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Biomedical Electromagnetic Instruments, EM Condensed Materials and Imaging

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Contact-less Concentration Measurements in Aqueous Sodium-chloride Solutions Using Microwaves

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Abstract— Sodium chloride NaCl and its aqueous solutions have a wide variety of uses in foods, medicines, chemicals etc, because they are indispensable for supporting life of organisms. The NaCl concentration (c) therein is usually measured either by chemical methods such as a Mohr method and an ion chromatography, or by physical methods such as a conductivity measurement and an optical reflection method. However, contact-less measuring methods haven't been established yet.

Aqueous sodium-chloride solutions are well known to be one of the strong electrolyte solutions with both electrolytic ions Na^+ and Cl^-. These ions, together with H^+ and OH^- of water molecules, should cause a dramatic dielectric dispersion in the microwave range through complex interactions with each other by the following origins: One is a contribution from the electric conductivity (σ) of electrolytic ions in electric fields with frequency f, which is proportional to σ/f. Another is a dielectric relaxation phenomenon, mainly coming from rotational motions of water molecules and/or its macro-molecules via hydrogen bonds. Such phenomena cause a significant energy absorption in passing through microwaves therein, so that it should lead to developments of microwave contact-less testing (MCLT) system to determine the concentration c in aqueous sodium-chloride solutions.

For this purpose, we measure the complex dielectric constant $\varepsilon^* = \varepsilon' - j\varepsilon''$ as a parameter of the concentration c in aqueous sodium-chloride solutions in the microwave range using a network analyzer to obtain the basic data for MCLT. In parallel, we construct the experimental apparatus to measure the microwave transmission into the solutions, which is composed of a pair of monopole antennas, a signal generator with a power amplifier, a spectrum analyzer and a sample holder with a rotation mechanism by a stepping motor. Using this apparatus, we obtain the regression curve between the transmission loss P and the concentration c in aqueous sodium-chloride solutions crucial for developments of MCLT. We also elucidate the dominating factor of P based on an equivalent-circuit model of microwave transmission using the data of $\varepsilon^* = \varepsilon' - j\varepsilon''$.

FPCB RF Coil for Small Animal NMR Imaging at 3T MRI Systems

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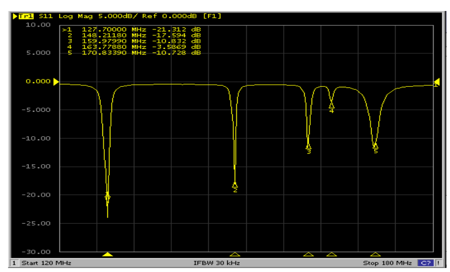
Abstract— Radio frequency (RF) coil is used to transmit an RF pulse and receive the weak nuclear magnetic resonance (NMR) signal in a magnetic resonance imaging (MRI) system. An RF coil is basically a RF resonator which has the ability to produce strong magnetic field in its coverage area. The NMR signal can be detected if the frequency of magnetic field produced by the RF coil is matched with the frequency of the NMR signal. There are available a number of different designs however the birdcage type RF coils because of their strong magnetic field development property are considered as the best candidate at medium and high field MRI systems.

In this paper we are presenting a method of implementation a birdcage coil in band pass configuration for NMR imaging in small animal as shown in Figure 1(a). The RF coil is designed for 3T MRI system and is able to resonate at 127.7 MHz resonance frequency as shown in Figure 1(b). The major difference between our implemented coil and the traditional birdcage coil is the utilization of flexible printed circuit board (FPCB) etched copper conductors as the legs and end rings of the RF coil. This introduction of FPCB improves the performance of the RF coil. The most important and desired parameter in the RF coil design is the magnetic field homogeneity inside the RF coil. It is observed that the utilization of FPCB in the RF coil improves the field homogeneity inside the RF coil. It also helps to suppress the undesired resonances which are a source of increasing SAR in the RF coil. The coil is implemented to perform the whole body NMR imaging of ^{1}H in small animal. The coil is composed of eight legs and two end rings with 4 cm internal diameter and 21.25 cm overall length. The coil dimensions were optimized with full wave 3D electromagnetic simulation software. The basic testing of the RF coil was performed with network analyzer. There is present a good agreement between the simulated and measured results. The NMR images of a small mouse were also obtained with the help of implemented RF coil.

(a)



(b)

Figure 1: (a) Implemented RF coil for ^{1}H NMR imaging at 3T. (b) Frequency response of RF coil.

