibility, rapid mixing, kinetic measurements).

1.2.3 The Need for Purpose-Built Hardware

What is needed is hardware specifically designed for:

(1) Efficient delivery of 10–20 GHz radiation to aqueous biological samples;

(2) Optical access for fluorescence and other spectroscopic detection;

(3) Precision temperature control with minimal heating from irradiation;

(4) Compatibility with both H_2O and D_2O solvents;

(5) Compatibility with folding initiation methods (mixing, temperature jump);

(6) Safe operation with adequate shielding;

(7) Accurate dosimetry and calibration.

1.3 Objects of the Invention

It is an object of the present invention to provide hardware that:

(1) Efficiently couples 10–20 GHz radiation into biological samples;

(2) Provides optical access for detection;

(3) Integrates with temperature control;

(4) Supports multiple sample formats (cuvette, microfluidic, tissue);

(5) Includes shielding for safe operation;

(6) Includes calibration and dosimetry capabilities.

2 SUMMARY OF THE INVENTION

2.1 General Statement of the Invention

The present invention provides hardware components for resonant protein folding modulation, comprising:

(a) Waveguide-coupled cuvette applicators;

(b) Microfluidic flow chamber applicators;

(c) Near-field antenna applicators;

(d) Resonant cavity applicators;

(e) Electromagnetic shielding enclosures;

(f) Calibration phantoms;

(g) Dosimetry systems.

2.2 Hardware Categories

Figure 1: Seven categories of delivery hardware

2.3 Frequency Range

All hardware is designed for operation in the 10–20 GHz range:

Solvent	Target Frequency	Operating Range
H_2O	14.65 GHz	12–17 GHz
D_2O	10.4 GHz	8–13 GHz

Table 2: Target frequencies for protein folding modulation

3 BRIEF DESCRIPTION OF DRAWINGS

Figure 1: Hardware Categories

A list of the seven categories of delivery hardware.

Figure 2: Waveguide Cuvette Applicator

Cross-sectional view showing waveguide, cuvette holder, optical ports, and thermal management.

Figure 3: Microfluidic Flow Chamber

Diagram showing flow channels, microwave coupling, and detection integration.

Figure 4: Near-Field Antenna

Design of antenna for localized delivery with field distribution.

Figure 5: Resonant Cavity

Cylindrical cavity design with mode pattern and sample positioning.

Figure 6: Shielding Enclosure

Construction details of electromagnetic shielding.

Figure 7: Calibration Phantom

Phantom construction and dielectric property verification.

Figure 8: Dosimetry System

Block diagram of power measurement and control system.

4 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

4.1 Hardware 1: Waveguide-Coupled Cuvette Applicator

4.1.1 Design Overview

The waveguide cuvette applicator couples microwave energy from a rectangular waveguide into a standard spectroscopy cuvette containing the protein sample.

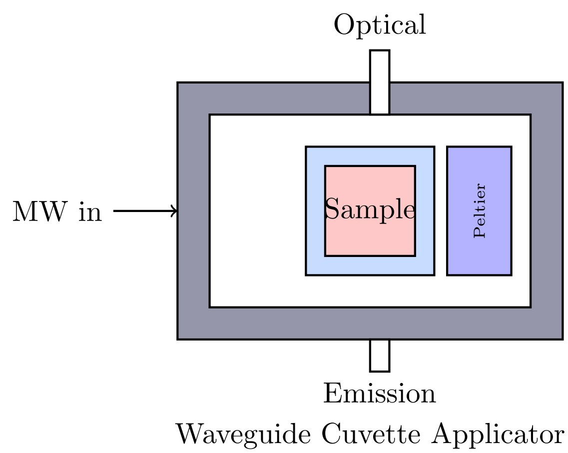

Figure 2: Cross-section of waveguide-coupled cuvette applicator

4.1.2 Waveguide Specifications

For 10–20 GHz operation, the waveguide dimensions are:

Waveguide	**Dimensions (a × b)**	**Frequency Range**
WR-62	15.80 × 7.90 mm	12.4–18.0 GHz
WR-75	19.05 × 9.53 mm	10.0–15.0 GHz
WR-90	22.86 × 10.16 mm	8.2–12.4 GHz

Table 3: Standard waveguide dimensions for 10–20 GHz

For full coverage of 8–18 GHz, a tapered transition or dual-waveguide design is used.

