AN OVEREVIEW OF BREAST CANCER DIAGNOSTIC TECHNIQUES

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Abstract

Breast cancer threatens many women, and early detection is a primary part of controlling and managing this disease. Mammography is widely used for the detection of breast cancer, but as this modality exposes women to ionizing radiation which can be a dangerous effect on their health, there are some doubts whether or not women under the age of 50 should be exposed to x-ray Mammography or not as a demand to detect breast cancer at early stages. Early detection of breast cancer plays a key role in rescuing lives which results in better quality of life. Many modalities used for detection of breast cancer still suffer some deficiencies such as the failure of mammography to detect 20%of the tumors, its uncomfortability to many of the patients in addition to considering it as a threatening source for the patients due to the increase of the possibility of cancer with the exposure repetition to the x-rays of the mammograms. Other modalities such as magnetic resonance imaging (MRI) and ultrasound are too expensive relatively. In this study a new technique using confocal microwave imaging (CMI) is studied. Breast tissue samples will be collected from department of surgery in UMMC. These samples will be subjected to study. Dielectric contrast between these samples will be determined based on their water content by utilizing the translucent characteristic of the breast. The tissue is to be determined whether it is cancerous or not using simple signal shifting, and summing and complex image composing algorithms is to be avoided. The permittivity values of normal and cancerous breast tissues also to be measured and compared. The digitized image of a cancerous breast tissue formed by hemispherical breast model using simple signal shifting is also to be studied.

Abstrak

Kanser payudara mengancam ramai wanita. Pengesanan awal adalah penting untuk mengawal dan menguruskan penyakit ini. Pelbagai teknik dan kaedah telah diselidik dalam pengenalpastian kanser payudara. Mamografi adalah cara yang paling meluas digunakan untuk mengesan kanser payudara, tetapi kaedah ini mendedahkan wanita kepada sinaran ion yang boleh meninggalkan kesan berbahaya pada kesihatan mereka. Persoalan wujud sama ada wanita di bawah umur 50 tahun perlu didedahkan kepada sinar-xmammografi atau tidak dalam usaha mengesan kanser payudara pada peringkat awal. Pengesanan awal kanser payudara memainkan peranan penting dalam menyelamatkan nyawa dan juga manjamin kualiti hidup yang lebih baik. Kekurangan masih wujud dalam kaedah yang digunakan kini untuk mengesan kanser payudaram. Contohnya kegagalan mamografi untuk mengesan 20% daripada tumor. Pesakit juga berasa tidak selesa kerana berasa pendedahan kepada sinar-X akan meningkatkan lagi kebarangkalian mereka untuk mendapat kanser. Kaedah seperti pengimejan resonans magnetik (MRI) dan *ultrasound* pula adalah terlalu mahal berbanding kaedah lain. Dalam kajian ini, pelbagai jenis kaedah telah dikaji semula dalam usaha untuk menyediakan panduan yang mudah dan cepat untuk pesakit. Kajian ini memberi tumpuan dalam pembangunan gelombang mikro confocal pengimejan termasuk antena yang digunakan, algoritma FDTD dan kaedah pembinaan semula imej. Kaedah-kaedah dan keputusan oleh penyelidik sebelum ini yang dikaji semula telah dibincangkan dan diringkaskan dalam jadual, di samping bahan yang digunakan dan kaedah yang digunakan untuk fabrikasi. Bahan-bahan berkandungan air tinggi digunakan sebagai tisu kanser manakala bahan berkandungan air yang rendah digunakan untuk meniru tisu payudara yang normal. Kesimpulan didapati bahawa

confocal gelombang mikro pengimejan adalah kaedah yang mantap dan novel, ia boleh juga mengesan ketumbuhan sekecil 2 cm dalam bentuk 3D. Keberkesanan kaedah ini telah menjadikannya kaedah yang paling biasa dan paling banyak digunakan. Oleh itu, ianya mendapat perhatian penyelidik-penyelidik dalam dua dekad yang terdekat ini.

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Abbreviations

BRCA: Breast Cancer

CBE: Clinical Breast Exam

CMI: Confocal Microwave Imaging

CT: Chromotography

DCIS: Ductal Carcinoma In Situ

DNA: Deoxyribonucleic acid

ECB: Error Correction

ER: Estrogen Receptor

FDTD: Finite-difference time-domain

FNAC: Fine Needle Aspiration and Cytology

HER: Human Epidermal growth factor Receptor 2

IDC: Invasive Ductal Carcinoma

IHC: Immunohistochemistry

LWCT: Low Water Content Tissue

MBC: Metastatic Breast Cancer

MRI: Magnetic Resonance Imaging

PR: Progestrone Receptor

S/C: Signal to Clutter Ratio

SAR: Synthetic-Aperture Radar

UWB: Ultrawide Band

HWCT: High Water Content Tissue

SWR: Standing Wave Ratio

APES: Amplitude and Phase Estimation

MAMI: Multistatic Adaptive Microwave Imaging

CHAPTER 1

BACKGROUND

1.1. Introduction

As breast cancer shows a continuous increment in its incident rates causing early mortality in women, studies were conducted to provide an early detection method of breast cancer as an urgent demand to provide suitable treatment plans to decrease the risk of this disease and to rescue lives.

Among the emerging breast cancer detection methods, microwave imaging is one of the most effective and attractive technology, due to it is nonionized beam nature, comfortable for patients and it is sensitivity to malignancies Threatening and uncomfortably to many patients, 20% failure of breast tumor detection and the idea of repeated X-Ray Mammography exam can increase the risk of cancer while MRI in addition to the fact that ultrasound is less effective these reasons are considered as the main factors which lead to searching for an alternative technique to mammography.

Universally, there are agues about screening breast using mammography for people under 40 years old; this method is highly recommended for older women by national organizations. For 50 to 74 years old women with no family history of breast disease and risk, screening mammography is being recommended to be performed every 2 years (Smith-Bindman R, 2005). For older women who are expected to have longer life period there are several available tools to perform the breast tumor and disease screening. MRI also is an alternative technique to perform similar studies. For women at high risk of having breast disease, it's recommended to have more frequent,

aggressive and earlier screening, particularly those with family history of breast cancer, ovarian, once treated from breast disease and confirmed with BRCA-mutation. When an abnormality is found by any screening technique then further removing surgery of the target lump will be done to investigate further exams under microscope, this process called biopsy. During biopsy procedure ultrasound may be used to control biopsy needle. While MRI is not a recommended screening technique for healthy women, it commonly used to guide and control treatment.

Procedure of using low energy (around 30kVp) X-ray to screen breast tissue is called Mammography. It is the most common screening technique and diagnosis tool. The main aim of mammography is to detect breast cancer at early stages by detecting microcalcifications or masses. In spite of argument of using this technique, studies indicate 20% reduction of mortality among women with breast cancer because of existence of this technique (Gøtzsche PC, 2006). X-Ray Mammography, just like other x-ray techniques and methods, for creation of images it needs to use some amount of ionizing-radiation. By analyzing these images, radiologist can find any abnormality in chest and breast. Radiography of bones typically uses higher energy x-ray rather than those used for X-Ray Mammography. At this time preferred technique of breast cancer early detection is Physical breast examination and X-Ray Mammography. In adjunct to X-Ray Mammography, techniques such as positron emission mammography or PEM, ultrasound, magnetic resonance and ultrasound are used as alternative and complimentary techniques. Usually after detection of a mass by X-Ray Mammography if a palpable mass could not be recognized by then ultrasound exam will be performed for further evaluations. In the case of non-diagnostic mammography of discharge bloody nipple, Dutograms will be used for further evaluation. For pre-surgical and also

questionable finding MRI can be useful to detect if there are any additional lesions that can cause changing the surgery procedures, mastectomy to lumpectomy of breast conserving is an example of this situation. In case of dense tissues, 10% false-negative rate of mammography is a common problem. The reason of false negative result of mammogram is due to overlapping of appearance of normal tissue on appearance of cancer tumors.

Microwave screening technique overcomes the disadvantages of X-Ray Mammography, although X-Ray Mammography still known to be the common technique of breast cancer detection at early stages but still is not known to be the best solution for women under 50 years old Hence many doctors recommend it for older women. Threatening and uncomfortability to many patients, 20% failure of breast tumor detection and the idea of repeated X-Ray Mammography can increase the risk of cancer while MRI and ultrasound are too costly and less effective are among those reasons of searching for an alternative to common used method of X-Ray Mammography .

Breast cancer threatens many women; hence early detection is a primary part of controlling and managing this common disease. Mammography is widely used for the early detection of breast cancer, but this modality exposes women to ionizing radiation which can be a dangerous effect on their health, there are some doubts whether or not women under the age of 50 should be exposed to X-Ray Mammography or not as a demand to detect breast cancer at early stages. Early detection of breast cancer plays a key role in rescuing lives which results in better quality of life. Currently used modalities for detection of breast cancer still suffer some deficiencies such as the failure of mammography to detect 20%of the tumors, its unconfortability to many of

the patients in addition to considering it as a threatening source for the patients due to the increase of the possibility of cancer with the exposure repetition to the x-rays of the mammograms. Other modalities (except ultrasound) are too expensive relatively.

The potential of microwaves in the detection of tumors is based on the quite significant difference of actual dielectric properties between normal biological tissues and cancerous tissues. The use of microwave technology in the field of clinical breast cancer detection is based on two main dielectric properties of breast tissues. First, the significant difference in relative permittivity (ϵ_r) and conductivity (σ) between healthy and cancerous tissues which causes the cancerous tissues to have backscattering with large angles compared to healthy tissues of the same size. Second, the attenuation of healthy breast tissue is significantly low (less than 4dB/cm up to 10 GHz) which allows accumulation of the backscattered microwave signals using confocal imaging systems (Popovie, Hangess, & Taflove, 1998). Confocal microwave technique can detect breast tumors at any size and location. In confocal microwave technique ultrawideband pulse is emitted from single or multiple antennas, then by using the contrast in dielectric properties between malignant and normal tissue of breast, artificially focusing backscatter pulses can detect breast tumors at any size (Elise C. Fear, Xu Li, Susan C Hagness, & Maria A. Stuchly, 2002). Malignant tumors are considered as objects with strong scattering characteristics; thus confocal microwave detects malignant tumors using coherent addition of backscattered energy from these tumors.

CHAPTER TWO

METHODOLOGY

2.1. Introduction

Well known research tools were exploited in this study to discuss about widely used methods for detection of breast cancer to be compared the best available breast cancer detection technique which is presented in imaging confocal microwave technique. Quality of articles and managing bibliography to save the time were the priorities and the most important issues of writing this review study. Using web of science and selecting appropriate keywords is the second important issue led this study to employee qualified information and data. Moreover using Google Wonder wheel and Quintura website helped for not missing any sub-studies and information around the main objective. Method of Categorizing impact factor and SJR of each journal, which have been used in this study, and employed for ensuring availability and importance of information and also as a reference to be used for future studies.

2.2. Searching and selection of best related keywords

Aim of using appropriate keywords is for time saving and easy searching of required article and information related to main studies and detail information related to this review study. Selecting best key-words for searching search engine optimization and Web of science provided huge number of related studied and article. Breast cancer, breast cancer detection techniques, Breast phantoms and breast cancer detection using confocal microwave techniques are the main keywords used for searching articles and

information related to the study. Using keyword research tools such as Quintura (Figure 2.1) helped to find subtitles of main keyword.

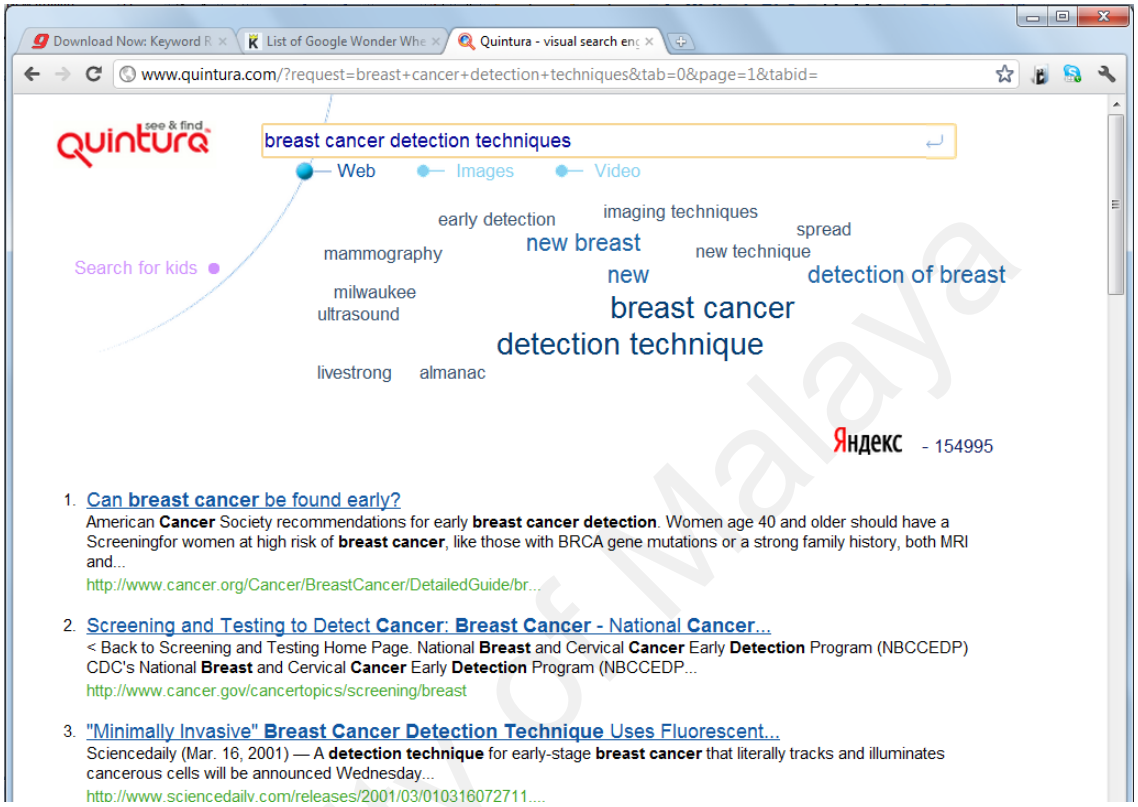


Figure 2.1 Quintura online keywords research tool

2.3. SCImago Journal Rank (SJR)

Scientific influence of a scholarly journal can be measured, using SCImago Journal Rank (SJR indicator), this parameter account for both importance of prestige of a journal (where the citation came from) and number of citations received by the journal. SJR indicator is size independent, and SJR value indicates of a journal's average prestige per article can is being using for journal comparisons in process of science evaluation.

Open access journal metric indicator of SJR use and algorithm similar to Page-Rank and can be use an alternative to the Impact-Factor (IF). Impact factor is based on from

the science citation index, while average citation per document in each 2 year measured by the scientific impact of an average article published in the journal. SJR employs an application process to estimate value through successive cycles. First calculates raw impact average citations of each document; however fist process is similar to impact factor measurement but after first cycle difference of values will be clear.

In the first cycle, an identical and arbitrary value is appointed for all the sources in the data bases. This value will be nay number above zero. SCImago sets at 0.1 mean that every source inside Scope starts with an SJR 0.1 and all sources outside Scopus have value of 0. Hence 0.1 indicates of minimum value that every journal achieves just by being included in the database. In the first cycle of the iterative process, all citations are worth the same because all the journals have the same prestige. Second step, is the process of prestige finding.

It employs the average citations per document value measured in the first step as the prestige of the journal for the second step. Citation start to have different weights according to the journals of the origin and this cause change the value of the citation they are making. Values measured at the end of this step will be different from those measured at the end of first step and will be similar to SJR. Cycling process will be continues until reaching a steady states, means the iterative process runs until the differences between the prestige values of journals in two consecutive iterations are no longer significant.

2.4. Quality analysis of data

To select the best available article from Web of Science (one of the best, most expensive and comprehensive online library in the world that is available for all students of University Malaya) information, number of citation and h-index has been categorized. Moreover, the most recent articles, books and other available data have been considered in advance.

Any data collected from journal are those published in ISI journals to insure the validity and acceptance of collected data Moreover, process of filtering lees qualifies information, which obtained from journal having less quality and low impact factor, have been done to use the data from best available journals, books and conferences

2.5. Data Comparison

Comprehensive study about any issue around breast cancer and also all well-known breast cancer detection methods has been done. Hence; it is possible to compare different methods to find out the most appropriate one which already is being used, and also the method that has enough advantage to be developed and be used in future.

Breast cancer detection using confocal microwave, is known to be the best recent promising technique to be used in clinics for detection of breast cancer at early stages and also be recommendable for frequent clinical checkup. Hence a comprehensive study about different accept of confocal Microwave technique have been studied.

After comparing most used available techniques of breast cancer detection, the best of them will be compared with confocal microwave technique, to ensure if confocal microwave can be a replacement of the best available frequent technique or no.

2.6. Referencing

In this review study more than hundred references have been used thus, endnote software version X5 have been employed to manage all the references information.

CHAPTER THREE

BREAST CANCER

3.1. Introduction

The body is made up of huge number of living cells. Normal cells pass through a life cycle of growth, division, and death. During the early years of a human's life, normal cells exhibit fast division in order to allow the growth of the human. When the person is an adult, warning-out or dying cells or repairing injuries become the excitation factors for the division of the cells in order to be replaced.

When cells in any part of the human body start to grow extremely out of control this is called cancer. Each type of cancer depends on the place of origin of the abnormally growing cells. The difference between the life cycle of the cancerous cell and the normal cell is that cancer cell does not dye after division, instead it continue growing and invades other regions of the body. The main features of the cancerous cell are continuous growing and invasion of the adjacent tissues.

The reason behind transforming the normal cell into cancerous cell is a damage caused to the DNA of the normal cells. Every cell in the body contains DNA. DNA forms the center where all the actions of the cell are managed. In the normal cell any damage occurs in the DNA, the cells either die or repair. In the cancerous cells the damage in the DNA cannot be repaired and the cell does not die though, the cell continues growing and dividing producing new cells have the same DNA damage in the origin cell which produced them.

Cancer cells metastasis into different organs of human body through bloodstream and lymph nodes. When these cells spread to other regions and organs it starts to grow abnormally forming new tumors. Different types of cancer vary in their path, prognosis, growth rate and different response for the treatments. So that people with different types of cancer receive different types of treatment suitable for their situation.

Malignant breast-neoplasm or Breast cancer is a kind of cancer which grows from milk ducts (inner lining) breast tissue, most commonly from the inner lining or milk supplier of ducts (lobules), which are parts of breast tissue itself (Sariego, 2010). Ductal carcinomas refer to cancers which originate from milk ducts and lobular carcinomas (cancers which originate from lobules). Any mammals include human either female or male may have breast cancer disease. However; women are the majority to have breast cancer.

Breast cancer is a malignant tumor starting to spread from breast tissue. Differences between early stages, which are curable and metastatic breast cancer (MBC), which is usually incurable, will be discussed.