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Point Spread Function for Optical Transillumination Imaging of Animal Body

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Abstract— We can obtain transillumination images of an animal body using near-infrared light with a 700–1200 nm wavelength. However, the images are blurred by the strong scattering in the body tissue. If there is a light source at a specific depth inside the scattering medium, this blurring can be characterized by the point spread function (PSF) which is obtained as a solution of the diffusion equation for a point source case. The blurred transcutaneous image of a fluorescent source inside the body can be improved by the deconvolution with this depth-dependent PSF. We also attempted to apply this PSF to the transillumination image of a light-absorbing structure in a scattering medium. In a simulation, it was confirmed that the blurred transillumination images were effectively improved by the PSF for a fluorescent source. The effectiveness of the proposed technique was examined in an experiment using a tissue-simulated phantom. The transillumination image of an absorber (black-painted square metal plate, $10 \times 10 \times 2$ mm) appeared almost a black disc due to the strong scattering effect of the surrounding scattering medium (the reduced scattering coefficient and the absorption coefficient were 1.0/mm and 0.01/mm, respectively), when the depth of the absorber was 15 mm from the observing surface. The blurred image was significantly improved by the deconvolution with the PSF for 15 mm depth. These results suggested that the depth-dependent PSF we have derived for fluorescent imaging can be used to obtain a clear transillumination image of the internal structure of an animal body using near-infrared light.

Maxwell Sumudu Based Magnetic Solutions

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Abstract— The Dynamics of a planar, transverse electromagnetic (TEMP) wave propagating in the direction z in lossy media with constant permittivity ϵ, permeability μ, and conductivity $\sigma > 0$, are best described by Maxwell's equations.

$$\begin{cases} (i)\nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \\ (ii)\nabla \times \mathbf{H} = \epsilon \frac{\partial \mathbf{E}}{\partial t} + \sigma \mathbf{E} \end{cases} \tag{1}$$

Various forms of solutions for the electromagnetic couple solutions and profiles of (1) have been found, using various techniques, subject to distinct assumptions on the medium coefficients and fields initial directions.

In view of its advantageous attributes and many quantities preserving properties, the Sumudu turns out to be an ideal tool for many science applications and engineering. Without resorting to a new frequency domain, as in the case of Laplace or Fourier, having units and scale preserving properties, the Sumudu turns out to be the ideal tool, for engineering and many applied mathematics and physics problems. The Sumudu operator is defined by,

$$G(u) = \mathbb{S}[f(t)] = \int_0^\infty f(ut)e^{-t}dt, \quad u \in (-\tau_1, \tau_2) \tag{2}$$

over the set of functions,

$$A = \{f(t)/\exists\ M, \quad \tau_1, \tau_2 > 0 \quad |f(t)| < Me^{\frac{|t|}{\tau_j}}, \quad \text{if } t \in (-1)^j \times (0, \infty)\} \tag{3}$$

The function, $G(u)$, is then referred to as *the Sumudu of* $f(t)$. The Sumudu Operator is clearly linear since,

$$\mathbb{S}[af(t) + bg(t)] = a\mathbb{S}[f(t)] + b\mathbb{S}[g(t)] \tag{4}$$

Computationally, denoting the gamma function by, Γ, wherever, $\Gamma(\alpha+1)$ can be defined (classically for $\alpha > -1$), we then have,
$\mathbb{S}[t^\alpha] = \int_0^\infty (ut)^\alpha e^{-t}dt = u^\alpha \int_0^\infty t^\alpha e^{-t}dt = \Gamma(\alpha+1)u^\alpha$. So, $\mathbb{S}[1] = 1$, $\mathbb{S}[at+b] = au+b$, and $\mathbb{S}[t^n/n!] = u^n$, for any integer $n \geq 0$. Discretely, $\mathbb{S}[\exp(at)] = \mathbb{S}[\sum_0^\infty (at)^n/n!] = \sum_0^\infty (au)^n = 1/(1-au)$, for $a \in (-1/a,\ 1/a)$.