4.1.3 Cuvette Holder

- Accepts standard 10 mm path-length cuvettes (quartz or UV-transparent plastic)

- Spring-loaded retention for consistent positioning
- Electrical isolation from waveguide walls
- Thermal contact to Peltier element

4.1.4 Optical Access

- Top and bottom ports for fluorescence excitation/emission
- Ports fitted with microwave-blocking mesh ($<$ 1 mm aperture)
- Mesh transmits $>$ 90% of 250–700 nm light
- Optional side ports for 90° detection geometry

4.1.5 Thermal Integration

- Peltier element in thermal contact with cuvette holder
- Fiber-optic temperature sensor inside cuvette
- Heat sink with fan for Peltier hot side
- Temperature control range: 4–50°C
- Stability: ±0.1°C

4.2 Hardware 2: Microfluidic Flow Chamber

4.2.1 Design Overview

The microfluidic flow chamber enables continuous processing and kinetic studies by flowing sample through a microwave irradiation zone.

4.2.2 Channel Specifications

4.2.3 Substrate Materials

- **Fused quartz:** Low microwave loss, excellent optical properties

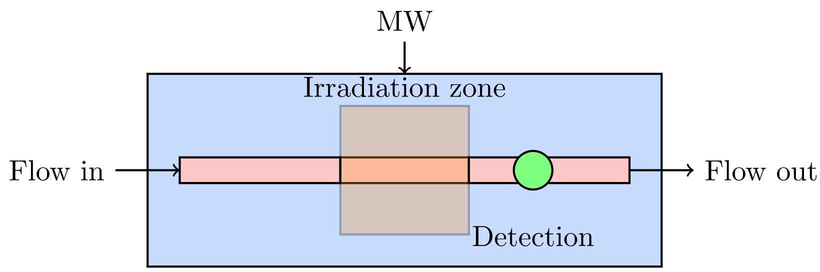

Figure 3: Microfluidic flow chamber for continuous processing

Parameter	**Value**	**Notes**
Channel width	100–500 μm	Protein-dependent
Channel depth	50–200 μm	Limits thermal gradient
Irradiation length	5–20 mm	Residence time control
Flow rate	1–100 μL/min	Kinetic resolution
Volume in zone	0.1–2 μL	Sample efficiency

Table 4: Microfluidic channel specifications

- **Borosilicate glass:** Lower cost, adequate performance
- **COC/COP polymers:** Low-cost, disposable, good optical
- **PDMS:** Rapid prototyping, but higher microwave absorption

4.2.4 Microwave Coupling

- Coplanar waveguide (CPW) on chip surface
- Stripline embedded in substrate
- External waveguide with aperture coupling
- Near-field antenna probe

4.2.5 Integration Features

- Mixing junction upstream for rapid initiation
- Temperature sensors at inlet, zone, and outlet
- Optical fiber ports for inline detection
- Waste collection or downstream analysis

4.3 Hardware 3: Near-Field Antenna Applicator

4.3.1 Design Overview

Near-field antennas enable localized delivery of microwave energy to small volumes, including cells, tissue samples, or specific regions of larger samples.

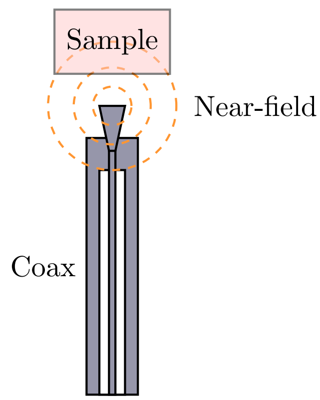

Figure 4: Near-field antenna for localized delivery

4.3.2 Antenna Types

Type	Size	Field Pattern	Application
Monopole	5–10 mm	Omnidirectional	General
Dipole	10–20 mm	Bidirectional	Symmetric
Patch	5×5 mm	Unidirectional	Surface
Slot	3×10 mm	Focused	Localized
Aperture probe	1–3 mm	Highly localized	Cellular

Table 5: Near-field antenna types for 15 GHz

4.3.3 Near-Field Characteristics

For antenna dimension a at frequency f:

$$\text{Near-field radius} \approx \frac{2a^2}{\lambda} = \frac{2a^2 f}{c} \tag{1}$$

At 15 GHz ($\lambda = 20$ mm), a 5 mm antenna has near-field radius ∼2.5 mm.