Breast cancer cells often spread by contiguity, lymph channels, and through the blood resulting in metastatic disease. The most common metastatic locations are lymph nodes, skin, bone, liver, lungs, and brain.

3.2. Signs of Breast Cancer

Abnormal feeling from breast tissue known as feeling lump is typically the first common breast cancer symptom. A painless lump that is typically solitary, unilateral, solid, hard, irregular, and nonmobile are the initial sign in the majority of women with

breast cancer. At advanced stage of the disease signs are presented as prominent skin edema, redness, warmth, and indurations.

Signs of metastatic breast cancer depend on the location of metastases; it may include bone pain, breathing difficulty, mental status changes, and abdominal pain and enlargement. Many women detect their abnormalities by self-test but mostly these early tumors can be detected by routine test of mammography screening. It is very important to know that pain or mastodynia is an unreliable sign of absence or presence of breast tumor, as it indicates any other breast disease and health issue rather than breast cancer (Society, 2007).

3.3. Benign Tumors vs. Malignant Breast Cancer

New growth of tissue which forms an abnormal mass with no defined function is called as tumor. Cancer is a disease results from growth of malignant tumor. Tumors are divided into two classes according to their growth: benign and cancer. ***Malignant tumor*** multiplies out of control, which threatens health and as a result requires treatment. ***Benign tumors*** stop growing and do not spread from their site of origin but can press surrounding cells like what can happen in brain tumors and warts.

3.4. Development of Breast Cancer

Interaction between defective gene and environment is the main reason of causing breast cancer just like any other cancer occurs. Normal cells deviation stop after enough number of cells have been produced also they stay in a certain location of tissue by attaching to other cells of the same place. Cancerous cells are produced when

mutations cause non-stopping division of cells, those cells do not attach to another ones thus cannot stay on their target location of tissue. Usually DNA of a divided cell copied with or contains a lot of mistakes and these mistakes will be fixed by Error Correction Proteins (ECP).

Some mutations which can cause cancer occur during ECP Procedure. The most common kinds of these mutations are BRCA1, BRCA2 and p53 which are acquired or inherited after birth. other types, that cause uncontrolled and unexpected division and cells stop attaching to the other cells and travelling to unexpected far tissues (Dunning AM, 1999).

Experimentally mutations related to exposure for estrogen, lead to occurrence of breast cancer. When immune surveillance fails, immune system removes malignant cells during the whole life of the human (Cavalieri E, 2006). Malignant cell growth is facilitated by signaling of abnormal growth-factors during interaction of epithelial-cells and stormal-cells (Haslam SZ, 2003; Wiseman BS, 2002). In tissue with breast adipose, excessive leptin can cause enhanced proliferation of cell and cancer (Jarde T, 2011).

3.5. Classification of Breast Tumors

Several systems need to be used to grade and classify breast cancer. Classification of breast tumors helps to choose the most efficient treatment method and the highest expected result of treatment. Histopathology, Grade, Stage, receptor status and DNA assays known as factors which optimally can describe a breast tumor or breast cancer.

3.5.1. Histopathology Classification of Breast Cancer

Histopathology is a method that is primarily used to classify breast tumors. Epithelium lining the lobules or/and ducts are roots of most breast tumors and these cancerous tumors called lobular or ductal carcinoma. Precancerous cells are low-grade cancers that cause Carcinoma in situ to grow among a specific tissue subdivision just same as mammary duct without spreading around tissue. In opposite, invasive-carcinomas do not enclose themselves to the tissue subdivision (Hagness, Taflove, & Bridges, 1998).

3.5.2. Grade Classification of Breast Cancer

Appearance of normal and breast cancer cells can be compared by using of grade classification method, knowledge of normal breast cells forms and shapes in an organ helps to differentiate them with cancerous cells, while forms and shape of normal cells indicate of their performance and function in the organ. Cancerous cells nuclei are not as uniform as normal cells and microscopy shows the uncontrollable division behavior of cancer cells. Cancerous cells under light microscopy can be classified in three types of grade; low-grade which described as well-differentiated in pathology science, intermediate-grade which pathologically described as moderately of medium differentiated and high grade which indicates that the features lose of cells are in advance level and cancer differentiation is weak thus prognosis is the worst type.

3.5.3. Stages of Breast Cancer

Staging of breast cancer is based on the size of primary tumors (T1-4), lymph node involvement (N1-3) and distant metastases (M0-1). These stages in early breast cancer include Stage 0, Stage I, and Stage II. Stage 0 represents carcinoma in situ or disease

that has not invaded the basement membrane. Stage I represents small primary tumor with no involvement of any lymph node. In Stage II regional lymph nodes are involved. In locally advanced breast cancer stage III represents a large tumor with considerably extensive nodal direct involvement in where node or tumor appeared on the human chest wall; also includes inflammatory breast cancer, which has fast growth rate. In advanced or metastatic breast cancer, stage IV metastases through all the body. Breast cancer is the most spread type of cancer and also the second cancer which leads to mortality among women western countries (Jemal, Siegel, & Ward, 2006). Early breast cancer indicates of the cancer which is in stages 0, 1 and 2 (Greene et al., 2002). With stage 0, which is also known as ductal carcinoma in situ, the cancer is non-invasive and still didn't reach to the surrounding area tissues. Figure 3.1 shows ductal carcinoma in situ (Kalogerakos, Sofoudis, & Baltayiannis, 2008).

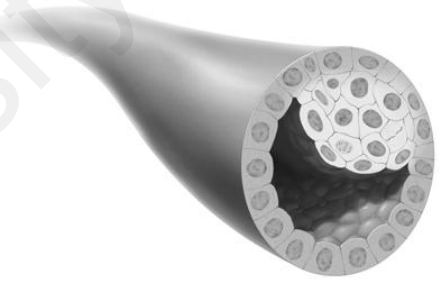


Figure 3.1 Ductal carcinoma in situ . Adapted from: http://appliedresearch.cancer.gov/dcis/workshop/DCIS_Schnitt.pdf

In stage I, the size of the tumor is not more than two centimeters and also has not spread to other parts rather than the breast. Cancer cells invaded outside the duct and invaded neighbor tissue inside the breast (Kalogerakos et al., 2008). Figure 3.2 and Figure 3.3 shows cells during stage I of breast cancer.

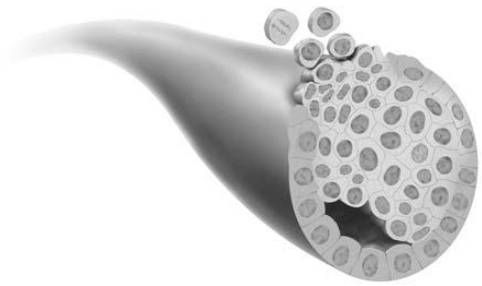


Figure 3.2 Breast cells during stage I of breast cancer. Adapted from: http://appliedresearch.cancer.gov/dcis/workshop/DCIS_Schnitt.pdf

Figure 3.3 Stage I of breast cancer, Adapted from: http://www.cancers.biz/breastcancer-stage.html

In stage II, the cancer may have one of several phases. In the first phase the tumor is not detected in the breast, but the tumor exists in the lymph nodes which are axillary. In the second phase, the tumor is not larger than two centimeters in size but it has reached to the axillary lymph nodes. Phase three of the second stage cancer represents a tumor with size between two to five centimeters and also has reached to the lymph nodes which are axillary. Phase four of the second stage refers to tumor larger than five centimeters and has not reached to the axillary lymph nodes. In phase five, not more than three lymph nodes are involved with cancer (Kalogerakos et al., 2008). Stage II of breast cancer is illustrated in Figure 3.4.

Figure 3.4 Stage II of breast cancer, Adapted from:
http://www.cancers.biz/breastcancer-stage.html

Stage III is locally known as advanced cancer. This stage is classified into Stage IIIA, B, and C. Stage IIIA is has different cases, as an instance diameter of the tumor size not more than five centimeters. The cancer has spread to underarm lymph nodes which are connected to other structures or/and each other, and also it may spread to lymph nodes close to the breastbone. Second the size of the tumor is greater than 5 centimeters in diameter. Third, the cancerous tumors have invaded underarm lymph nodes that are either attached to tissues or each other or alone. Figure 3.5 illustrates stage IIIA of breast cancer.

Figure 3.5 Stage IIIA of breast cancer, Adapted from:
http://www.cancers.biz/breastcancer-stage.html

Stage IIIB is the type of the tumor which can be of any different size that has invaded into the breast surface or wall of the chest. It also may be accompanied with breast swelling or with lumps exist in the skin of the breast. In this stage the cancer can represent in different cases: first, the cancer may have reached to lymph nodes in the armpit. Second, the cancers which are invaded the lymph nodes in the underarm that are connected to her structures or each other. Third, the cancer may have reached to the lymph nodes behind the breast bone. A type of breast cancer called Inflammatory also represents one case of stage IIIB in which the surface of breast appears red and swollen, resulted from cancer cells close the lymph vessels in the skin of the breast. Figure 3.6 shows stage IIIB of breast cancer.

Figure 3.6 Stage IIIB of breast cancer, Adapted from: http://www.cancers.biz/breastcancer-stage.html

The type tumor known as stage IIIC indicate of any size and also it can be spread either behind the breastbone to the lymph nodes and under the arm or to the lymph nodes below or above the collarbone. Stage IIIC is illustrated in Figure 3.7.

Figure 3.7 Stage IIIC of breast cancer, Adapted from: http://www.cancers.biz/breast-cancer-stage.html

In stage IV the cancer has invaded to the other organs of the body such as bone and liver. Figure 3.8 shows stage IV of the breast cancer.

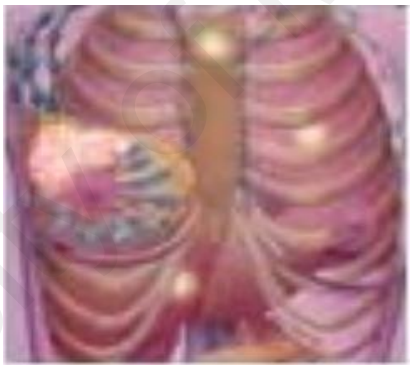


Figure 3.8 Stage IV of breast cancer Adapted from: http://www.cancers.biz/breast-cancer-stage.html

TNM system used for staging classification of breast cancer and tumor, staging of breast tumors and cancer strongly based on tumors' size (T), whether and/how the tumors have been speared among the armpits along lymph nodes (N) and whether cancerous tumors have been metastasized (M). Small metastasized, nodal speared and small size indicate can has better prognosis and indicate of low stage. Table 3.1 shows the description of the main stages of breast cancer according to the TNM system.

Table 3.1 Description of the main stages of breast cancer according to the TNM system

Main Stages	Description
Stage 0	Known as a marker or precancerous sign, either) or lobular-carcinoma in situ (LCIS) and ductal carcinoma in-situ (DCIS).
Stage 1-3	Among local lymph-nodes or within tissue of breast
Stage 4	Worst prognosis as cancer is metastatic

3.5.4. Receptor Status

Breast cancer also can be classified by receptor status, receptors of breast cancer are located in their nucleus, cytoplasm and also on surface of cells. Cells change the receptors which attach to hormones and other chemical messengers. There are three well known receptors, Progesterone-receptor (PR), Her2/neu and estrogen-receptor (ER). These receptors may be missed in the cancerous cells (Perou, 2011). Growth of ER+ cancerous cells strongly relies on estrogen; drugs such as tamoxifen that can block effects of estrogen can be used to treat these cells. Worse prognosis considered for HER2+, however prognosis significantly can be improved by combination of trastuzumab (monoclonal antibody) and/or some other drugs with chemotherapy (Filho, Ignatiadis, & Sotiriou, 2011). Triple negative is an expression use for a cell with none of the three previously mentioned receptors.

3.5.5. DNA Classification

DNA classification using DNA testing called DNA assay such as DNA microarrays compares breast cancer and normal cells (Lazebnik, McCartney, et al., 2007). Cancer can be classified in many ways by special changes in a part of breast tumor. Indication

of the right classification leads to choose the most efficient DNA treatment method (J. S Ross, et al., 2008). Table 3.2 shows the classification according to different factors.

Table 3.2 Breast cancer tumors Classification according to different factors

Factor	Technique	Type of cancer	Type	Description
Histopathology	physical and Microscopy examination (Light Microscopy)	Mammary Ductal Carcinoma	Ductal Carcinoma in Situ(DCIS)	Non-invasive malignant-neoplasm's that are attached to the milk-ducts(Virnig, Tuttle, Shamliyan, & Kane, 2010)
			Invasive Ductal Carcinoma(IDC)	Normal tissue surrounded (replace and invade) by cancerous cells which are. Infiltrating of abnormal proliferation of neoplastic and malignant cells in breast (Tan JC, 2007).
			Invasive Lobular Carcinoma	In case of E Cadherin losses, 85%, 5 year survival rate is considered for the patients with Invasive Lobular Carcinoma
Grade	microscopic comparison of normal breast cells and breast cancer cells by means of three parameters: Nuclear pleomorphism, Tubule formation and Mitotic-count(Genestie et al., 1998)	Tumor	3-5 Grad 1 Tumor	Low differentiation Grade (Best Prognosis). Tumor can be treated much less aggressive than the others and thus likelihood of survival is high (Genestie et al., 1998).
			6-7 Grad 2 Tumor	Intermediate differentiation grade (Average Prognosis)
			8-9 Grad 3 Tumor	High differentiation grade (The Worst Orognosis). Treatment aggression is high and likelihood of survival is low.
Stage	CT, X-Ray Mammography and any other available information	Any (indication of cancer size and spreading condition)	Stage 0	Carcinoma in Situ
			Stage I	Cancers are speared to only on part of the body
			Stage II	Locally advanced cancers, also depend on type of cancer such as Hodgkin's Disease when one part of diaphragm is affected by lymph node.
			Stage III	Tumor sizes and the type of cancer are more advance than stage II
			Stage IV	Cancers are speared through body or other organs.
DNA Assays	DNA Testing and DNA Microarrays (Sparano JA, 2010)	Any , Specially for patients with family history	Level I evidence	Level I couldn't verify any test(Mandrekar SJ, 2010)
			Level II evidence	Use to support Oncotype DX and can be used for Estrogen-Receptor of Positive Tumors(J. S Ross et al., 2008)
			Level III evidence	Use to support MammaPrint and can be used for Estrogen-Receptor of both Negative and Positive tumors (Albain, Paik, & Veer, 2009)
Receptor Status	immunohisto-chemistry (IHC)(J. S. Ross, 2009)	Any, Specially After screening image of breast cancer.	Basal-like	ER-, HER2- and PR-, triple negative breast cancer (TNBC).
			ERBB2/HER2+	Include amplified HER2/neu(Perou, 2011)
			Luminal A	Low Grade ER+
			Luminal B	High Grade ER+
			Claudin-low	Triple Negative, low cell-cell junction proteins, infiltration with lymphocytes including E-cadherin(Harrell et al., 2011; Herschkowitz et al., 2011; Prat & Perou, 2011)
			Normal breast-like	-

3.6. Cancer Classification According to Symptoms

Cancer classified according to different criteria. Different symptoms appear or is been detected, indicates of different type of breast cancer and disease and also symptoms indicate of the origin of the disease, hence it let to classify breast cancer in four different subclass such as inflammatory Breast cancer, Paget's beast disease, Fibroadenoma breast tumors and Metastatic Breast disease.

3.6.1. Inflammatory Breast Cancer

A type of breast cancer tumors known as Inflammatory is the type which a particular kind of breast tumor can represent a significant detection dispute. Symptoms and signs of inflammatory breast cancer can include nipple inversion, redness and warmth throughout the breast, pain, skin orange peel texture and swelling. Late detection of breast cancer due to absence of discernible lump is a problem and also very dangerous.

3.6.2. Paget's Breast Disease

A different complex symptoms of breast cancer called is represents as eczamatoid change of skin such as milk flaking and redness of skin of the nipple. When Paget's getting advanced, symptoms may consider itching, Prickling, pain, sensitivity increase, burning and also nipple discharging. Among diagnosed women with Paget's, approximately 50% have a lump on their breast too.

3.6.3. Fibroadenoma or Phyllodes Breast Tumor

In some cases, what primary symptoms indicates as hard-movable lump called fibroadenoma can also be a phyllodes tumor, this tumors are made up among the

connective tissue called storma of the breast, and comprise stormal tissue and glandular. Phyllodes tumors are classified rather than staged. Classification of this tumors is according to their shape under microscope as malignant, borderline or benign (Lacroix, 2006).

3.6.4. Metastatic diseases

One in a while, breast cancer exhibits as metastatic disease. Metastatic diseases are those types of cancers that have been spread beyond original tissue and organ. Symptoms of Metastatic breast cancer are strongly depends on the metastasis location. Liver, brain and lung are common metastasis sites. There are also nonspecific symptoms which may be due to breast cancer; however these symptoms are common in other diseases as well. Thus; these symptoms cannot be used as manifestations of breast cancer. Bone or joint pains, unexpected weight loss, chills or fevers and neurological symptoms or jaundice are kind of nonspecific symptoms which are considered as common signs of many different diseases (Lacroix, 2006).

Lumps and lot of other breast disease symptoms of breast disorders do not terminate to express underlying breast tumor or cancer. Usually Symptoms of breast disorders are caused by fibroadenoma and mastitis disease or benign breast disease. Due to possibility of breast cancer at any age, doctors should pay attention to these new symptoms and new studies should be conducted to investigate these symptoms.

3.7. Cancer Classification According to Tissue of Origin

Cancer is classified into three types according to the tissue or cell from which they developed. First, carcinoma which presents the cancer in the immune system of the epithelial tissue and it forms 90% of the common cancers. Second, sarcomas present

solid tumors and occur in the connective tissue such as bone and muscle. Third, leukemia and lymphoma are cancers develop from blood forming cells this is the least common one among the all the types which forms eight percent.

3.8. Risk Factors of Breast Cancer

Risk factors of breast cancer become more threatening with increasing age and female gender. Breast cancer original risk factors are higher hormonal level, economic status, breastfeeding or childbearing, age , race, dietetically iodine-deficiency, female gender (Aceves, 2005; Collaborative Group on Hormonal Factors in Breast Cancer, 2002; E.Santoro, DeSoto, & Lee, 2009; NE, 2006; Patrick, 2008; Saslow et al., 2004; Stoddard Fr, 2008; Venturi, 2001).

One of the problems which happen in the most of the cases is the lack of a suitable way to prevent breast cancer by any direct action on the cancerous parts of the body. According to the estimation of world cancer research foundation it is possible to prevent 38% cases of the breast tumors in the United States when the physical activity exercise is increased, healthy weight is controlled and alcohol intake of the cases is reduced. Also it has been estimated that 20% of breast cancer cases in china 28% of cases in Brazil and 42% of the cases in England could be prevented.