Consequently, for any frequency, w, $1/(1+(wu)^2)$, $(wu)/(1+(wu)^2)$, are the respective *Sumudi* of $\cos(wt)$, and, $\sin(wt)$, which may be obtained,

$$\mathbb{S}[\cos(wt) + j\sin(wt)] = \mathbb{S}[e^{jwt}] = 1/(1-jwu) = (1+jwu)/(1+(wu)^2).$$

Conversly, (with $w = 1$), $1/(1+u^2) = \sum_0^\infty (-1)^n u^{2n}$, with u in $(-1, 1)$, and applying the inverse operator, yields, with t in $\mathbb{R}$, $\mathbb{S}^{-1}\sum_0^\infty (-1)^n u^{2n} = \sum_0^\infty (-1)^n t^{2n}/(2n)! = \cos t$, & $\mathbb{S}^{-1}[u/(1+u^2)] = \mathbb{S}^{-1}\sum_0^\infty (-1)^n u^{2n+1} = \sum_0^\infty (-1)^n t^{2n+1}/(2n+1)! = \sin t$.

Furthermore, for $a \geq 0$, the Heaviside or unit step function, $H_a(t)$, any function shift, $f(t-a)$, has for sumudu,

$$\mathbb{S}[f(t-a)] = \mathbb{S}[H_a(t)f(t)] = e^{\frac{-a}{u}}\mathbb{S}[f(t)], \quad \text{for } u > a \tag{5}$$

The TEMP problem, like general field couple problems, can be considered in the Sumudu Transform frame work. Upon Sumudu transformation, Maxwells Equations are made to yield transient magnetic field solutions. In previous works, Sumudu based techniques were used to deliver transient electric field solutions for electromagnetic planar waves moving in the transversal direction of lossy media. Here we present a parallel treatment for the magnetic field, using Sumudu established properties. In this abstract, we first albeit briefly, state some Sumdu Convolution, Integration and Differentiation Properties whose application will help us solve the TEMP problem. The next theorem allows us to use the Sumudu transform efficiently to solve differential equations involving multiple integrals of the dependent variable as well, by rendering them into algebraic ones.

Cryptography of the Medical Images

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Abstract— Nowadays, digital exchanges of medical images are frequently used throughout the world in a fraction of a second via the Internet. These data can be read or modified during their transmission via a non-controlled channel. Therefore, it becomes very important to protect this private information against unauthorized viewers by using cryptography.

Cryptographic techniques can be divided into symmetric encryption (with a secret key) and asymmetric encryption (with private and public keys).

In symmetric cryptosystems, the same key is used for the encryption or decryption and this key need to be secure and must be shared between the emitter and the receiver. These cryptosystems are very fast and easy to use.

In proposing specific algorithms for the transfer of medical data ensuring total privacy in parallel on the emission and receipt of data, by using 1D chaotic algorithms [5]: **BRIE** (Bit Recirculation Image Encryption), their basic ideas is the recirculation of bits (pixels) image in clear, so we resorted to study a simple logistic model: $x_{n+1} = rx_n(1 - x_n)$. This chaotic system is a deterministic nonlinear dynamic system which has an unpredictable long-term. This unpredictability is due to the sensitivity to initial conditions, the mixing property and the density of periodic points. This logistic model can generate chaotic binary sequences and pseudo-random, to manipulate of each pixels of the image, by the two properties "**confusion**" and "**diffusion**" in classical cryptography. It is a natural idea to use chaos to conceive new cryptosystems.

Indeed, the use of this new cryptosystems in the sector of the medical sciences, with evolves in the latter years in a remarkable way, generating applications related to the use of chaos in the security communication systems, for to realize the transfer of the medical data, is the object of this work.

Expandable Multi-frequency EIT System for Clinical Applications

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Abstract— An electrical impedance tomography (EIT) system can visualize conductivity and permittivity distributions inside the human body from measured boundary voltages induced byexternally injected currents. We have developed a fully parallel multi-frequency EIT system called the KHU Mark2.5. It is based on an impedance measurement module (IMM) comprising a current source, a voltmeter and a calibration circuit. Each IMM is independent and can calibrate its own current source and voltmeter through an automatic self-calibration procedure. We found thatthe output impedance values of all current sources are greater than 1M at the chosen frequencies. The CMRR is around 96 dB and the voltmeter SNR isbetween 80 and 85 dB depending. To increase spatial resolution of conductivity and permittivity images, we can cascade multiple EIT systems to form a system with a larger number of channels.They are synchronizedby clock synchronizationcircuits. Physiological events such as cardiac and respiratory functions alter electrical tissue properties. To correlate such events with EIT images, we can perform a biosignal-gated EIT imaging. We can improve interpretation of EIT images by incorporatingreal-time ECG and respiration signals into EIT images. This may allow us to separate fast cardiac events and slow respiratory events from reconstructed EIT images and also improve the SNR by signal-gated data averaging We present the performance of the KHU Mark2.5 system with experimental results of animal and human subjects.