4.3.4 Applications

(1) **Cell culture:** Irradiate specific wells in multi-well plates

(2) **Tissue sections:** Localized treatment of tissue samples

(3) **In-vivo (future):** Potential for localized therapeutic delivery

(4) **Microscopy integration:** Combined microwave-optical imaging

4.4 Hardware 4: Resonant Cavity Applicator

4.4.1 Design Overview

Resonant cavities provide high-efficiency coupling for bulk sample processing by matching the cavity resonance to the molecular gate frequency.

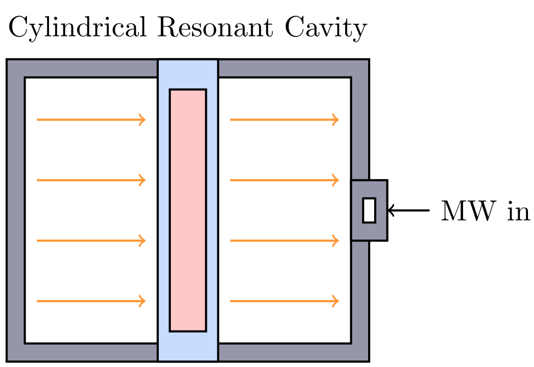

Figure 5: Resonant cavity applicator with sample tube

4.4.2 Cavity Modes

For a cylindrical cavity of radius a and height d:

$$f_{mnp} = \frac{c}{2\pi\sqrt{\mu\epsilon}}\sqrt{\left(\frac{x'_{mn}}{a}\right)^2 + \left(\frac{p\pi}{d}\right)^2} \tag{2}$$

where x'_{mn} is the n-th root of $J'_m(x) = 0$ for TE modes.

4.4.3 Cavity Dimensions

For TE_{011} mode at 14.65 GHz:

Parameter	Value	Notes
Radius a	12.5 mm	For $f_{011} = 14.65$ GHz
Height d	25 mm	$d = 2a$ for high Q
Sample tube ID	5–8 mm	Standard NMR tube
Quality factor Q	5000–10000	Unloaded
Loaded Q	500–2000	With sample

Table 6: Resonant cavity dimensions for 14.65 GHz

4.4.4 Tuning

- **Mechanical tuning:** Adjustable plunger or end plate
- **Electronic tuning:** Varactor diode in coupling circuit
- **Sample-dependent:** Cavity tracks sample dielectric

4.4.5 Advantages

(1) High efficiency: >90% power into sample

(2) Uniform field: Sample at field maximum

(3) High Q: Low power needed for strong field

(4) Stable: Temperature-compensated design possible

4.5 Hardware 5: Electromagnetic Shielding

4.5.1 Shielding Requirements

Standard	Limit	Notes
IEEE C95.1	10 mW/cm^2	Occupational, 10–300 GHz
ICNIRP	10 W/m^2	General public, 10–300 GHz
FCC 47 CFR 1.1310	1 mW/cm^2	Uncontrolled environment

Table 7: Electromagnetic exposure limits at 10–20 GHz

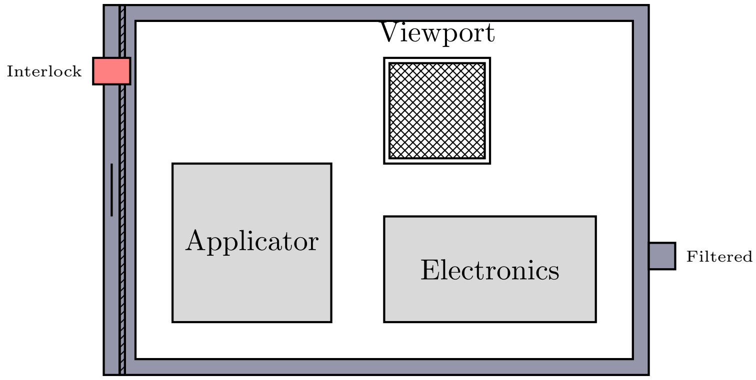

Figure 6: Shielding enclosure with safety features

4.5.2 Enclosure Design

4.5.3 Shielding Effectiveness

For aluminum enclosure at 15 GHz:

$$SE = 20 \log_{10} \left(\frac{E_{\text{incident}}}{E_{\text{transmitted}}} \right) > 60 \text{ dB} \tag{3}$$

4.5.4 Construction Details

- **Material:** Aluminum (6061-T6) or steel, 1–3 mm thick
- **Seams:** Welded or with conductive gasket (EMI gasket)
- **Door:** Finger-stock gasket, knife-edge contact
- **Viewports:** Conductive mesh (honeycomb, 2 mm cells)
- **Cable entries:** Filtered feedthroughs (Pi-filter or waveguide below cutoff)
- **Interlock:** Door switch disables power when open

4.6 Hardware 6: Calibration Phantoms

4.6.1 Purpose

Calibration phantoms are reference samples with known dielectric properties used to verify system performance and calibrate power measurements.