3.8.1. Family History

Women having family history of any type of breast cancer with different stages should gather enough information about her influenced relatives, involving the age at which the cancer started and kind of cancer. Danger of development of breast cancer may be linked to family history arises with the number of relatives those face to this disease, certain age and lineage at diagnosis. The younger the age at diagnosis, the more the

genetic component may be involved (Ceschi et al., 2007). Any individual breast cancer history relatively demographic a higher breast cancer risk factor as well as family history, especially if sister, daughter or mother had this cancer. Higher risk will be considered if a family member of the woman who is under 40 years old got breast cancer. In a case, two of her family members got ovarian or breast cancer this woman is facing with the highest risk of breast cancer.

3.8.2. Genes

Some of breast cancer cases are known to be related to alterations in specific genes. BRCA 1 and BRCA 2 are the most common genes. Women with alterations in BRCA 1 or BRCA 2 have increased risk of developing ovarian cancer, breast cancer and many other kinds of cancer through their life-times. Anyhow, most diagnosed cases of breast cancer happen accidently. Still the reasons are unknown, however there is probably a group of factors involving lifestyle factors, hormone factors and environmental factors (Mcpherson, Steel and Dixon, 2000).

3.8.3. Smoking Tobacco

Risk of breast cancer also can be increased by smoking tobacco and as much starting to smoke at earlier age and as much smoking greater amount of tobacco the person having higher likelihood of breast cancer (Xue F, 2011). Regional Study at 1995 estimated some of epidemiological factors increase risk of breast cancer incident is giving a birth at later age and not giving birth at all, 29.5% of women with breast cancer in the United States had these conditions. Nine percent of breast cancer cases had family history and 18.9% of breast cancer cases were among group of society with higher annual income (Madigan MP, 1995).

3.8.4. Effect of Diet, Alcohol and Other Behaviors on Risk of Breast Cancer

More recent study on effect of diet and some other behaviors on breast disease shows some more risk factors such as high fat diet (Chlebowski RT, 2006) , obesity, shift work, endocrine disruptors, radiation, tobacco use, alcohol intake and some other environmental factors (Boffetta P, 2006). Although mammography radiation dose is too low, however when the effect considers in an accumulative amount then the effect of causing breast cancer cannot be neglected (Feig SA, 1997).

3.9. Diagnosis and Detection of Breast Cancer

Primary diagnosis for a woman presenting with abnormal masses should include a careful history, physical examination of the breast and breast screening. Breast biopsy can be taken after malignancy is detected in the breast after screening using mammography and ultrasound. Number of earliest cases of breast tumors detection, which diagnosed after women feel lump, exceed from 80% and the most of cases diagnosed using mammography. Some lump found in the armpits through lymph nodes is sign of breast cancer disease. Sign and symptoms of breast cancer rather than lump can also include changes in breast size or shape, skin dimpling, spontaneous discharging of single nipple called nipple inversion. Asymptomatic medical screening called breast cancer screening which attempt to early checkup and detection of breast cancer for healthy women to have the most efficient treatment of breast disease in any case. Genetic screening, mammography, magnetic resonance imaging (MRI), ultrasound, self breast exam and clinical exams are some kinds of screening methods which are employed for detection of breast diseases and cancer.

3.9.1. Breast Cancer Detection Using Screening Methods

It is well-known that Screening techniques are the most important techniques for detection of cancer, however screening is usually followed by important tests to determine whether the detected lump by screening is a cancer or not. In some cases, results of mammography and noninvasive examination are followed by further tests to make sure of definitive diagnostic; those tests are the excisional-biopsy and curatives. Either clinical breast-exam or mammography can be performed and can roughly determine whether the detected lump is a cancer tumor, at the same time other lesions can be detected (Saslow et al., 2004).

3.9.2. Mammography

Mammography persists to be the most common and reliable technique of breast cancer screening. It produces breasts radiographic images as a two sets of images according to the view taken, the mediolateral oblique and cranial-caudal. One Rad (pulse illumination) per breast is restricted to the breast and surrounding areas when screened with a modern mammography unit. Several investigations have showed that 23% of mortality can be decreased by mammographic screening (Vachon et al., 2007). Figure 3.9 shows the mammography instrument of the breast cancer screening.

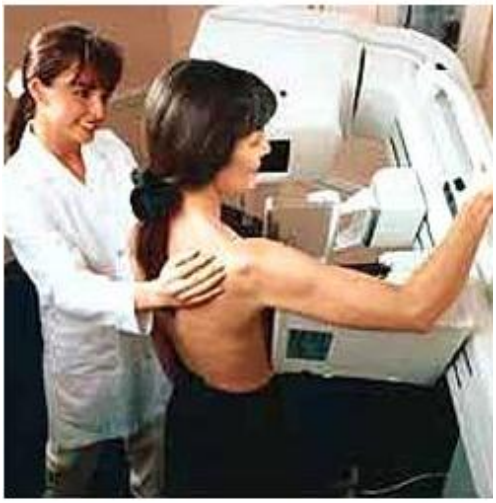


Figure 3.9 Mammography screening instrument of breast cancer, Adapted from: http://bajajsurgical.com/Bajaj%20Memography.htm

3.9.3. Ultrasonography

Ultrasonography, is an imaging technique, utilizes sound waves that go through a gel-covered skin probe to specify if densities which are found on a physical rest are solid or cystic. The advantage of complete breast ultrasound continues to be investigated and it is not considered a replacement for screening mammography but is an additional method to further detect abnormalities defined on CBE or mammography (Vachon et al., 2007).

3.9.4. Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is considered effective and useful as a screening technique for women who have enhanced lifetime risk of cases with breast cancer. Those women having family history of breast cancer and subjects who are previous malignancy survivors which were treated with chest radiation therapy (Kaiser, Pfleiderer, & Baltzer, 2008).

MRI is not usually recommended for cases having a personal breast cancer history, although 5% to 10% arise in danger of a second primary cancer in the first ten years

after diagnosis, as the utilize of adjuvant chemotherapy and/or hormonal therapy reduces total risk to less than 5% (Hazard & Hansen, 2007). Figure 3.10 illustrates the magnetic resonant imaging of the breast cancer.

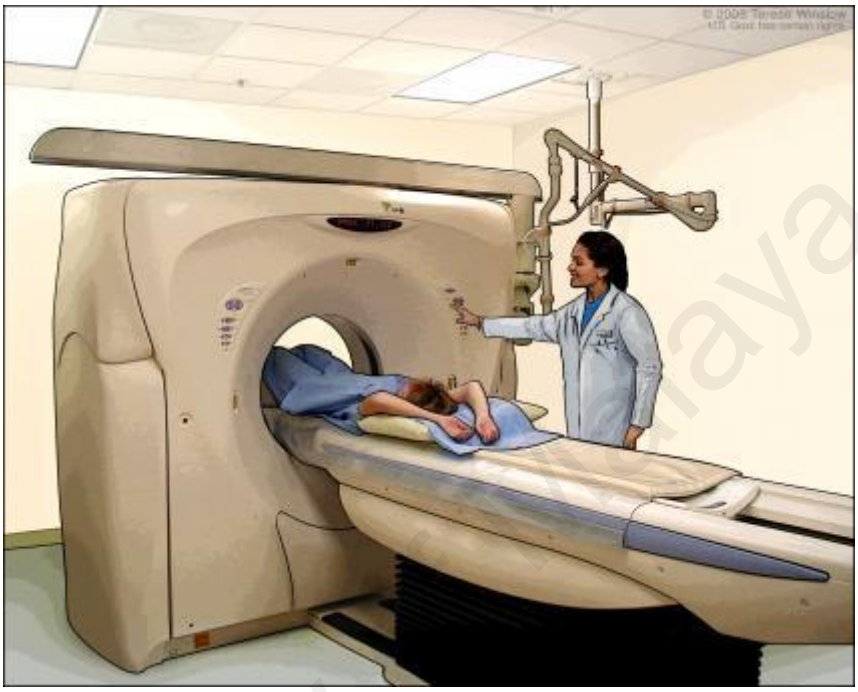


Figure 3.10 magnetic resonance imaging instrument for breast cancer, Adapted from: http://www.cancer.umn.edu/cancerinfo/NCI/CDR62878.html

There are prevention methods to reduce risk of breast cancer such as avoiding obesity, alcohol, reducing drinking alcohols, feeding child with breast, increasing physical activities and keeping healthy weight (Eliassen AH, 2010).

3.9.5. Core biopsy

Core biopsy can be included in some cases such as after removal of a section or a part of the lump; while in a case of removal of whole lump excisional biopsy can be performed. For the women who are detected having breast cancer disease, for reliability of the mammography result, additional test of vacuum assisted breast biopsy can be performed (YH, Liang, & Yuan, 2010).

3.9.6. Self Examination

Touching the breast for abnormalities and lump as a kind of clinical exam which is called self-breast exam is used widely nowadays; although there is no evidence for efficiency of this test for women with family history of breast disease (Kösters JP, 2003).

3.9.7. Needle Aspiration and Cytology

As an inconclusive test, Fine Needle Aspiration and Cytology (FNAC) can be performed. FNAC will be done in a GP's office by mean of local anesthetics. In this procedure small amount of liquid need to be extracted from the lump, bloody fluids and clear fluids indicate the high likelihood of cancerous lump or noncancerous. More analysis will be done on bloody fluids by microscope to check whether or not the small portion of fluid is normal or cancerous cells. Using this method High degree of accuracy can be provided for detection of breast tumor and cancer.

3.10. Treatment of Breast Cancer

The plan of breast cancer treatment for each patient will be determined by knowing rate of growth, stage, size and other breast cancer properties and characteristics of the subject. Hence; exact diagnosis of the disease at early stage is an important factor to determine the most comfortable and effective method for the treatment. Chemotherapy, drugs, surgery, Immunotherapy or radiation and hormone therapy are the treatment methods that is chosen according to the breast cancer characteristics of each patient (Florescu, Amir, Bouganim, & Clemons, 2011).

3.10.1. Surgical Tumor-Removal

Surgical tumor-removal is one of the most common breast cancer treatments and large benefits have been gained by this single method of treatment, just surgery itself shows of being capable to cure a large group of cases. Surgery and several regimes which mostly include chemotherapy increase long term survival of subjects. Surgery of breast tumors includes removing the tumor with some surrounding tissue which is usually done using sentinel node biopsy. Surgery of the breast tumor is divided into subdivisions according to size of the tissue removed from the breast.

In mastectomy surgery the whole breast is removed. Quandrantectomy involves removing quarter of the breast. In lumpectomy surgery small part of the breast is removed. For cosmetic purposes, surgery of breast tumors can be followed by either breast reconstruction surgery or use of breast prostheses.

3.10.2. Drugs Used for Treatment of Breast Cancer

Drug used for treatment of breast cancer are divided into two main types according to the time of it is usage, prior or after surgery. Adjuvant therapy refers to drugs or chemotherapy which is received prior to surgery. Adjuvant breast cancer treatments include three basic groups: chemotherapy, monoclonal antibodies and hormone blocking therapy.

3.10.2.1. Hormone Blocking Therapy

For some types of breast cancer, cannot stop their growth, Estrogen is a hormone which is needed. This hormone can be identified by the estrogen receptors (ER+) and progesterone receptors. Hence, these (ER+) receptors can be stopped by either blocking the production of the hormones or by blocking their receptors.

3.10.2.2. Monoclonal Antibodies

A percentage of 15 to 20 of breast cancer have an increment of the HER2 /neu gene of its protein output. HER2 receptor is triggered by a growth factor that leads the cell to divide. If the growth factor does not exist, then the growth of the cells will be stopped. Overexpression of HER2 receptor in breast cancer is accompanied with increment in disease propagation. Trastuzumab is a monoclonal antibody which has enhanced the disease survival during stage 1-3 HER2+ breast cancer to become 95%. However, Trastuzumab has high cost and two percent of the patients experience heart damage.

3.10.2.3. Chemotherapy

Common methods of chemotherapy kill or prevent rapid dividing cells in the body; hence, side effects of chemotherapy methods are disturbance of digestive and hair losing for temporary. Radiation is applicable mostly after conserving surgery of breast and effectively increase the local relapse rate and in addition to enhance the likelihood of survival (Buchholz, 2009).

Sensitivity of breast tumors to progesterone and/or estrogen and some other hormones make possibility of breast cancer treatment by preventing hormone's effect. Survival rates and prediction strongly depend on stage, type and treatment of the breast cancer. Survival of 5 years relatively varies from 23% to 98%, with an average survival-rate of 85%. Comparing male and female likelihood of having breast cancer is 1 to 100, diagnosis of male always was with delay which leads to poorer outcomes (Cancer, 2008).

3.11. Problem Statement

Breast cancer shows a continuous increment in its incident rates causing early mortality in women. Frequent screening of breast and early detection of breast tumors is an important key for reducing mortality rates related to breast cancer disease. Moreover, the most effective and less aggressive treatment can be done, when breast cancer is detected at early stages. Mammography exam can increase the risk of cancer while MRI in addition to the fact that ultrasound is less effective these reasons are considered as the main factors which lead to searching for an alternative technique to mammography.

Threatening and uncomfortably to many patients, 20% failure of breast tumor detection using X-Ray Mammography, which is the best current available breast cancer detection method, also caused of many researchers to study to find an alternative technique that can overcome disadvantages of X-ray mammography.

3.12. Objectives

- Study of breast cancer and its diagnostic and detection techniques
- Comprehensive study of breast cancer detection using confocal microwave technique
- Comprehensive study of different phantoms used to simulate electric and dielectric properties of breast tissue and tumor.
- Comparison of commonly used breast cancer detection techniques
- Comparison of the most reliable and widely used breast cancer detection technique with Confocal Microwave technique

CHAPTER FOUR

DETECTION TECHNIQUES IN BREAST CANCER IDENTIFICATION

4.1. Introduction

Microwave imaging has been introduced in the medical field several decades ago (E. C. Fear et al., 2002). Microwave imaging mainly comprises three types: passive, active and hybrid. Passive microwave modality includes the use of microwave radiometry to detect the differences in temperature between the breast tissue which are normal and the cancerous tissue (K. L. Carr, 1989) (Bocquet, Velde, et al., 1990). Hybrid microwave modality is based on two fundamental parts: first, radiometer to heat the cancerous tissue and ultrasound transducers to measure pressure-waves generated by dilation of the tissues due to the increase of their temperature. Active microwave approach is separated into two types: tomography image reconstruction (P. M. Meaney et al., 2000) (Souvorov et al., 2000) and the ultra-wideband confocal microwave imaging (X. Li & S. C. Hagness, 2001). Tomography image reconstruction method illuminates the breast with microwaves then the reflected waves will be measured in order to compute the quantitative values of the spatial distributions of the conductivity and dielectric constant. In UWB CMI, Microwave pulses which are transmitted from antennas at several sites near to the breast then the energy of the reflected microwaves from the breast is computed. Using the backscattered energy, the location of the backscattered energy waves is determined through their relative times and amplitude. High backscattered waves indicate abnormal or cancerous parts of tissue with due to their high metabolism rates. Microwave technique as a high capable screening method can be a replacement technique to mammography and it can complement X-Ray

Mammography while overcoming some disadvantages of this technique (Hagness, Taflove, & Bridges, 1997).

4.2. Basis of the Confocal Microwave Technique

Confocal microwave used for detection of breast tumors operate according to physical properties of tumors and also the behavior of tumors and normal tissue under microwave frequency.

4.2.1. Physical Basis of the Technique

The strongest physical basis of confocal microwave imaging technique is based on the level of tissue water content. Most of the confocal microwave techniques are based on two breast tissue fundamental properties. Property of breast tissue under microwave frequencies is the interaction of biological tissue with microwave, which is quite different from X-ray interaction mechanism.

Breast cancers, especially malignant tumors, in compare to normal breast tissue have significant difference of dielectric properties and these characteristic of breast, malignant tumors results in geometrical comparison to have greater microwave scattering cross-section than normal tissues. Under frequency up to 10GHz, normal breast tissue has microwave alternative of less than 4dB/Cm. This fundamental properties of normal tissue helps to fix a standard dynamic range and sensitivity for microwave equipment to detect tumors which are about 5cm under the skin. Microwave imaging technique inhibits returns from illegitimate scattered of breast and breast cancerous tumors.

4.2.2. Technology Bases of the Technique

Technology basis of confocal microwave imaging technique is similar to confocal microscopy in optics. Focusing an illuminate microwave signal at the potential tumor site 2 then the microwave energy backscattered from the breast tumor, by refocusing it at the origin point of illumination, it will be collected efficiently. This characteristic provides a special resolution of received signals and transmitted (Hagness, Taflove, & Bridges, 1998). Normal breast tissue in compare to breast tumors, Malignant and benign, has much more less conductivity and dielectric properties, thus microwave energy backscattered from tumor and sensor antenna, that lies at focal point out of the breast, efficiently can be collected.

4.3. Data Acquisition

The significant feature of the UWB CMI is it is high resolution due to the ultra-wide signaling. Based on the way in which the data is acquired, UWB CMI is classified into three parts: monostatic (X. Li & S. C. Hagness, 2001), bistatic (Guo, Wang, Li, Stoica, & Wu, 2006) and multistatic. In the monostatic method one antenna works as a transmitter and as a receiver, this antenna moves across the breast forming a synthetic slot. The bistatic method involves two antennas one works as a transmitter where the other works as a receiver, in other words transmitting and receiving are performed in separated antenna. For the multistatic method, the operation of this method is based on the use of antenna arrays. Each antenna in the array has it is own turn to transmit the probing pulse while all other antennas will be responsible for receiving the backscattered waves.

In 1997, Hagness et al. have introduced a system of pulsed microwave confocal in order to detect breast cancer. This system is composed of an elliptical reflector which sends a

microwave signal at a potential tumor collects and site back the energy which backscattered by sending it again at the focus point where the illumination is generated (S. S. Hangess, Taflove, & Bridges, 1997). In 1998, Hagness et al. have exchanged the fixed elliptical reflector into a variable focus antenna array they involved small tumors appeared in veins, mammary glands and ducts in addition to breast tissue (Popovie, Hangess, et al., 1998). Then on the same study they have investigated the effect of alterations in tumors and skin parameters. They found out that the signal to clutter ratio (S/C) is affected in the cases when the skin conductivity value is between (0.5-5), when the tumor parameters are decreased and when the vein parameters were doubled, while the effects of the increment of the mammary gland parameters to 30% greater than the healthy breast tissue parameters were negligible.