Conductivity Imaging of Animal and Human Body Using 3T Magnetic Resonance Electrical Impedance Tomography (MREIT)

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Abstract— Magnetic resonance electrical impedance tomography (MREIT) aims to produce cross-sectional images of conductivity distributions inside animal and human subjects. In this study, we validate its feasibility by performing conductivity imaging experiments of animal and human bodies. We attached four carbon-hydrogel electrodes on the imaging area and placed the imaging object inside our 3T MRI scanner. We injected imaging currents in a form of short pulses into a chosen imaging area, of which timing was synchronized with an MRI pulse sequence. Obtaining images of induced magnetic flux density distributions inside the imaging object, we reconstructed conductivity images using the single-step harmonic B_z algorithm based on the relation between the conductivity and the induced magnetic flux density. Reconstructed conductivity images of the canine heart, kidney, prostate, and other organs exhibit unique contrast information which is hardly observed in other imaging modalities. The conductivity images of the human lower extremity well distinguished different parts of the subcutaneous adipose tissue, muscle, crural fascia, intermuscular septum and bone. We could observe spurious noise spikes in the outer layer of the cortical bone primarily due to the MR signal void phenomenon there. Providing cross-sectional conductivity images with a spatial resolution of a few millimeters, MREIT may deliver unique new diagnostic information in its future clinical studies.

Microwave-heating for Liver Cancer Thermothrapy with Three Layer Tapered Coaxial Line Applicator

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Abstract— The conventional applicators are slot type antennas which are made from commercially available semi rigid cables, therefore the impedance mismatching has occurred between the applicator and the liver tissue [1]. This mismatching causes unwanted heating of normal tissue and relatively large power (over 72 W) is required to get the proper operation temperature. The novel applicator structure is developed by inserting the impedance matching sections between the radiation port and the feeding coaxial line to ensure the better impedance matching with liver tissue. Reflection S_{11} can be reduced from −9.8 dB to −18.6 dB at 2.45 GHz by inserting intermediate material which has a proper selection of geometry and permittivity for impedance matching section [2]. In this study, we perform the finite element method (FEM) simulation to get the relationships between the power and temperature and obtain the detailed SAR (specific absorption rate) at 2.45 GHz. This optimized applicator can reach required temperature with smaller power 10 W with constantly feeding, and we can use the low power microwave source instrument which will provide safer environment for patient and operating staffs.

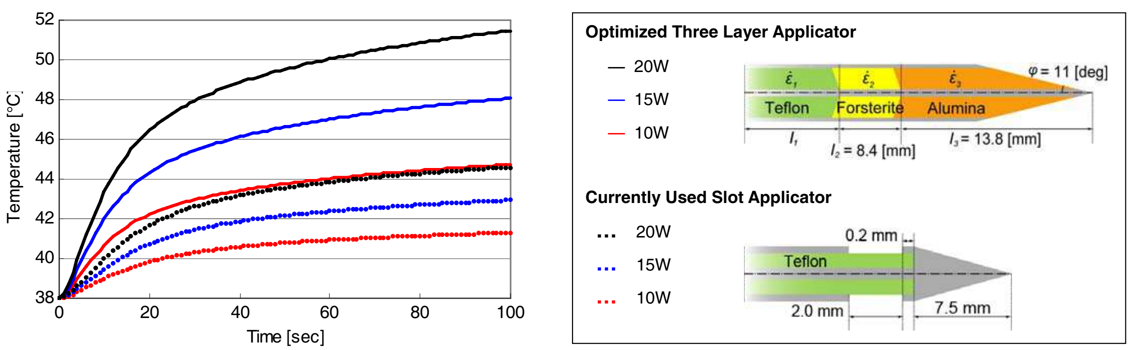

Figure 1: Time domain temperature of optimized three layer applicator and currently used slot applicator.

REFERENCES

1. Tumeh, A. M. and M. F. Iskander, "Performance comparison of available interstitial antennas for microwave hyperthermia," *IEEE Trans. on MTT*, Vol. 37, No. 7, Jul. 1989.
2. Urata, M., S. Kimura, K. Wakino, and T. Kitazawa, "Optimization of three layer tapered coaxial line applicator for cancer thermotherapy by impedance matching of transition layer sections," *The 2011 IEEE ISAP and USNC/URSI National Radio Science Meeting*, Jul. 2011.