4.6.2 Phantom Requirements

Property	Requirement	Notes
Dielectric constant ϵ'	Known $\pm 2\%$	Traceable calibration
Loss tangent $\tan\delta$	Known $\pm 5\%$	Determines heating
Stability	$<1\%$ change/year	Long-term reference
Homogeneity	$<2\%$ variation	Spatial uniformity
Temperature coefficient	Characterized	For correction

Table 8: Calibration phantom requirements

4.6.3 Phantom Materials

Material	ϵ' at 15 GHz	$\tan\delta$	Use
Distilled water (25°C)	$\sim$50	$\sim$0.4	High-loss reference
Saline (0.9%)	$\sim$55	$\sim$0.5	Tissue-like
Glycerol/water	10–50	0.1–0.5	Adjustable
Silicone oil	2.5	0.001	Low-loss reference
PTFE (Teflon)	2.1	0.0002	Minimal interaction
Ceramic (Al_2O_3)	9.4	0.0001	Stable reference

Table 9: Calibration phantom materials at 15 GHz

4.6.4 Phantom Construction

(1) **Liquid phantoms:** Glass or quartz container, sealed

(2) **Gel phantoms:** Agar or polyacrylamide matrix with salts

(3) **Solid phantoms:** Ceramic or polymer with known properties

(4) **Tissue-mimicking:** Glycerol/water/NaCl mixture in gel

4.6.5 Verification Protocol

(1) Measure phantom with calibrated network analyzer

(2) Verify ϵ' and $\tan\delta$ against specifications

(3) Use phantom to calibrate applicator power delivery

(4) Verify temperature rise matches predicted heating

(5) Document and store calibration data

4.7 Hardware 7: Dosimetry System

4.7.1 Dosimetry Requirements

Parameter	Requirement	Notes
Power range	0.01–10 W	Covers typical experiments
Accuracy	±5%	Traceable to NIST
Frequency range	8–20 GHz	Covers H_2O and D_2O
Real-time readout	Yes	For feedback control
SAR calculation	Supported	Specific absorption rate

Table 10: Dosimetry system requirements

4.7.2 Measurement Methods

(1) **Calorimetric:** Measure temperature rise in known thermal mass

$$P = mc_p \frac{dT}{dt} \tag{4}$$

(2) **Power meter:** Directional coupler + calibrated detector

$$P_{\text{delivered}} = P_{\text{forward}} - P_{\text{reflected}} \tag{5}$$

(3) **Field probe:** E-field sensor in sample region

$$\text{SAR} = \frac{\sigma |E|^2}{\rho} \tag{6}$$

4.7.3 SAR Calculation

Specific Absorption Rate for biological samples:

$$\text{SAR} = \frac{P_{\text{absorbed}}}{m_{\text{sample}}} = \frac{c_p \cdot \Delta T}{\Delta t} \quad [\text{W/kg}] \tag{7}$$

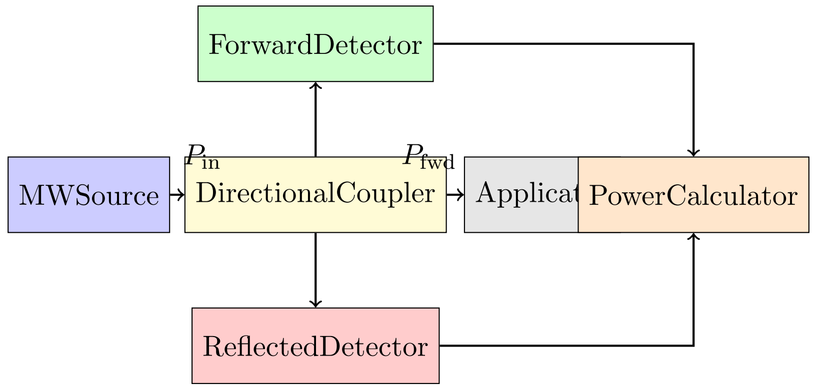

Figure 7: Dosimetry system using directional coupler

4.7.4 Dosimetry Display and Logging

- Real-time display: Power (W), SAR (W/kg), Energy (J)
- Logging: Time-stamped power profile
- Alarms: Over-power, reflected power limit
- Integration: Interface to control system (USB, Ethernet)