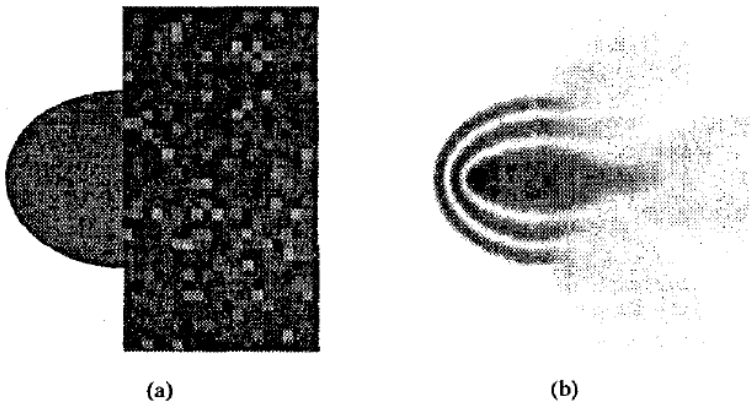
In 1998, Popovic et al. introduced a frequency window for optimum operation of the confocal microwave system. They used the finite difference time domain (FDTD) technique to investigate 2D breast tissue near to an elliptical reflector antenna. They showed the focusing abilities of the reflector antenna by presenting the power density results at frequencies 3, 6, and 9 GHz. They observed that at 6 GHz, within the breast tissue the concentrated power density within the breast tissue is around the in-breast focus. Furthermore, to find out the pulse response of the antenna as a function of the size of the tumor they included a tumor sited at the in breast focus of the antenna at frequencies 3, 6 and 9 GHz. They noticed that the incident beam shows sharpening with frequency which means at frequencies higher than 9 GHz, more sharpening will be observed (Popovie, Hagness, Taflove, & Bridges, 1998). To enhance detection of cancerous tumors while restraining the absorption and heterogeneity effect, this system uses time gating and technique of pulsed confocal to intensify detection of cancerous tumors. Scientist still doesn't count on confocal microwave imaging technique as an alternative to mammography, however they believe these technique can be used as a

complement to mammography while neglecting the mentioned disadvantages of X-Ray Mammography .

4.4. Two and Three Dimensional Tumor Imaging

Active microwave technique was desired to detect breast tumors in viva. To this end, image and analyze the system, for solving Maxwell equation, finite difference time domain (FDTD) is being used. In primary studies on 1997 ellipsoidal reflector in microwave's sensors is being used, had two focal points one at the breast and the other one at the dipole-antenna element. Ellipsoidal shell is being assumed to be filled up by a material having similar dielectric properties of the breast tissue. By one of the several dielectric interface plates (having specific thickness), along the surface of breast was raster scanned. In-breast confocal points were successfully placed at grids called voxel-positions of X, Y and Z spaces. Due to ellipsoidal reflectors' properties, backscattered energy from any of voxel positions could be refocused at the element of antenna (Popovi, Hagness, & Taflove, 1998). Figure 4.1 shows two dimensional (2D) FDTD model, it illustrates the elliptical reflector geometry next to the heterogeneous breast tissue and the power density model at ***6*** GHz receive from electric field data from the FDTD simulation (dark gray indicates high power, light gray indicates low power).

Figure 4.1(a) illustrates a randomly model of heterogeneous normal breast tissue adjacent to 2D geometry of ellipsoidal microwave-sensor. Diameter of reflector aperture is 80 mm with an in-breast focus of 38 mm deep within breast tissue. Dielectric material used to fill the elliptical reflector which resting on the breast tissue and have similar dielectric constant as the underlying breast tissue. Continuous sinusoidal waveforms were considered for studies of power-depositions and whiten the reflector focal points.



(a) (b)

Figure 4.1 (a) 2D FDTD model, illustrates the elliptical reflector geometry next to the heterogeneous breast tissue. (b) Illustrates the power density model at ***6*** GHz receive from electric field data from the FDTD simulation (dark gray indicates high power, light gray indicates low power), (E. C. Fear & Stuchly, 1999).

A monopole source is located 5 x 5 mm region of breast tissue. Blocks randomly varies in electrical properties (ϵ, σ) by mean value of 10%+- , thus in Figure 4.1(a) tissue presented as heterogeneity (as square zone of different gray scale). Malignant and normal breast tissue measured data up to 3 GHz (Chaiidhiiry, Mishra, Swariip, & Thomas, 1984; Joincs, Dhenxing, & Jirtle, 1994), by means of a Debye approximation were extended up to 9 GHz in the performed simulation value of mean extrapolated as shown in Table 4.1.

Table 4.1 electrical properties of Breast tissue under Microwave frequency spectrum measured by (Popovi et al., 1998).

Microwave Frequency	**σ S/m**	**ϵ_r**
3 Ghz	0.21	9.96
6 GHz	0.38	9.84
9 GHz	0.63	9.65

Figure 4.1 (b) illustrates a gray scale image of FDTD computed normalized 6GHz power density of electrical field. It's obviously clear that source is at the in reflector and the density of power within the breast tissue focus is concentrated around the in-breast.

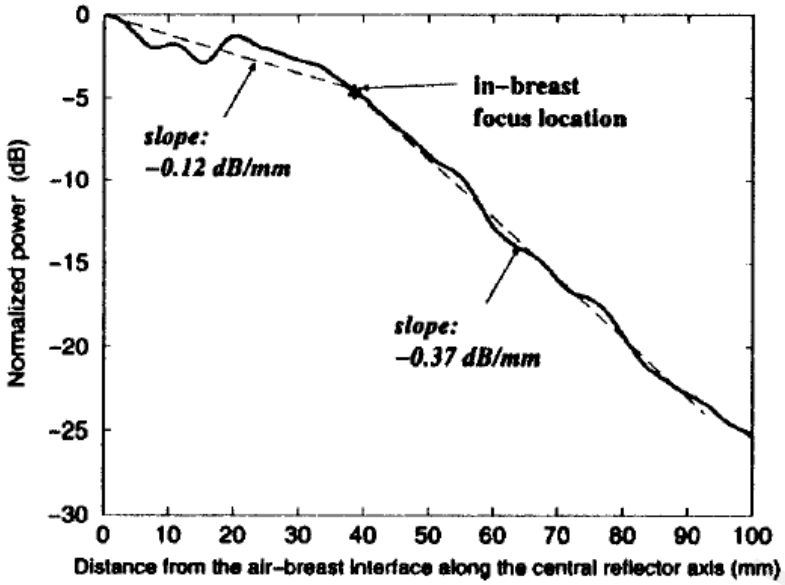


Figure 4.2 Normalized power density as a function of depth within the depth along the central elliptical sensor axis for an excitation of G GHz (Popovi et al., 1998).

Figure 4.2 illustrate density of the normalized power among the breast tissue as a function of distance from the surface of tissue along to the central reflector axis at 6 GHz. Attenuation above 6 GHz in the zone of between the in-breast focus and breast surface, however ellipsoidal reflector gain increases.

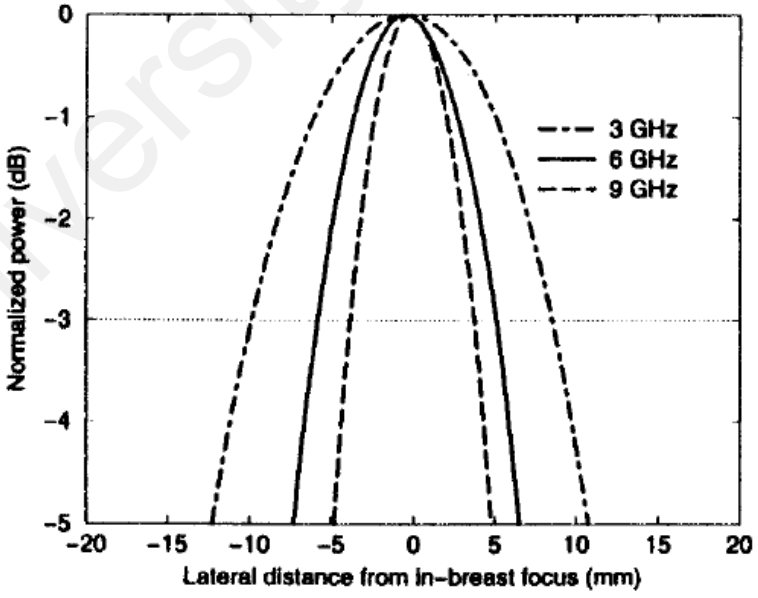


Figure 4.3 Normalized power density as a function of lateral distance from the in-breast focus located 38 mm from the air-breast interface at 3, 8 and 9 GHz (Popovi et al., 1998).

Figure 4.3 indicates the lateral distance vs. normalized power density at the depth of the in-breast focus; this shows the expected incident beam sharpening with frequency. Tissue random heterogeneity resulted from the slight departure from even symmetry and above 9GHz at the reflector on a spherical tumor, located at the in-breast. According to analysis based on measured data at 6GH, electrical properties of the tissue assume to be as following: σ=7 S/m and ϵ_r= 50 (Chaiidhiiry et al., 1984; Joincs et al., 1994).

Gaussian pulse modulating assumed to be excitation source at 3,6 and 9 GHz. FDTD model shows, advantage of ellipsoidal sensor is in the range of 3-9 GHz and above 9 GHz, breast microwave attenuation consider to be high, yield signal to clutter ratios are reduced. These mentioned series of studies indicates, range of 3-9 GHz provides windows of frequency for breast cancer detection by means of operation of focus elliptical reflector system.

For practical implementation of a breast cancer detection system, an exploratory numerical analysis is needed. General idea in previous studies done before 1999 based on confocal imaging and ultra wide band radar. Simulation of each antenna placed far from the breast tissue in the array form, accomplished by mean of FDTD method.

To enhance tumor return, combine skin return subtraction and also to the received data an algorithm of cancer tumor detection is being applied (E. C. Fear & Stuchly, 1999). Hegness et al. introduced new concept (C. Gabriel, Gabriel, & Corthout, 1996; S. S. Hangess et al., 1997). System uses confocal pulsed microwave to detect breast cancer tumors (Chaiidhiiry et al., 1984; Joincs et al., 1994). This idea is similar to system of optical confocal system while in compare optical confocal system doesn't penetrate as depth as confocal microwave technique does.

In 1999 a study by means of 9 antennas, that were concentric located with 10 cm diameter and breast model on a 5 mm diameter tumor located 1.25 cm from the skin and other in test 11 antennas were positioned 203 cm from the breast on a 4mm tumor located 2 cm under breast skin, shows same electrical properties mentioned in Table 4.1 In these tests patients lies down in prone position and breast swallows up is a kind of liquid and antenna were located by position in an arc, a small distance from breast. For data achievement the same antenna used to transmit an ultra-wide band pulse, records the backscattered return. For each antenna in the array, to reduce coupling of antennas, they need to be spaced. This signal sending and transmitting repeated and vertically transmitting of arrays of antennas allow the scanning of breast by different cross sections. To achieve additional data method of rotating the arrays to a new position is being used. Arrangement of antennas in this mentioned study is quite different from previous ones, by planning arrays sufficient away from the skin, moment of breast returns arrival, will be different from pulse transmitting. This process helps to recording of reflection of skin in such a way that it can be used in image processing.

4.4.1. Two Dimensional FDTD Model of Tumor Imaging

In 1998, Hagness et al. investigated 2D FDTD modeling of a pulsed confocal microwave system to detect breast cancers. This system utilizes the physical properties of the breast tissue special to the microwave spectrum. The physical properties which were used include the translucent nature of the breast tissue and the relevant dielectric contrast between normal breast tissues and malignant tumors. Exploitation of the confocal approach and time gating enables the improvement of the backscattered signals from the cancerous tissues, while reducing clutter which is generated as a result of heterogeneity of the normal tissues which surround the cancerous tissues. They found out that this model can detect tumors as small as 2 mm in diameter and the tumor

location has a lateral spatial resolution of about 0.5 cm (S. C. Hangess, Taflove, & Bridges, 1998).

In 1999, Fear and Stuchly have proposed and modeled a system that is appropriate for routine scan. Figure 4.4 illustrates their model. This model is similar to the models proposed by Hagness et al. as mentioned previously except that they fixed the array far from the skin in a way that the reflections from the breast don't reach during the transmission of the pulse. This permits recording of the skin returns and using this records for image processing. This system is considered more practical than the previous proposed modeled systems. Table 4.2 shows the tumor responses at single antennas with different sizes and locations where Rs indicates the tumor response compared to skin returns, while Re indicates the tumor response compared to the excitation signal (E. C. Fear & Stuchly, 1999).

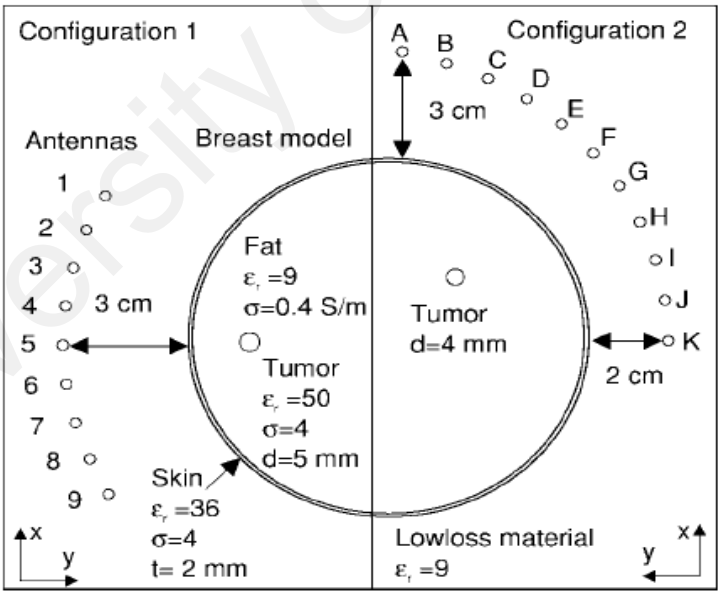


Figure 4.4 Microwave system for the detection of breast tumor (E. C. Fear & Stuchly, 1999).

During electromagnetic analysis of the system, two dimensional finite difference time domains (FDTD) conducted, using available information of dielectric properties of malignant and normal tumors.

Table 4.2 Tumor response at different tumor sizes and at different depths (E. C. Fear & Stuchly, 1999)

Antenna to skin	Tumor diameter	Tumor depth	Rs (dB)	Re (dB)
3 cm	5 mm	3.75 cm	-45.8	-104.5
	5	2.75	-39.2	-97.8
	5	1.25	-27.7	-86.4
	5	0.75	-23.5	-82.1
	2	3.9	-50.2	-108.9
	2	0.9	-24.8	-82.9
2 cm	4	2	-26.3	-82.2

By mean of FDTF, small tumor as 2mm is possible to be detected while heterogeneity of normal tissue surrounding generates background clutter. Lateral sidelong special resolution of location of tumor measured to be 0.5 cm (Susan C. Hagness et al., 1998). Study on the same year by Susan C. Hagness at el. Investigate on three dimensional FDTD simulations, designing a single resistively-loaded bowtie antenna element for an array of confocal sensors. This study presented the scattering properties, radiation and reflection of the antenna element electromagnetic pulse radiation within homogenous layer of breast cancer and frequency responses and polarization of generic tumor shapes characteristics.

4.4.2. Three Dimensional FDTD Model of Tumor Imaging

To construct three dimensional image of a tumor, a set of preselected voxels used to systematically scanning the in-breast focal points that lie within those sets of voxel. In 1998 studies proved the possibility of getting three dimensional images of breast tumors using circular synthetic aperture radar (SAR) and confocal microwave (3D space-time). Successful result of this to detect breast cancer and demonstrate the study and further studies on different microwave imaging techniques to detect breast tumors in non-invasive ways and as small as 1cm.

First at each antenna, the recorded voltages are calibrated by reducing results of previous without an object present, obtained simulation. In the calibrated voltage, components of dominant signal are the reflection from the thin layer of skin. Returns from skin obscure those from tumors, however still there is valuable information in these returns.

Second step in breast cancer detection is subtraction of skin initial reflection. To the skin reflection an approximation is formed using returns computed for a solid cylinder of skin with similar size. Solid cylinder returns summed version and scaled as two time shifted used to form the mentioned approximation. This provides additional estimation of skin thickness and location. This method have been used for varies distance from the antenna, skin thickness and for tumor present modules. Effect imaging and detection greatly reduced by subtraction of skin from total recorded signal using approximation signals. In order to enhance the returns of tumor, calibration voltage correlated with modified data.

Circular-SAR geometry and curved-SAR used for theory of Straight path SAR to SAR and resulted of a wavelength with height resolution. 3D confocal microwave imagining technique experiment had been conducted at X-Band frequency of (Akira Ishimaru, Tsz-King Chan, & Yasuo Kuga, 1998)

In 1999, Hagness and Bridges attempted to detect tumors that are invisible to x-rays. They implemented 3D finite difference time domain (FDTD) simulations and they focused on designing a single resistively bowtie antenna of the confocal sensor array. The results showed that the dynamic range of the sensor array constructed with microwave instrument is enough to detect small malignant tumors which cannot be detected using X-Ray Mammography (S. C. Hangess, Taflove, & Bridges, 1999a).

Hagness et al. developed a sensor formed from electronically switched monostatic antenna array that concentrates a low power pulsed microwave signal at a focal point in the breast and then collects the backscatters. As the malignant tissue has different dielectric properties compared to the surrounding normal tissue, their reflections are wide and have high intensities. They defined two performance specifications for the microwave sensor, the first was signal to clutter ratio (S/C) which refers to the ratio of the peak reflection from the tumor to the peak reflection from the clutter. Second, the dynamic range which refers to the ratio of the peak power pulse to the ratio of the noise generated from the system. They concluded that this system can detect early stage tumors with a size of 0.5 cm in diameter which are at small depth from the wall of the chest (S. C. Hangess, Taflove, & Bridges, 1999b).

Since the systems introduced by Hagness et al. cannot be used for complex constructions, Fear and stuchly introduced a new system where complex constructions can be involved.

Table 4.3 Means of tumors and breast interior Region of interest for images reconstructed with different numbers of antennas and immersion media (E. C. Fear & Stuchly, 2000a).

Reconstruction		**Interior mean**	**Tumor mean**	**Detect**
Number	**Medium**			
26	Skin	56	815	Yes
15	Skin	148	1188	Yes
6	Skin	222	1728	Yes
30	Breast	205	1665	Yes
15	Breast	178	1830	Yes
6	Breast	448	1877	Yes
30+	Breast	1657	4139	Yes
15+	Breast	3202	4199	Yes
6+	Breast	3004	6241	Yes

This system uses the same principles of those used by Hagness et al. but differs in three ways. First, the construction was an array of small antennas encircles the breast.

Second, the antennas were placed far from the breast so that the skin reflections can be detected and suppressed. Third, the systems were immersed in a liquid that is similar to breast tissue or the skin. They found out that this system can detect tumors as small as 6 mm in diameter. Larger response was detected from the system which was immersed in the skin.

Due to placing the antennas in a way that to encircle the breast, they obtained images that represent the entire cross section of the breast. Table 4.3 demonstrates the image formation of the breast with and without skin subtraction (E. C. Fear & Stuchly, 2000a).

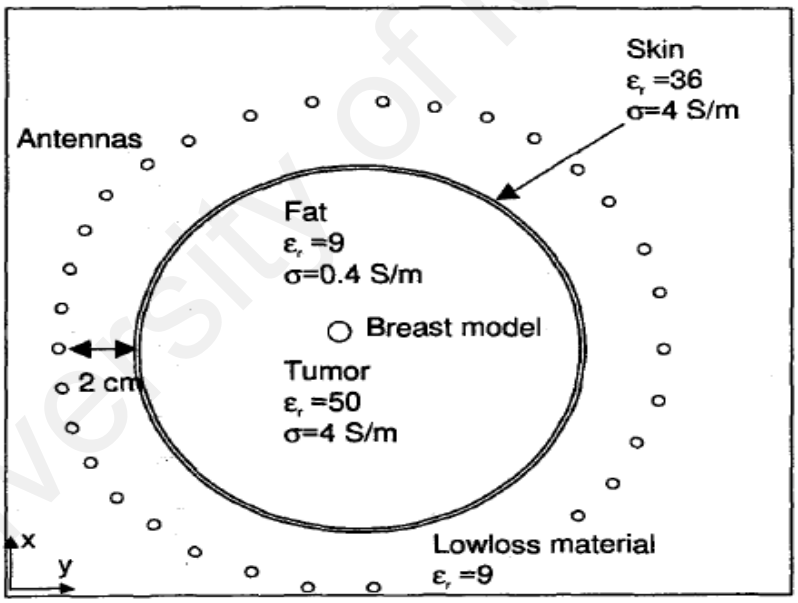


Figure 4.5 The model of the breast with 6 cm diameter and 2 mm skin thickness (E. C. Fear & Stuchly, 1999).

In 2000, fear and stuchly conducted a study in which they investigated the number of antennas needed for detection of malignant tumors. They recorded the response of the tumors from various tumor sizes in different image configuration methods. Figure 2.4 represents the system which they proposed. The results showed that 10 antenna

locations are adequate for the detection of tumors in heterogeneous breast model. Where this technique is more robust for the homogeneous breast model where the tumors shows stronger response. Tumors as small as 2 mm could be detected with depth of 3 cm and it was concluded that increasing the number of antennas provides more accurate detection in complex models (E. C. Fear & Stuchly, 2000b, 2000c).

4.5. Electrical Properties of Beast and Tumor Tissues

As mentioned in introduction, the primary leading feature in microwave imaging of breast tumors is the contrast between the electric properties of benign tumors, normal breast tissue and malignant tumors. These contain varieties in conductivity and dielectric permittivity. It is explained in (S.C. Hagness et al., 1998) that the relative conductivity and dielectric permittivity of biological tissues strongly depend on level of water they content. Hence, high water content (HWCT) tissues, such as muscle and also malignant tumors, relatively are having similar conductivity and dielectric permittivity than malignant surrounding. and in order of magnitude tissue content low level of water relatively or low-water content (LWCT) tissue such as fatties that are gathered in normal tissue of breast (S.C. Hagness et al., 1998). Although, the biological tissue contains high amount water are containing more than 80% water (Lazebnik, McCartney, et al., 2007). The contrast of electrical properties result in variety of scattering parameters for breast tumors and normal breast tissue is known as the main indicator of detecting tumors. In determining the electric properties of normal breast tissue, heterogeneity present as one of the main challenges. Breast tissue is also highly depended to the patient herself (Lazebnik, McCartney, et al., 2007).

The most general available data of the electrical properties of malignant, normal and benign breast tissue has been investigated in different studies (Lazebnik, McCartney, et

al., 2007; Lazebnik, Popovic, et al., 2007). In addition to details about the sources of data applied as the techniques used to analyze the electrical characteristics of normal biological tissue, although (Lazebnik, Popovic, et al., 2007) characterized those studies used to analyze characteristics of cancerous tissue.

The first most significant result is shown in Figure 4.6, which indicates that on normal, more than half of the breast structure is comprised of fat or adipose-tissue. Hence, the utilization of phantoms, which are fat, mimicking, in many investigations is a legitimate techniques to analyze the capability of detecting breast cancer by the application of microwave imaging.

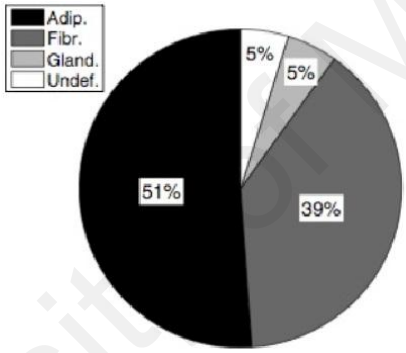


Figure 4.6 Contribution of dominant tissue in the breast. ‘Adip.’: adipose tissue, ‘Fibr.’: fibroconnective tissue, ‘Gland.’: glandular tissue, ‘Undef.’: undefined, which denotes cases the legions of tissue in the histology slide exhibited high heterogeneity to specify the dominant type (Lazebnik, McCartney, et al., 2007).

Study conducted by Lazebnik et al. to study the dielectric constant and conductivity of high water and low water content tissues (Lazebnik, McCartney, et al., 2007), the frequency of operation for this study was in the frequency range between 0 to 20 GHz. the results are shown in Figure 4.7, to 4.9.

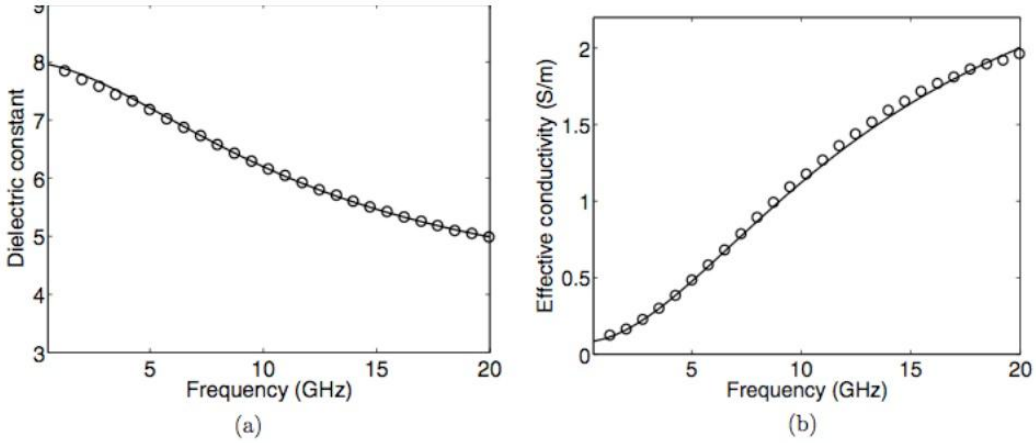


Figure 4.7 Dielectric constant and conductivity of low-water-content tissues as function of frequency. (a)Dielectric constant property, (b) Effective conductivity property.o: indicates measured data, solid line: indicates Cole-Cole fit(Lazebnik, McCartney, et al., 2007).

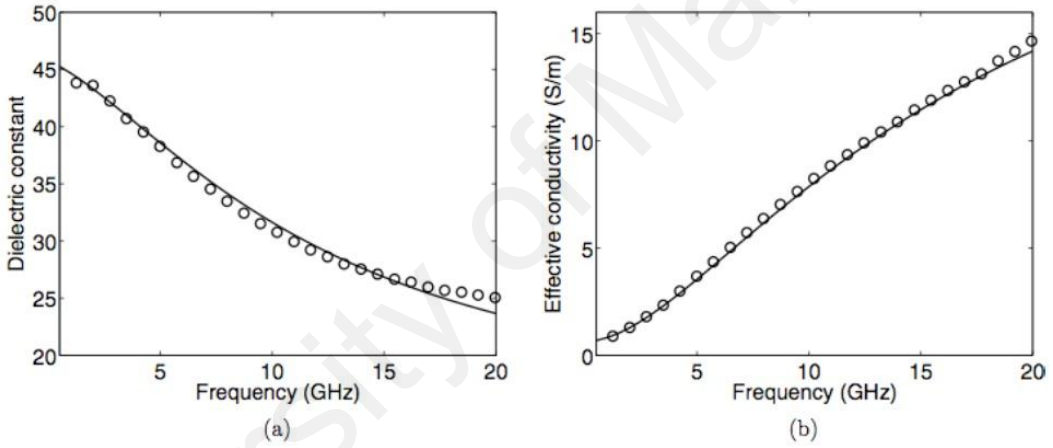


Figure 4.8 Dielectric constant and conductivity of high-water-content tissue as function of frequency. (a)Dielectric constant, (b) Effective conductivity. o: indicates measured data, solid line: indicates Cole–Cole fit(Lazebnik, McCartney, et al., 2007).

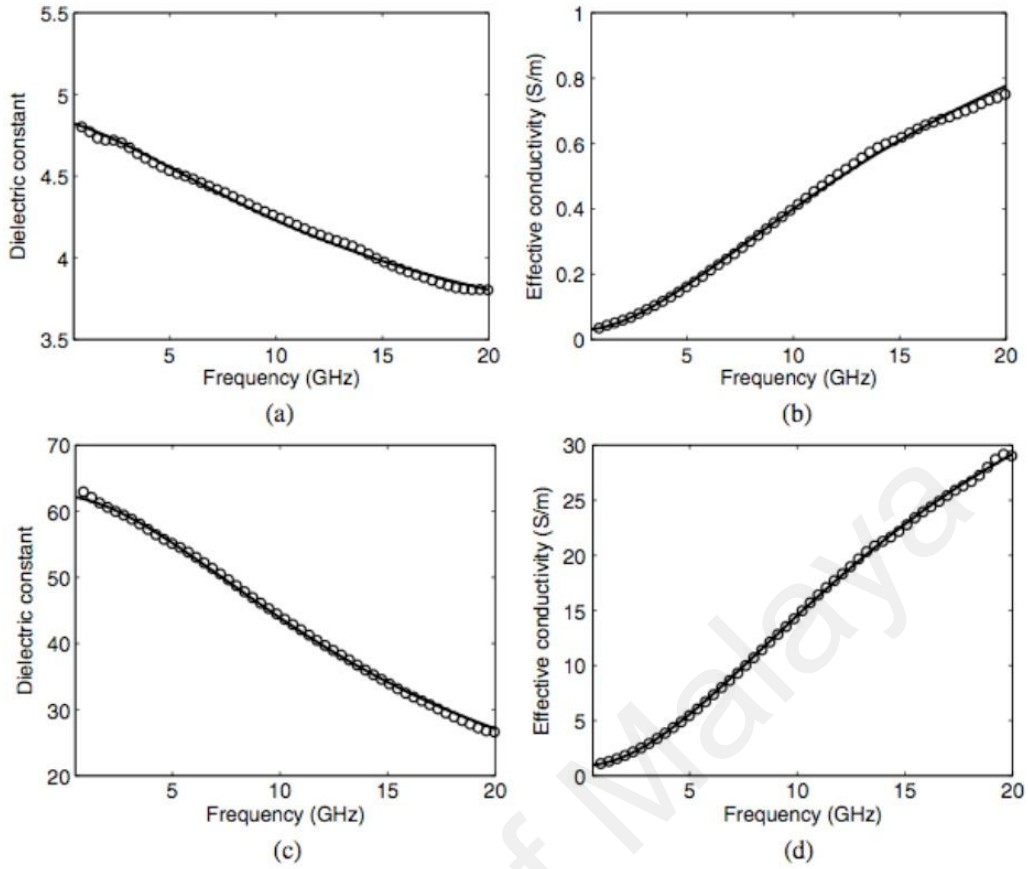


Figure 4.9 Two representative experimental data sets represented by Cole-Cole fits. (a)Dielectric constant as a function of frequency of healthy tissue.(b) Effective conductivity as a function of frequency for a healthy tissue (c) Dielectric Constant of cancerous tissue as function of frequency. (d) Effective conductivity as a function of frequency for a cancerous tissue (Lazebnik, Popovic, et al., 2007).

Table 4.4 dielectric properties of different breast tissue

Tissue	$\varepsilon'(\omega)$	σ_{eff} (S/m)
LWCT	5 - 8	0.2 - 2
HWCT	25 - 45	1 - 15
Malignant	25 - 65	1 - 30

Table 4.4 demonstrates that the dielectric properties of adipose tissue are different than that of cancerous tissue so detection of breast cancer can be done accurately. This significant difference in dielectric properties between healthy and malignant tissue is much greater than the difference in many other breast imaging techniques (E.C. Fear et al., 2002). Results available in the literature show the reasons behind using of microwave imaging for breast cancer detection as a potential method that offers sensitivity and specificity that are not attained using other modalities.

4.6. Breast phantoms

Series of studies proved that high water content tissues' dielectric properties, such as muscles, have greater dielectric properties compared to low water content tissues such as fats (C. Gabriel et al., 1996; S. Gabriel, Lau, & Gabriel, 1996a, 1996b), under radio frequency spectrum, power frequency to millimeter, this contrast is more clear. Some other research studies (Chaudhury, Mishra, Swarup, & Thomas, 1984; Joines, Dhenxing, & Jirtle, 1994) (Jacobi & Larsen, 1986) indicate that dielectric properties of malignant tumors have similar properties to muscle, while dielectric properties of normal breast tissue is identical to fat. Dielectric properties of normal breast tissue is measured to be varied in an approximate range of 10%+- about a nominal value of 0.45 S/m for conductivity, an abruption loss of 2-3 and 9 for relative permittivity. Primary active-microwave system investigated in 1997 was based on an identical radar signal processing (Jacobi and Larsen, 1986) and a confocal microwave (Lichman, 1994).

In primary studies breast was modeled as a finite cylinder with material (fat) that has same electrical properties of breast tissue and very low conductivity also covered by outer layer of skin. Tumor modeled as small cylinders. The primary breast cancer detection, by assuming the breast cross sections are in circular form, located tumors in two dimensional images. The method of signal processing involves correlation detection, decreasing of skin returns, focal point synthetic scan through the region of interest and calibration.

Study of the biological tissue reaction to electromagnetic radiation leads to search for phantoms that effectively simulate the biological tissue electromagnetic properties (Lazebnik, Popovic, et al., 2007).

Physical model of a biological tissue that can contain some properties and characteristic of the tissue is called Phantom. By a desired phantom it is also possible to simulate

wave distribution behavior of a particular biological tissue (E.C. Fear, S.C. Hagness, et al., 2002; Lazebnik, Popovic, et al., 2007). By using phantoms, studying deposition of electromagnetic radiation have been made easy for variety of application such as, estimation of specific-absorption rate (SAR) for cancer treatment by mean of microwave-hyperthermia.

However SAR doesn't shoes the value of changed temperature, it indicates amount of the electromagnetic field's production. Having maximum SAR, frequency range of 100 KHz to 6 GHz is the standard operation range of device, especially for safety standard of electromagnetic systems (Ibrahim, Algabroun, & Almaqtari, 2008).

Different phantoms, made of variety of materials used to model biological tissue according to materials used to fabricate phantoms and the proposed tissue, are being classified into three classes (Nikawa, Chino, & Kikuchi, 1996). First classes are those phantoms used to simulate tissue's electrical properties, having similar complex permittivity parameters value to the tissue. Second classes are those phantoms used to simulate deposition of internal electromagnetic power, having similar electrical and thermal properties, third class are phantoms used to simulate internal temperature transport, having similar temperature perfusion and heating pattern (Nikawa et al., 1996).

Tissue dielectric characteristic as a frequency function is one of the reference characteristic used to evaluate a phantom, thus a desirable phantom is the one can be used for different range of frequency especially in mentioned standard range.

To make a phantom to simulate dielectric properties of biological tissue, different materials with similar dielectric properties need to be mixed. By dividing human tissues into two main type of Low Water content tissue and High Water content tissue it's require to make two similar group of phantoms to simulate the related biological tissue.

4.6.1. Phantoms Used to Simulate Low Water Content Tissue

Fat and bone are two type of Low water content tissue and first phantom introduced for simulating these types of tissue (Ibrahim et al., 2008), made of black acetylene, catalyst, powder of aluminum and laminac polyester resin. By using variety amount of aluminum powder and black Acetylene it's possible to control the dielectric constant and conductivity values. Although this first model couldn't follow the expectations, as this first model was very difficult to fabricate thus couldn't be used as model of variety super-stuff muscles. Later Nilsson added more polythene powder to Guy's model reduce permittivity and use it as fat phantoms instead of muscle phantom, however he couldn't get any accepted result from this attempt. One of the first successful researches was making dough by saline oil flour, 0.9 NaCl and 500:225; 50 weight ratio. To prevent normal flour made phantom of becoming dry, the oil content need to be reduces to have manageable phantom. This phantom was as a successful simulation of bone tissue and fat and at frequency of 451MHZ had ε^* value of 7.3-j1.5 (Ibrahim et al., 2008).

Bini et Al. introduced phantoms made of new materials, using low permittivity liquid of glycol ethylene, dioxane and pyridine instead of water (Ito, Furuya, Okano, & Hamada, 2001). Low permittivity and good mechanical properties of the phantoms are being achieved using dioxane. In cases were transparency of phantom was a primary object, ethnediol could be used as fatty tissues simulation between less than 1 GHz up to 5.5 GHz (Ito et al., 2001).

EGP Material are low permittivity material which is combined of 5% gelatin, 55% ethanedioland 40 % powder of polythene as wetting component. Permittivity result of suing this material shows to be a bit higher than fatty biological tissue, ε^* value of 8.2-j3.6 in frequencies of 1000Mhz, however its being suggested to increasing powder of

polythene parentages to reduce permittivity (Mazzara, Briggs, Wu, & Steinbach, 1996). This phantom is as soft as it's easy to cut it by knife and after designing the shape a rigid form will be produced.

Dry phantom to use as low water content tissue simulation has been introduced by Nikawa. This phantom is made of a curing agent, raw silicon rubber and carbon-fibers having two size of gain. Complex permittivity of this phantom is being measured, using reflection method (Nikawa et al., 1996); after shaping the material inserting it to coaxial cable which is opened end. Similar Resulted permittivity using HP85070 and HP8752A indicates that loss factor and relative permittivity increase by using carbon fiber, thus to simulate low water content tissue it's important to use proper amount of carbon-fiber. Despite of difficult fabrication of this phantom, preservation is superior and modeling of the material is easy.

4.6.2. Phantoms Used to Simulate High Water Content Tissue

In 1971 phantom used for simulating dielectric properties of high water content tissue introduced by Guy, a model combined of TX-150 (jelling agent) called super stuff, saline solution which is consists of NaCl and Water and powder of polyethylene (Nikawa et al., 1996). Later Chou et al. changed the ingredient and introduced the phantom to be used at frequency range between 13.56 to 2450 MHZ (Lazebnik, Madsen, Frank, & Hagness, 2005). Changing of salinity helps to control conductivity while changing powder of polyethylene value helps to change dielectric constant. The advantage of this phantom made it as a successful phantom that have been used in many studies and researches, advantage of being easy to control, low cost to prepare and easy to use. Preservation of this model also cause moisture separation and bacteria invasion, these are known as main disadvantage of using this phantom. Bini et al was the person

who introduced quite different type of material for making model of high water content tissue (E. C. Fear, Meaney, & Stuchly, 2003) and after him Andreuccetti et al. studies microwave application of the phantom (E. C. Fear, 2005). This phantom is being made of polymerized of C_3H_5NO in water, acrylamide and adding salt doping to achieve similar electric properties of different type of high water content tissues (Ibrahim et al., 2008). At 5 frequencies from 0.75 to 5.5 Ghz, complex permittivity have being measured and results shows the possibility of controlling the dielectric constant and loss factor by changing acrylamide value and having a desire conductivity by adding enough salt. This phantom has low optical absorbance, is transparent and stands without needing any mechanical support. Main disadvantage of this phantom is short life time when it is exposed to air and also doesn't tolerant when it's tight to air. Preparing this phantom requires difficult methods of fabrication and obtaining of chemical also is not easy.