4.8 Integrated System

4.8.1 Complete System Configuration

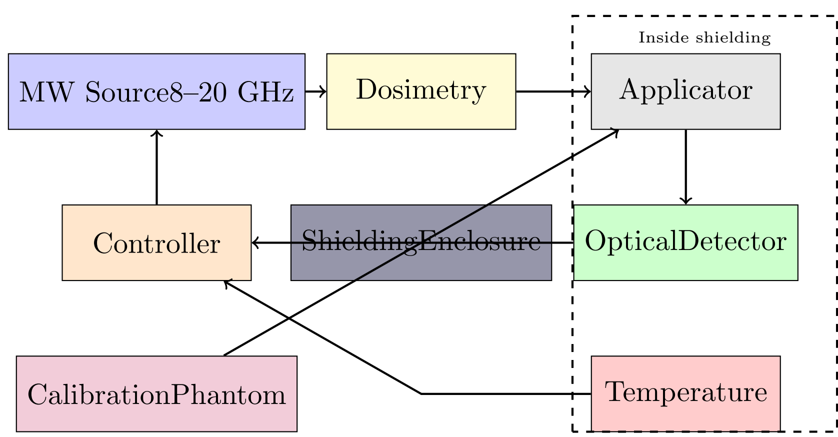

Figure 8: Integrated system block diagram

4.8.2 System Specifications

Parameter	Specification	Notes
Frequency range	8–20 GHz	Covers H_2O and D_2O
Power range	0.1–10 W	Adjustable
Temperature control	4–50°C, ±0.1°C	Peltier-based
Shielding	>60 dB	All frequencies
Optical access	250–700 nm	Fluorescence compatible
Sample formats	Cuvette, microfluidic, cavity	Modular
Safety	Interlocked, CE marked	Regulatory compliant

Table 11: Integrated system specifications

5 CLAIMS

What is claimed is:

5.1 Waveguide Cuvette Claims

1. An applicator for delivering microwave radiation to a protein sample for folding modulation, comprising:

(a) a waveguide configured for operation in the frequency range of 10 to 20 GHz;

(b) a cuvette holder configured to position a sample cuvette within the waveguide;

(c) optical access ports configured to allow fluorescence excitation and detection while blocking microwave leakage; and

(d) a thermal management element in thermal contact with the cuvette holder.

2. The applicator of claim 1, wherein the waveguide is selected from WR-62, WR-75, and WR-90.

3. The applicator of claim 1, wherein the optical access ports comprise conductive mesh with aperture size less than 2 mm.

4. The applicator of claim 1, wherein the thermal management element comprises a Peltier thermoelectric module capable of maintaining temperature to within ±0.1°C.

5.2 Microfluidic Claims

5. A microfluidic flow chamber for continuous protein folding modulation, comprising:

(a) a substrate of microwave-transparent material;
(b) a flow channel formed in the substrate;
(c) an irradiation zone where microwave radiation is coupled into the flow channel;
(d) inlet and outlet ports for sample flow; and
(e) detection ports for optical monitoring of the sample.

6. The flow chamber of claim 5, wherein the substrate is selected from fused quartz, borosilicate glass, and cyclic olefin polymer.

7. The flow chamber of claim 5, wherein the flow channel has a width of 100 to 500 micrometers and a depth of 50 to 200 micrometers.

8. The flow chamber of claim 5, further comprising a mixing junction upstream of the irradiation zone for initiating protein folding.

5.3 Near-Field Antenna Claims

9. A near-field antenna applicator for localized delivery of microwave radiation, comprising:

(a) an antenna element configured for operation at 10 to 20 GHz;
(b) a coaxial or waveguide feed;
(c) a positioning mechanism for placing the antenna in proximity to a sample; and
(d) wherein the antenna delivers microwave energy to a localized region having a dimension of 1 to 10 mm.

10. The antenna of claim 9, wherein the antenna element is selected from monopole, dipole, patch, slot, and aperture probe.

11. The antenna of claim 9, configured for integration with a microscope for combined microwave-optical experiments.

5.4 Resonant Cavity Claims

12. A resonant cavity applicator for high-efficiency protein folding modulation, comprising:

(a) a conductive cavity having a resonant frequency in the range of 10 to 20 GHz;

(b) a sample tube holder positioning a sample at a field maximum within the cavity;

(c) a coupling iris or probe for coupling microwave energy into the cavity; and

(d) a tuning mechanism for adjusting the resonant frequency.

13. The cavity of claim 12, wherein the cavity is cylindrical and configured for TE_{011} mode operation.

14. The cavity of claim 12, wherein the unloaded quality factor Q is greater than 5000.

15. The cavity of claim 12, wherein the resonant frequency is approximately 14.65 GHz for H_2O samples or 10.4 GHz for D_2O samples.

5.5 Shielding Claims

16. An electromagnetic shielding enclosure for protein folding modulation apparatus, comprising:

(a) a conductive enclosure providing shielding effectiveness greater than 60 dB at frequencies from 10 to 20 GHz;

(b) a door with conductive gasket for access;

(c) a door interlock that disables microwave power when the door is open;

(d) filtered feedthroughs for electrical connections; and

(e) a shielded viewport for visual observation.

17. The enclosure of claim 16, wherein the conductive enclosure is constructed of aluminum or steel with thickness of 1 to 3 mm.

18. The enclosure of claim 16, wherein the shielded viewport comprises conductive mesh or honeycomb with cell size less than 3 mm.

5.6 Calibration Phantom Claims

19. A calibration phantom for verifying performance of a protein folding modulation apparatus, comprising:

(a) a container of known dimensions;

(b) a material having known dielectric properties at frequencies from 10 to 20 GHz; and

(c) wherein the dielectric constant and loss tangent are characterized to within $\pm 5\%$.

20. The phantom of claim 19, wherein the material is selected from distilled water, saline solution, glycerol-water mixture, and tissue-mimicking gel.

21. The phantom of claim 19, further comprising a temperature sensor for correcting dielectric properties for temperature.

5.7 Dosimetry Claims

22. A dosimetry system for measuring power delivered to a sample during protein folding modulation, comprising:

(a) a directional coupler in the microwave path;

(b) forward and reflected power detectors connected to the coupler;

(c) a processor configured to compute delivered power as the difference between forward and reflected power; and

(d) a display configured to show delivered power in real time.

23. The dosimetry system of claim 22, further configured to compute and display specific absorption rate (SAR) based on sample mass.

24. The dosimetry system of claim 22, further comprising an alarm for over-power conditions.

25. The dosimetry system of claim 22, further comprising a data logger for recording power profiles.

ABSTRACT

Hardware components for delivering resonant microwave radiation at the molecular gate frequency (10–20 GHz) to biological samples for protein folding modulation. The hardware comprises: (1) waveguide-coupled cuvette applicators with WR-62/75/90 waveguides, optical access ports with conductive mesh, and Peltier thermal management; (2) microfluidic flow chambers with quartz or polymer substrates, 100–500 μm channels, and integrated mixing junctions; (3) near-field antenna applicators (monopole, dipole, patch, slot, aperture probe) for localized delivery to 1–10 mm regions; (4) resonant cavity applicators with TE_{011} mode, Q > 5000, and tunable resonance at 14.65 GHz (H_2O) or 10.4 GHz (D_2O); (5) electromagnetic shielding enclosures providing >60 dB attenuation with door interlocks, filtered feedthroughs, and shielded viewports; (6) calibration phantoms with characterized dielectric properties (water, saline, glycerol-water, tissue-mimicking gel) for system verification; and (7) dosimetry systems using directional couplers for real-time power measurement, SAR calculation, and logging. All hardware is designed for the 10–20 GHz frequency range specific to protein folding modulation, with features including optical access for fluorescence detection, precision temperature control, isotope compatibility, and modular construction. Applications include laboratory research instruments, biopharmaceutical manufacturing equipment, and potential therapeutic delivery devices.

— END OF SPECIFICATION —

INVENTOR DECLARATION

I, Jonathan Washburn, declare that:

(1) I am the original and sole inventor of the delivery hardware described and claimed in this application.

(2) I have reviewed the above specification and claims and believe them to be accurate and complete.

(3) I believe the claimed invention to be novel, useful, and non-obvious over the prior art.

(4) I authorize the filing of this provisional patent application to establish a priority date.

Inventor Signature: ______________________________

Name: Jonathan Washburn

Email: washburn.jonathan@gmail.com

Date: ______________________________

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