Robinson et al. also introduced another type of transparent phantom to simulate high water content tissue. Materials use to fabricate this phantom is composed of 48% ethanediol, 40% water, 2% NaCl (Salt) and 10% gelatin and it called HWCT (Ibrahim et al., 2008). An open ended coaxial-sensor connecting to an automatic network analyzer and numerical-analyzer program used to measure complex permittivity of this phantom at frequencies 500,1000 and 2450 MHz. this test at 1000 MGh frequency has ε^* value of 49.2-j24.4 and for simulation of muscle at other frequency its needed to contests percentages. This phantom is soft and is rigid enough to hold its shape, is transparent thus has more advantage over TX-150.

Agar is a material used in different type of phantom used in researches related to microwave imaging techniques to simulate high water content tissues. Usually these phantoms combine of water and sodium chloride in addition to ager. Although Ito et al. by making some changes used this phantom for simulation of muscle and brain tissue;

however unchanged ones decompose and dry, thus losing their electrical properties and this issue made them difficult to be used. The phantom Ito used was combination of TX-151, powder of polyethylene, deionizer water, sodium chloride and preservative in addition to basic ager (Ito et al., 2001). Ager makes the possibility of self shaping and also prevents separation of water, while viscosity can be raised by using TX-151.this phantom is being tested at frequency range between 300 MHz to 2.5 GHz using permittivity probe model HP85070 (Mazzara et al., 1996). Using plastic film to cover the phantom, one month's observation and permittivity measurement indicated of a slightly change of electrical properties of the phantom.

Many research works resulted wrong, just because of not considering the electrical properties changes of these mentioned phantoms due to exposure of these types of phantoms to air over time.

Preservation problems lead to study of dry phantoms that are preserving the changes of electrical properties, as there no water content.dry phantoms are fabricated by two methods. First type is combination of powder of graphite, powder of ceramic and resin. Tamura et al reported that ceramic has very small loss tangent thus to increase loss tangent graphite have been used (Kobayashi, Nojima, Yamada, & Uebayashi, 1993). At frequency between 0.5 to 5 GHz, complex permittivity of 27 different constitute ratio have been measured using HP8510 and resulted to obtain wide range of permittivity. This phantom is difficult to use as the ceramic is hard and reshaping of phantom is difficult and also for removing the air gap between pieces of ceramic it need to use special adhesive and this adhesive is not easy to be used.

Nikawa et al. introduced other type of dry phantom which is composed of carbon-fibers, silicon rubber and curing agent (Nikawa et al., 1996). Using reflection method to measure complex permittivity of this kind of phantom, indicate of effect of proper

selection of carbon ratio to simulating high water content tissue. Advantage of this phantom is being premium in preservation and disadvantage of this phantom is due to a equipment needed to give desire form to its shape and this problem prevent this phantom to be amenable.

4.6.3. Phantoms Used to Simulate Low Water Content Tissue

Both type of tissue are also possible to be simulated by same phantoms using same ingredients. Nikawa et al. introduced a dry phantom that by changing ratio of two of the carbon type it can be used to simulate both low water content tissue and high water content tissue (Nikawa et al., 1996).

Recently Mariya Lazebnik et al. proposed oil-in-gelatin based phantom to simulate both high and low water content tissue, and by varying the ratio of oil it's possible to obtain a wide range of complex permittivity value (Lazebnik et al., 2005). Repeated measurement after two months on the same sample, confirmed the stability of this phantom over long time and results indicates of 6 weeks expiration date of this phantom that consider a long time. This phantom has two important advantages first this phantom is suitable to be used for frequency range from 0,5 to 20 GHz thus it's applicable for ultra wideband breast cancer detection and imaging applications. Also this phantom can be use to fabricate heterogeneous construction and solute diffusion doesn't let the dielectric properties to be changed.

4.6.4. Homogeneous and Heterogeneous Breast Phantom

Homogeneous breast phantom are utilized for investigation techniques of ultra wideband breast cancer detection (Bindu et al., 2006; Li, Davis, Hagness, Van Der Weide, & Van Veen, 2004; Sill & Fear, 2005) as well anatomically numerical breast

phantom's simulation (Bond, Li, Hagness, & Van Veen, 2003; E.C. Fear, X. Li, S.C. Hagness, & M.A. Stuchly, 2002; X. Li & S.C. Hagness, 2001; Xie, Guo, Xu, Li, & Stoica, 2006). Soy oil bean has been widely used in the manufacturing of breast phantoms due to it is availability. This material was mixed with glycerin and corn syrup as a mixture to be used in ultra wide band imaging studies. However, these materials suffer of some limitations due to its low dielectric properties in compare with biological breast tissue. Although of this limitation, phantoms made of these materials are considered as relatively capable to simulate the heterogeneous nature of breast tissue.

There are features required to have desirable breast phantom to simulate glandular tissues as high water content tissue, adipose as low water content tissue and cancerous-lesions, the features are as following; Phantoms that is applicable on ultra wide band frequency range of 3.1 GHz to 10.6 GHz, to simulate breast tissue dielectric properties, also A significant feature which should be available in the materials of the made phantom should be capable of showing long time suitable heterogeneity configuration. Due to this stability changes in mechanical and electrical characteristics can be avoided during diffusion.

Lazebnik et al. introduced oil-in-gelatin phantom as an attempt to overcome the aforementioned limitation. This phantom is composed of formalin and oil droplets in gelatin solution (Lazebnik et al., 2005). Varying the percentage of gelatin and oil components helps to vary dielectric properties. These phantoms are considered as long lasting, which is nine weeks , this long period indicates the high stability of this phantom (Madsen, Zagzebski, & Frank, 1982).

Many studies have been conducted as an attempt to mimic the dielectric properties of human tissues. A study carried out by Lai et al. (Lai, Soh, Gunawan, & Low, 2010) purposed to produce heterogeneous and homogenous phantom to simulate dielectric

properties of the breast tissue. Table 4.5 shows the dielectric properties an conductivity of the phantoms used in the various studies. In several studies used a phantom with dielectric properties of 9.8 with variability of 10% as a standard (Campbell & Land, 1992; Chaudhary, Mishra, Swarup, & Thomas, 1984; Lazebnik, McCartney, et al., 2007).

Table 4.5 electrical properties of breast phantoms used in different studies

Study on Breast Phantom	**Frequency**	**Dielectric Permittivity**	**Conductivity S/m**	**Variability**
(Li et al., 2004)	6 GHz	2.6	0.05	0%
(Sill & Fear, 2005)	4 GHz	4.2	0.16	0%
(Bindu, Lonappan, et al., 2004)	3.2 GHz	11.2-44.4	0.66-2.8	0%
Phantom used to simulate breast tissue				
(E.C. Fear, X. Li, et al., 2002; X. Li & S.C. Hagness, 2001; Xie et al., 2006)	6 GHz	8.8-10.8	0.36-0.44	10%
(Bond et al., 2003)	6 GHz	9.8-33.2	0.4-2.9	10-50%
Biological Breast Tissue				
(Campbell & Land, 1992)	3.2 GHz	9.8-46	0.37-3.4	64%
(Lazebnik, McCartney, et al., 2007)	5 GHz	4.4-48	0.02-4.5	67%

4.6.5. Breast Phantom Fabrication

The latest study which introduced the method and the material heterogeneous and homogenous breast phantom to be used for microwave imaging techniques in ultra wideband frequency was in 2010. Campbell et al. investigated two larger scales of measurements (Campbell & Land, 1992) in addition to another study conducted by Lazebnik et al. the obtained results was opposite to what was revealed in the previous studies such that breast conductivity and dielectric permittivity showed higher variability (Lai, Soh et al., 2010).

A study carried out by Lai, Soh et al. aimed to fabricate breast phantoms with more desirable dielectric properties compared to previous numerical and experimental breast phantoms. Seven heterogeneous and three homogeneous breast phantoms which were fabricated in the study are shown in Table 4.6.

Table 4.6 Seven heterogeneous and three homogeneous breast phantoms

Breast Phantom	Mean Dielectric Permittivity	Dielectric Permittivity	Range of Dielectric Permittivity	Variability
Homo-80	8	8	0	0%
Homo-65	16	16	0	0%
Homo-50	24	24	0	0%
Hetero-17	10	8–24	16	±80%
Hetero-25	11	8–24	16	±73%
Hetero-33	13	8–24	16	±62%
Hetero-50	16	8–24	16	±50%
Hetero-60	13	8–20	12	±46%
Hetero-65	11	8–16	8	±36%
Hetero-70	10	8–12	4	±20%

In this study the mean Dielectric permittivity of biological breast tissue is considered to be 8 to 24, however, actual value is still not determined and it is specific for each subject.

Dielectric permittivity of the heterogeneous phantom is measured from matrices of different materials, clutters and dielectric permittivity. Materials used for production of Tissue mimicking Phantom is content of water and oil, fabricated in cylindrical-polypropylene-containers with 10 cm diameter 5 cm height in dimension just same as the way followed in previous investigation by (Lazebnik et al., 2005).

In order to fully fill the container, 400 ml of each material is needed to be used. To avoid depletion, the material sealed carefully by utilizing various percentages of oil which is varied from 10, 30, 50, 60, 70 to 80 percent, six different samples were fabricated.

Homogeneous Breast Phantoms Fabrication was made using different cylindrical Polypropylene-containers of 10 cm height and 8 cm in dimension. Using 50, 65 and 80% oil percentage, three different homogeneous breast phantoms have been fabricated. To fully fill the container 600 ml of each material is being used. For 6 hour after fabrication of breast phantom is performed, 12 times the phantoms are turned to water accumulation at the bottom of the phantom.

Heterogeneous Breast Phantoms Fabrication is performed by mixing oil and phantom materials using different percentages of oil. Consequently, seven heterogeneous breast-phantoms were achieved. To simulate the glandular-tissue, low oil container materials were used to fabricate Clutters. In order to keep the clutters and to simulate the adipose-tissue in breast, materials with high oil percentage used to fabricate matrix. Clutters were achieved by affectedly dainty the high-dielectric-phantom material to size smaller than 5 mm.

First phantom-container was mixed with a thin layer matrix of 80% oil material. On the thin layer of matrix, a thin layer of clutter 50% oil materials has been deposited.

Clutters are covered with other thin layer of matrix material. To fully cover the container this process has been repeated.

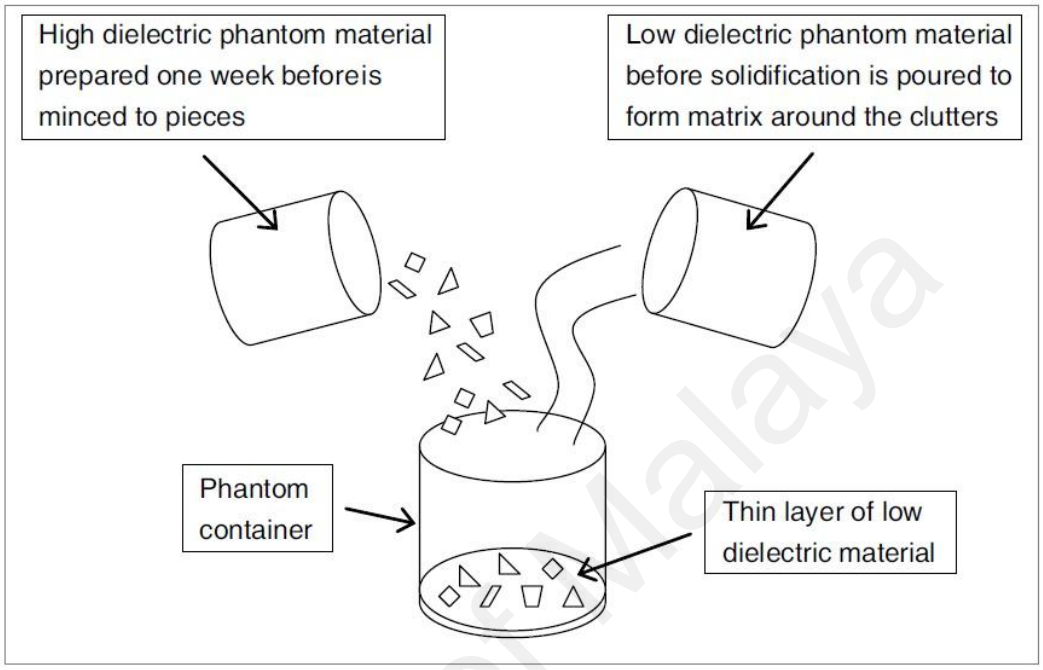


Figure 4.10 Heterogeneous breast phantom fabrication (Lai, Soh et al., 2010).

Utilizing mixture of clutters and different percentage of clutters to simulate fabroconnective tissues and variety of glandular value, four phantoms hetero 17, Hetero 25, Hetero 33, and Hetero 50 have been fabricated. Table 4.5 shows the composition of the seven heterogeneous phantoms components. Utilizing mixture of clutters and different percentage of clutters dielectric permittivity to simulate various dielectric properties of the breast, four phantoms hetero 70, Hetero 65 and Hetero 60 have been fabricated. Table 4.6 shows the composition of the four heterogeneous phantoms components. One week after fabrication, dielectric properties of materials were measured using Agilent N5230A. Agilent 85070 slim form open ended coaxial probe was used in operation frequency range between 0.5 GHz to 13.5 GHz.

Table 4.7 Seven heterogeneous breast phantoms' compositions (Lai, Soh et al., 2010).

Phantom	Volume % of oil in clutters	Volume % of clutters in phantom	Volume % of oil in phantom
Hetero-17	50%	17%	75%
Hetero-25	50%	25%	73%
Hetero-33	50%	33%	70%
Hetero-50	50%	50%	65%
Hetero-70	70%	50%	75%
Hetero-65	65%	50%	73%
Hetero-60	60%	50%	70%

For phantom material dielectric consistency analyzing, the material has been cut into three similar layers having four surfaces as shown in the Figure 4.11.

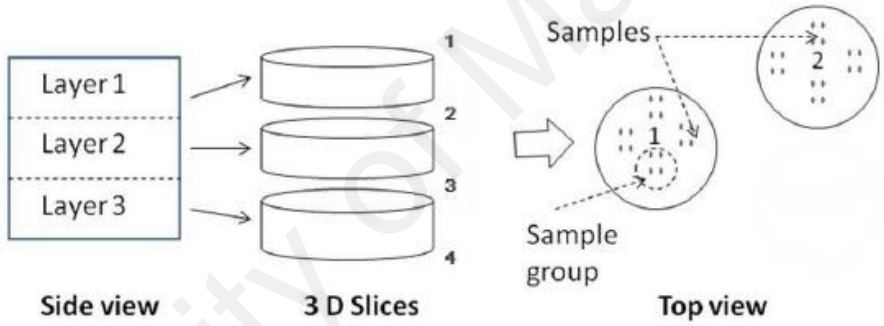


Figure 4.11 Phantom sliced in three similar layers having four surfaces (Lai, Soh et al., 2010).

Phantom homogeneity was identified by comparing the dielectric properties between different surfaces inside the same phantom and different areas inside the same surface.

4.7. Antenna

Fundamentally microwave images indicate maps of electrical property dispersion in the body. electrical property changes shows the deposition of heat in the tissues (E. C. Fear et al., 2003). Breast Cancer diagnosis by mean of microwave imaging is based on this kind of difference in electrical properties. Advantages of breast cancer detection using

microwave techniques are due to steady progressing imaging algorithms, microwave hardware and also computational power (E. C. Fear, 2005).

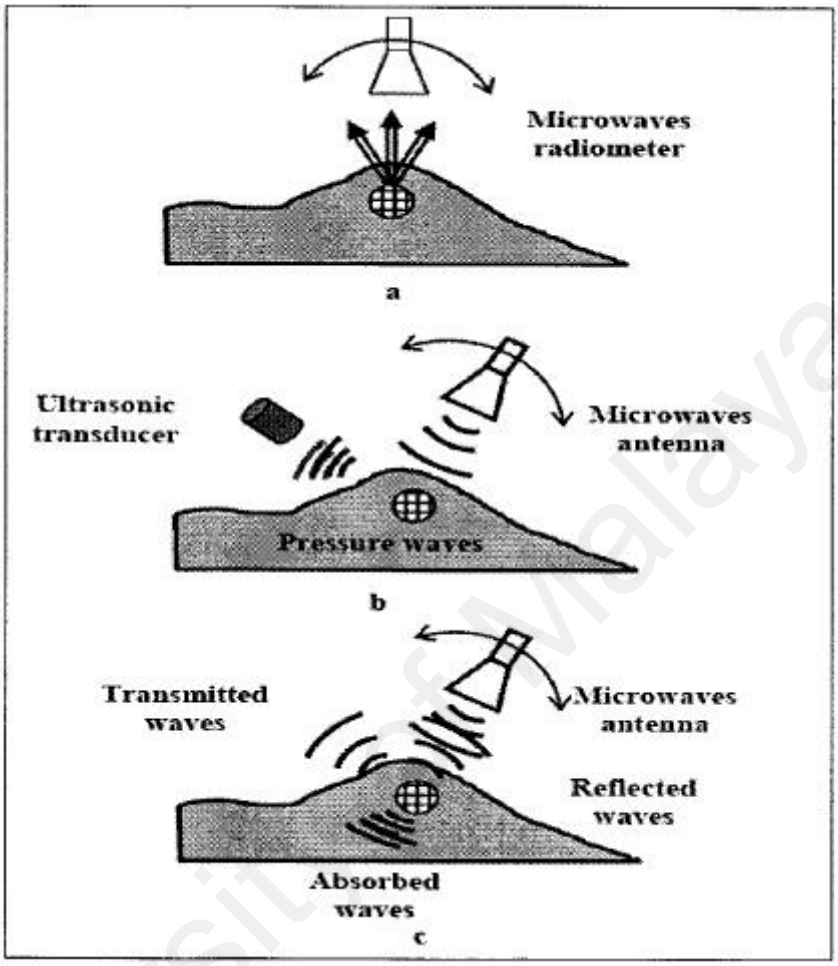


Figure 4.12 Three Different Microwave Imaging Techniques

Microwave imaging of breast tumors provides an acceptable alternative access to mammography. While X-ray detecting structural changes in tissue cells, microwaves detect and changes in dielectric properties. Some main advantages of the microwave imaging techniques are very rapid process, high sensitivity and specificity. Any small tumor can be detected by measuring the contrast in the electrical permittivity of malignant and normal tissues. 10-20% difference in the permittivity between the normal and malignant tissues make the possibility of tumor detection using confocal microwave technique. Different techniques are employed by different microwave research groups in all around the world to develop an efficient system for early breast cancer detection.

Different Research studies employee three different techniques to develop an applicable microwave imaging system to detect breast cancer at early stages.

4.7.1. Passive microwave Imaging

Passive microwave imaging techniques combine radiometers to measure difference of temperature in the biological breast tissue, detecting tumors based on their higher temperature in contrast to normal tissue. Microwave radiometry has been explored for breast cancer Detection as an accompanying to X-Ray Mammography (Bocquet, Van de Velde, et al., 1990; K.L. Carr, 1989; Carr, Cevasco, Dunlea, & Shaeffer, 2000). Two examples of microwave radiometers are Oncoscan (Carr et al., 2000) and the system reported by S. Mouty et al. (Mouty, Bocquet, Ringot, Rocourt, & Devos, 2000) .

4.7.2. Hybrid Microwave Imaging

These methods use energy of microwave to target and immediate heat tumors and ultrasound transducers to detect pressure waves produced by the expansion of the heated tissues. Due to higher conductivity of tumors more energy is absorbed by malignant breast tissue resulting in selective heating of these lesions. The tumors expand and generate pressure waves that are detected by ultrasound transducer. Two methods of image reconstruction proposed are Computed Thermo-acoustic Tomography (Kruger, Kiser, Reinecke, Kruger, & Eisenhart, 1999; R. A. Kruger et al., 1999) and Scanning Thermo-acoustic Tomography (STT) (Ku & Wang, 2000; Wang, Zhao, Sun, & Ku, 1999).

4.7.3. Active Microwave Imaging

These methods involve lighting up the breast with microwaves and then measuring transmitted or reflected microwave signals, then form images with received data. Active microwave methods of breast imaging can be categorize as tomography and radar based. Meaney et al. (P.M. Meaney et al., 2000; Meaney et al., 2007) the first radar based breast cancer detection proposed in 1998 by Hagness et al. (S.C. Hagness et al., 1998). After that two systems have been developed: Microwave Imaging via Space-Time beam forming (MIST) developed by Hagness (Davis, Bond, Hagness, & Van Veen, 2003; Hagness, Taflove, & Bridges, 1999) in 2003 and Tissue Sensitive Adaptive-Radar (TSAR) developed by Fear (E. Fear & Sill, 2003; Sill & Fear, 2005) .

All of microwave medical imaging techniques use microwave antennas to transmit and receive signals and/or energy. The characteristics of the microwave antenna greatly change in free-space and coupling-media. Imaging techniques use dielectric medium to abolition the reflections at the air-skin interface. Thus it is superior to study the behavior of the antenna used in relation to that of the lossy-medium employed.

4.7.4. Microwave-Antennas Employed in Medical Imaging

From the first engineers started employing microwaves for medical usages, the search for a desirable microwave antenna has been in progress. Different microwave antennas are used among the globe by various microwave medical imaging researchers. This part details four such antennas that are primary used in medical imaging applications or are recognize as promising solutions to be used; called the monopole-antenna, the vivaldi-antenna, the bow tie antenna and the pyramidal-horn antenna.

4.7.4.1. Monopole Antenna

By employing monopole antennas the whole imaging parts will be illuminated by locating them close to the target, although in different antennas the distance has to be greater in order to provide enough illumination coverage. Space advantage can be provided by the monopole transmitters can prove to be very useful for systems using multiple transmit or/and receive channels. Meaney et al. have designed arrangement that apply the monopole antennas to both transmit and receive basis(Meaney, Paulsen, & Chang, 1998). The monopole was assembled by having the centre conductor of a semi rigid cable of quarter wavelength (physical length of 2.5 cm) exposed in a medium at 500 MHz. The Figure of a typical Monopole-antenna constructed using semi-rigid-coax is shown in following Figure a medium such as air or water this type of antenna is prominent for producing exciting currents. Lack of any balun adjustment cause the characteristic blockage of the monopole antenna in de-ionized water is not balanced. Meaney et al. (Meaney et al., 1998) benefit from situation on the high attenuation of the enclose saline solution to limit this effect. The characteristic impedance of the monopole antenna in the saline solution (0.9%) is significantly altered; it presents a theoretical return loss of 9dB for the frequency range between 300 to 1100 MHz (Meaney et al., 1998).

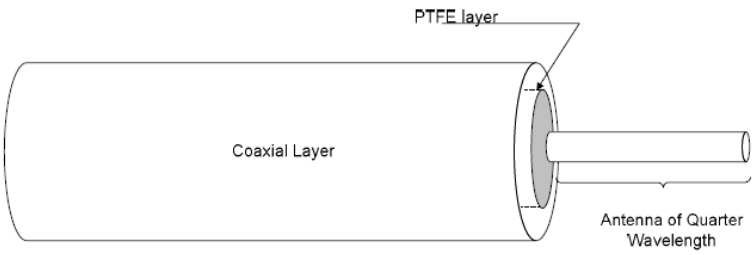


Figure 4.13 Construction of monopole antenna using semi rigid Coax (Meaney et al., 1998).

Through this identify (Meaney et al., 1998) determine that the isotropic radiation pattern of the monopole does not aid to degrade imaging performance in the near field

Frame work, Rather it absolutely enhance the image quality obtained. In order to realize a clinically practicable system, a fixed array data acquisition design will be required.

Because of the physical advantages offered by the monopole transceiver adjustment by removing the more bulky waveguides, they can be conducive to a fixed array design hence making this arrangement more desirable for medical usages.

4.7.4.2. Wideband Bow Tie Antenna

G. Bindu (Bindu, Hamsakkutty, et al., 2004) accomplished an effective wideband coplanar strip line fed bow tie antenna with advance bandwidth, low cross-polarization and less back-radiation. The new antenna is assemble by structurally adapt the accepted micro strip bowtie antenna design; this is accomplished by adding an image plane. The antenna is designed as a patch on a single layered substrate with er = 4.28 and thickness of 1.6 mm. The coplanar strip line is designed to have high input impedance in order to couple the antenna efficiently with the measurement system. The parameters, such as the distance to the image plane, flare angle of the bow, and dimensions of the antenna, are known to affect the bandwidth. These parameters are optimized to increase the performance.

The antenna shows uni-directional radiation design with increased bandwidth reduced back radiation and low cross-polarization in the operational band and thus making it efficiently for Confocal Microwave Imaging. A usual wideband bow-tie antenna with coplanar strip line feed for CMI is shown in Figure 4.13 CMI make use of back scattering to target breast cancer tumors, so the antenna employed is need to focus the microwave signal close to the target and collect the back scattered energy (E.C. Fear, X. Li, et al., 2002) . A 2:1 Standing-Wave Ratio (SWR) bandwidth of 45.9% is acquire for

the designed 4x4cm bow tie antenna in air that has a flare angle of 90°. The antenna works in the band of 1850MHz - 3425 MHz with a return loss of -53dB. It is announced that in adage syrup the bandwidth is increased to 91% in the range between 1215 MHz to 3810 MHz with resonance-frequency of 2855 MHz and loss return of -41dB.

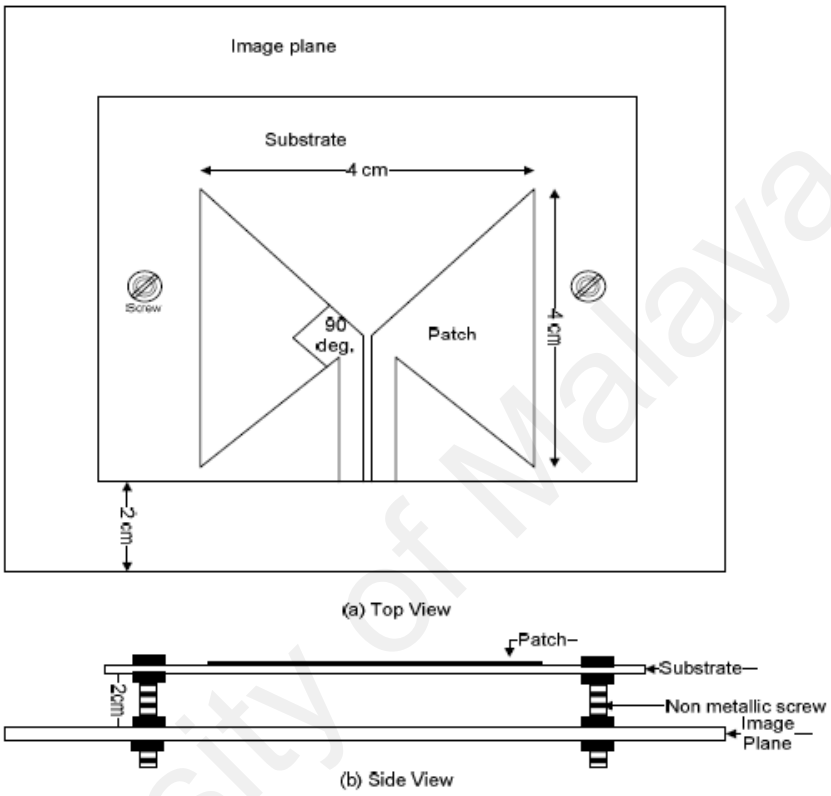


Figure 4.14 Wideband Bow Tie Antenna (Bindu, Hamsakkutty, et al., 2004).

4.7.4.3. Antipodal Vivaldi Antenna

these type of antenna is a form of the tapered-slot-radiator and has been exhibit to produce achievement on a wide bandwidth and limited by the ordinarily used slot line to micro-strip transition (Gibson, 1979). Langley (Langley, Hall, & Newham, 1996)designed a Vivaldi antenna which content the condition for imaging systems in terms of bandwidth, gain and impulse response, however at the expense of convincing volumetric size. Moreover the antenna holds up structure of the sub-nanosecond pulse transmission with insignificant distortion to achieve accuracy imaging without ghost targets. after that study in 2006, Abbosh (Abbosh, Kan, & Bialkowski, 2006) designed a

Vivaldi antenna that abridge its physical proportions in a way that it can be include in a compact microwave imaging detection system as long as keeping up its distortion less performance.

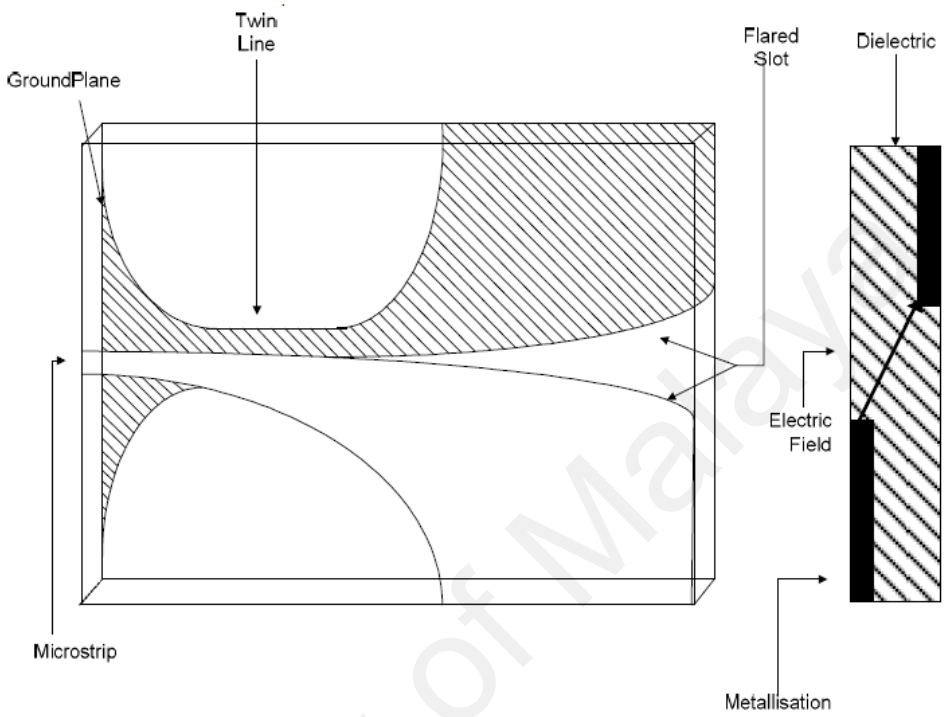


Figure 4.15 Antipodal Vivaldi Antenna (Abbosh, Kan, & Bialkowski, 2006).

A usual Ultra wideband Antipodal-Vivaldi antenna is exhibited in Figure 4.15. The antenna performs over an Ultra wideband between 3.1GHz and 10.6 GHz with a peak-gain of 10.2 dBi at 8 GHz. This typical feature indicates of the Antipodal Vivaldi antenna potential to have effective performance in medical imaging applications.

4.7.4.4. Pyramidal-Horn Antenna

These Antennas are well known for their great aperture adeptness but are restraining to certain function, due to their limited bandwidths. However, the bandwidth of the horn antennas can be greatly enhanced by adding metallic-ridges to the waveguide and flared-sections (Walton & Sundberg, 1964). Numerical and experimental analysis of pyramidal-horn antennas with double-ridges have been introduced by (Notaros,

McCarrick, & Kasilingam, 2001) . E.T. Rosenbury designed a modified version of the ridged horn antenna in which the waveguide section is removed and one of the two ridges is replaced by a curve metallic plane abolished by resistors (Rosenbury et al., 2002) . Later in 2003 Susan C. Hagness and her team introduced a complete numerical and experimental study of a specific realization the design, wherein the antenna is made in order to the centimeter scale dimensions for applications in the microwave frequency range of 1 to 11 GHz (Li, Hagness, Choi, & Van Der Weide, 2003).

The antenna combined of a pyramidal horn radiation-cavity, a metallic-ridge, and a curve-metallic launching plane ended to resistors. The pyramidal horn is terminated to the outer conductor of the coaxial-feed and supplies as the ground plane, supporting a current return path. Because of the coaxial-feed, the ground plane arrangement eliminated the need for a UWB Balun. The sendoff plane is a curved plane structure connected to the central conductor of the coaxial feed. Termination resistors are connected between the end of the launching plane and the side-wall of the pyramidal horn. Microwave energy is conducted and launched by this curved plane into the enclose medium. The termination resistors restrain reflections from the end of the launching plane. The top surface of the ridge curves toward the antenna hole. The dimensions of the horn antenna are selected according to the geometrical size required and functional frequency range. A typical Ridged Pyramidal-Horn antenna is illustrated in Figure 4.16. The bend shape and shape of the launching plane, the thickness and the outline of the curved side of the ridge and the termination-resistors are the basics factors affecting the input impedance of the antenna. The Pyramidal horn has a depth of 13 mm with a 25 mm x20 mm hole. The greatest width of the launching plane is 12 mm and the thickness of the ridge is 2 mm.

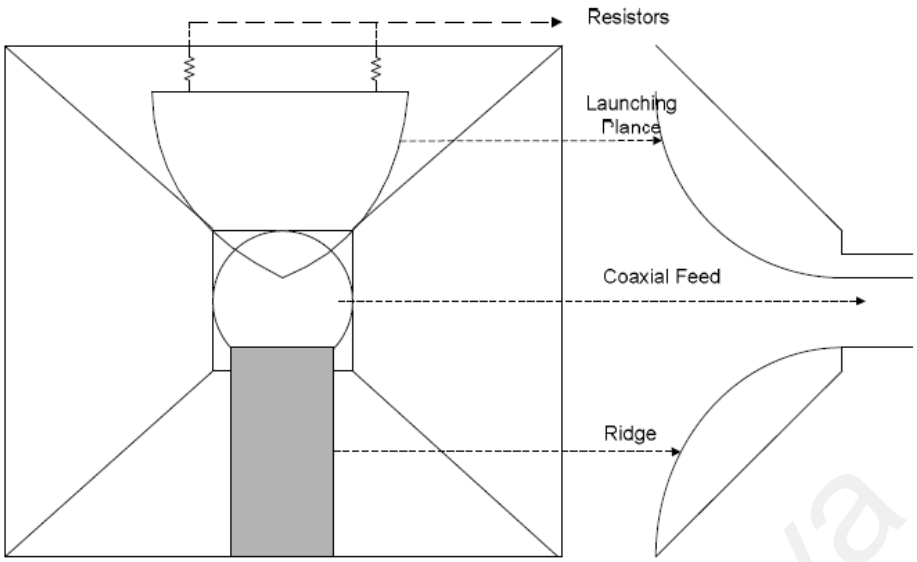


Figure 4.16 Ridged Pyramidal-Horn Antenna (Li, Hagness, Choi, & Van Der Weide, 2003) .

The antenna receives VSWR of less than 1.5 at frequency range and fidelity of 0.96, for both the simulation and experiment (X. Li, S.C. Hagness, et al., 2003) . The antenna has been analyzed under low loss absorption medium and acquires similar VSWR and fidelity. Overall it is axiomatic that this type of antenna can be efficient for biological sensing and the imaging applications.

4.7.5. Antenna Design Challenge in Medical Imaging Application

In order to establish a clinically practicable medical imaging system, it is necessary to considerable characteristics of the microwave antenna under coupling media. One of the main requirements of the microwave medical imaging is that the entire adjustment to be asperse in a coupling medium in order to account for reflections at the air skin blend. It is important that the system creators take into attention all the changes to the antenna characteristics used in contrasting to its free space behavior. Most imaging systems work on the contrasting of transmitting and receiving signal or/and energy to and from the object. The signal reproduce from the microwave antenna to the object and the re-scattered signal to the receiving antenna will be shift depend on the medium of

propagation in relation with free space propagation. The microwave signal propagation is characterized by a constant k, known as the propagation constant. In frees pace the propagation constant k is related to the angular frequency, the permeability μo and permittivity

ε_0 of free space and it is given in (1)

$$k = \frac{2\pi}{\lambda} = \omega\sqrt{\mu_o \varepsilon_o} \tag{1}$$

The permittivity of the coupling medium εr is given as $\varepsilon_r = \varepsilon_r^{'} - j\varepsilon_r^{''}$ here ε_r' and ε_r'' are the real part and imaginary part of the dielectric constant respectively. The conductivity σ of the coupling medium is given as $\sigma = \omega\varepsilon_o\varepsilon_r$. normally for medical applications coupling media with no losses are preferred, i.e., the imaginary part in the permittivity equation will be zero and the propagation constant k_r will given as

$$k_r = \omega\sqrt{\mu_o \varepsilon_o \varepsilon_r} \tag{2}$$

Practically it is not possible to have a coupling medium without any losses. Because of the conductivity values of the coupling medium the propagation constant k_r' will be a complex value and this will vary the wavelength λ to λ_r in coupling medium. The propagation constant k for a lossy medium is given as (3):

$$k_r^{'} = \omega\sqrt{\mu_o \varepsilon_o (\varepsilon_r^{'} - j\varepsilon_r^{''})} \tag{3}$$

In microwave antenna model, the size of the antenna will always be mentioned in terms of wavelength, for example l can be λ /4 long. This relation between the wavelength and size of the length will influence the length of the antenna in coupling medium when compared with free space length. The input impedance of the antenna will also be influenced by the coupling medium.

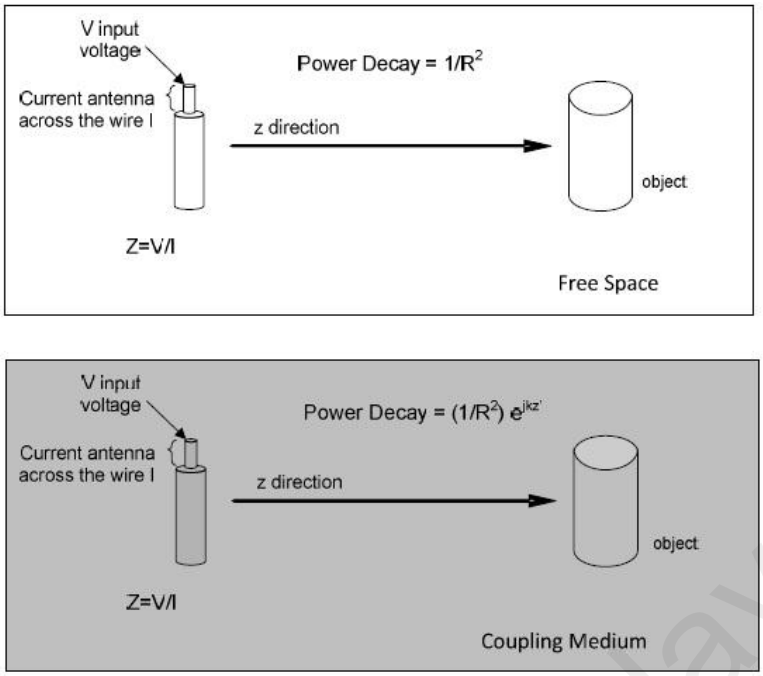


Figure 4.17 Difference of power decay component in coupling medium and free space (E.C. Fear, X. Li, et al., 2002).

The input impedance Z is basically derived as the ratio between the voltage applied and the current distribution ahead the antenna. The current distribution of the antenna in the coupling medium is depend on the new wavelength λ r and Hence changing the input impedance of the antenna. In order to properly match the antenna in the coupling medium it's needed to take into consider the input impedance in the coupling medium. This changes resulted from the change of conductivity in the radiation pattern of the microwave antenna have affect on the performance of the imaging system. In free space the power decay in far field is proportional to $1/R^2$ where R is the distance between the origin and the observation point. However, in lossy media this decay factor will be enhancing by a factor e^{jk_z}' this algorithmic term cause of additional loss in the system because of the coupling medium. Hence, the transmitted signal from the antenna cannot highlight whole object or reach the expected depth of penetration. Figure 5 shows the difference in the power loss in frees pace and coupling medium. These present the designer with the dispute the fully understanding of antennas behavior under the lossy

medium and appreciate the situation by changing the algorithm to board these changes or to adjust the design parameters of the antenna to increase its performance.

4.7.6. Suggested Solutions

As mentioned before one of the most necessary aspects of the proposed solution is the study of the antenna behaviors in coupling media. The desirable study involves study the difference in impedance and radiation pattern of an antenna in coupling media and free space. Albeit the usual analysis for actuating the impedance and radiation pattern is computationally awkward as soon as studies extend the surrounding beyond frees pace. This cause another challenge, terminating the behavior of microwave antenna in lossy medias. The primary part of the solutions has to be the inclusive study of the antenna in different materials of varies dielectric properties. Study the characteristic of the antenna in low, medium and high conductivity materials is primary. As it helps the researchers to predict the behavior of the antenna used in medical imaging applications as traditionally the work environment involves coupling media to reduce the reflections from skin/air interface. The proposed solutions involve analyzing the behavior of the monopole antenna in different dielectric materials such as water, saline solution and oil and compare the results with that of free space.

The next solution includes establishing a mathematical model to investigate the antenna in environment differ from free space. Normally, the Pocklington integral equation includes Method of Moment (Peterson, Ray, Mittra, Antennas, & Society, 1998) technique is used to decide the characteristics of a monopole antenna in free space. Because of the Method of Moment, this technique evolves into computationally annoying as the study extended the examination to coupling media such as oil and water. For more detail explanation this issue a new mathematical model is proposed

(Fernando, Elsdon, Busawon, & Smith, 2010).The new model tries to decrease the computational time and the annoying nature of the Method of Moment equation. The announcement of this new model is shown in Equation 4.

$$I(z) = I_0 e^{-\alpha z} \sin(k(l-z)) + f(z,\tau) \tag{4}$$

Above equation include of two parts, the first is

$$I_0 e^{-\alpha z} \sin(k(l-z)) \tag{5}$$

Counts of the damping in the current dispersion curve of Figure 4.18. This characterizes the effect around of the wire. The current dispersion curve in Figure 4.18 is of the wire of length λ/2 in free space. In this case the damping factor is equal to zero and its value varies as the surrounding medium varies. This is very efficient for usages including coupling medium with complex dielectric properties, such as medical imaging applications. This part also supports the complete shape of the current distribution curve in Figure 4.18 This part of the equation is coincident, to that of the current distribution expression given in (Balanis, 1997). The last part of the announcement is given by,

$$f(z,\tau) = \begin{cases} d_0 + \frac{\tau}{4}\sin\big(2k(l-z)\big) \; for \; l = \dfrac{(2w+1)\lambda}{4} \\ d_0 + 2\tau \sin\big(2k(l-z)\big) \; for \; l = \dfrac{2w\lambda}{4} \end{cases} \tag{6}$$

*d*0 is the dc component and w is a positive integer. This part counts for the variation due to the wire radii, acts as the dc term in the expression. It also supports the delay element in the current distribution curve shown in Figure 2.18.

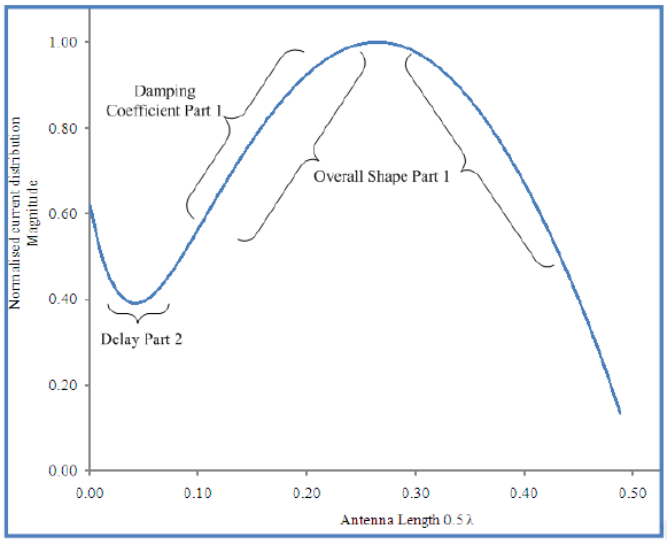


Figure 4.18 the current distribution curve of the semi-rigid coaxial wire of by length of λ/2 (Abbosh, Kan, & Bialkowski, 2006).

This new mathematical model reduce the calculation time as it related to only three parameters; Initial current I0, damping coefficient a and radial parameter t. Initial current I0 is the current at the first part of the wire, damping coefficient a characterizes the conductivity of the surrounding medium. It is this parameter of the articulation that makes this model suitable for anticipating the current distribution of the wire in other different surrounding media than free space and also, t is a parameter related to the radius of the wire.

4.8. Algorithms Used for Microwave Imaging of Breast Cancer

Microwave technique is a promising technology for both early detection of breast cancer and effective treatment. Several algorithms have been exploited for microwave imaging in order to find out the significant contrast in dielectric properties between normal breast tissue and tumor. These algorithms include Robust Capon Beamformer (RCB), Amplitude and Phase Estimation (APES), Delay and Sum (DAS) and Microwave Imaging via Space-Time (MIST).

4.8.1. Microwave Imaging via Space-Time (MIST)

MIST algorithm was introduced by Hagness et al. (X. Li, S. C. Hagness, & B. D. Veen, 2003). This algorithm includes two configurations. In the first configuration the woman lies in the supine situation, while an antenna array is positioned on the flattened surface of the breast. In the second configuration the woman lies in the prone situation where the breast is extending cross an opening of the treatment Table. In order to concentrate microwave signals MIST beamforming implements spatial filtering.

The location where microwave signals are concentrated is scanned throughout the breast and systematic scanning of the concentration from point to point creates a three dimensional image. Computations are carried out using FDTD method and Multi-static approaches. At the beginning two dimensional investigations were done and then three dimensional breast phantoms were introduced. Numerical study launched according to the FDTD simulations showed that MIST beamforming algorithm is efficient for detecting small malignant tumors in the heterogeneous tissue of the breast. Space-time beamformer is designed to form an image for the backscattered signals obtained at each antenna for each scan position. For each scan position the space-time beamformer is obtained which comprises a weighted combination of time-delayed backscattered signals as illustrated in Figure 4.19.

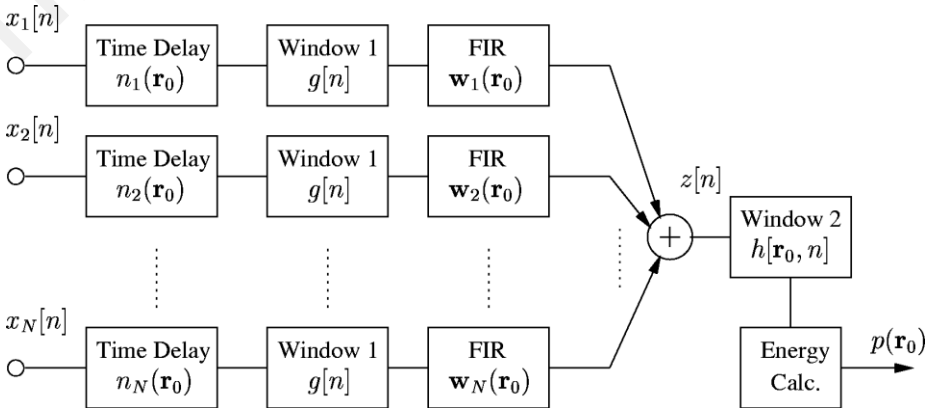


Figure 4.19 Block diagram represents the MIST beamforming process for location r0 (scan position) in the breast (X. Li, S. C. Hagness, & B. D. V. Veen, 2003).

The design of a space-time beamformer was considered for a certain scan position. The goal was to implement the beamformer in order to pass backscattered signals from the scan position with unit gain while slowing down signals from other positions.

It was assumed that the received signal in the channel contains the backscatter as a result of exist lesion at location. The Fourier transform of the received signal is given by:

$$X_i(\omega) = I(\omega)S_{ii}(\mathbf{r}_0, \omega), \quad 1 \leq i \leq N \tag{7}$$

4.8.2. Data-Adaptive Methods for Microwave Imaging

Multistate adaptive microwave imaging (MAMI) methods is being used for early breast cancer detection. Major difference of the dielectric properties of malignant and normal breast tissues is the main basis of microwave imaging techniques for early breast detection of breast cancer. One of the microwave imaging modalities is MAMI by using multiple antennas which transmit ultra-wideband pulses. MAMI can be taken into account as a typical case of the multi input and multi output (MIMO) radar with the multiple transmitted waveforms being either zero or/and UWB pulses .

4.8.2.1. Data collection and Early-Time Response Removal

There are early-time and late-time contents in the received backscattered signals: Early time signal means dominated by the incident pulse and reflections from the breast skin, while Late-time content contains tumor backscattered signals and other backscattering due to the inhomogeneous fatty tissue, glandular tissue, and chest wall.

The two antennas are placed at a position $r_i=[x_i,y_i,z_i]^T$, Let $E_i(t)$, $i = 1,\cdots,M$, refers to the received signal by the i^{th} channel at time instant t, and let r_{iT} and r_{iR} refers to the

positions of the transmitter and receiver antennas for the i^{th} channel. M indicates the number of channels or antennas per position.

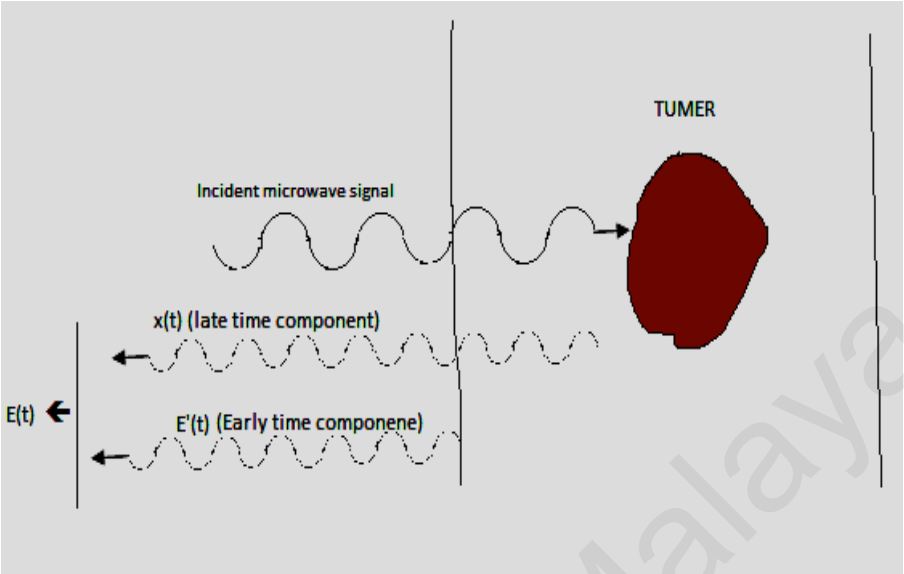


Figure 4.20 Scheme shows the steps of the data adaptive method for microwave imaging

Because the distance between the transmitter and the receiver is constant and the skin tissues are similar at different positions, the signals recorded at various antenna locations have similar direct propagations and skin reflections. Hence we can remove the early-time content by subtracting a fixed signal out from all channels.

$$X(t)=E(t) -\check{E}(t) \quad (8)$$

Where $\check{E}(t)$ is the Early time content, This calibration signal E(t) can be obtained simply by averaging the recorded signals at all channels.

4.8.2.2. Signal Time-Shifting, Windowing, and Compensation

For the i^{th} channel, we align the return from a specific imaging location r with the returns from the same location for the other channels by time-shifting the signal $X_i(t)$ a number of samples $n_i(r)$, discrete-time delay between the antennas and r can be calculated as $n\ I(r) = [1/t[\| ri - r \| /C + \| ri - r\| /C]$,C is the velocity of microwave

propagating in breast tissues, and Δt is the sampling interval, which is assumed to be sufficiently small.

The time-shifted signal is denoted as $\check{X}_i(t, r) = X_i(t+n_i(r)), t = -n_i(r), \cdots, T - n_i(r)$, where T is the maximum time needed by microwave pulse to propagate from the transmitter to the far side of the skin or chest wall and back to the receiver.

Next the aligned signals are time windowed to isolate the backscattered signals from location r. The windowed signals are denoted by $\check{X}i(t, r), t = 0, \cdots, N - 1$, where $N\Delta t$ is the approximate duration of the backscattered signal from location r.

The attenuation of the tumor responses at various channels is different because the distances from the transmitter to the imaging position r and back to the receiver are different. We only compensate out the attenuation due to the propagation and ignore the lossy medium effect because the propagation attenuation is the dominant factor.

For the i^{th} channel, the compensation factor is given by $K_i(r) = \| r_i^T - r \|^2 \cdot \| r_i^R - r \|^2$, and the compensated signal can be calculated as $y_i(t, r) = K_i(r) \cdot \check{X}_i(t, r), t = 0,\cdots, N-1$.

4.8.2.3. Data Model

We consider imaging at the generic location r only,so y(t,r) become y(t) then $y(t)=\sum y_i(t)$, i=1,…,N-1 ➔ $y(t)=[y_1(t)\ y_2(t).....y_M(t)]^T$ (9)

After preprocessing, each snapshot y(t) can be modeled as: $y(t) = a \cdot s(t) + e(t)$

Where s(t) is the backscattered signal, "**a"** denotes the steering vector, and $e(t) = [e_1(t)\ e_2(t) \cdots e_M(t)]^T (t =0, \cdots, N - 1)$ is a term comprising both interference and noise. Since y(t) was properly time-shifted and compensated for, the steering vector a is assumed to be $[1\ \ 1 \cdots 1]^T$. The problem of interest then is to estimate the backscattered signal s(t) from y(t).

4.8.2.4. Robust Weighted Capon Beamformer (RWCB)

The standard Capon beamformer (SCB) considers the following problem Min w^T $\hat{R}w$ subject to $w^Ta = 1$ (10)

Where "**w**" is the beamformer's vector, and $\check{R} \triangleq \sum_{t=0}^{N=1} y(t).yT(t)$ is the sample covariance matrix. The weighted Capon beamformer (WCB) uses a simple least squares estimate of s(t) as a weighting function:

$$h(t) = y^T(t) \cdot a/\|a\|^2 = \frac{1}{M}\sum_{i=1}^{M} y(t).y^T(t) \quad (11)$$

Then WCB is obtained by solving the following optimization problem

$$min_w w^T \check{R}w \quad \text{subject to } w^Ta = 1 \quad (12)$$

Where the weighted sample covariance matrix is defined as

$$\check{R}=\frac{1}{N}\sum_{t=1}^{N-1} y(t).y^T(t).h^2(t) \quad (13)$$

The solution of (3) is: $\hat{w}_{WCB} = \check{R}^{-1}a/a^T\check{R}^{-1}a$ and $\check{S}_{WCB}(t) = \hat{w}^T_{WCB} \cdot y(t)$

Then the backscattered energy can be calculated as:

$$P(P(r) = \sum_{t=1}^{N} \check{S}^2(t) \quad (14)$$

WCB has better resolution and much better interference rejection capability than the data-independent Beamformers. It suffers from severe performance degradations when some of the underlying assumptions on the environment, sources, propagation, or sensor array are violated. To improve the performance of WCB in the presence of model errors, we assume that the true steering vector is ã, which is a vector in the vicinity of "**a**", and that the only knowledge we have about ã is that $\|\tilde{a} - a\|^2 \leq \varepsilon$ where ε is a user parameter. The recently developed, Robust Capon Beamforming (RCB) approach to make WCB robust against the errors in "a", Consider the theoretical covariance matrix used by WCB

$$\check{R}= \alpha \cdot aa^T + Q \quad (15)$$

Where $\alpha \triangleq \frac{1}{N}\sum_{t=0}^{N-1} s^2(t)h^2(t)$ and $Q \triangleq \frac{1}{N}\sum_{t=0}^{N-1} h^2(t).E[e(t)e^T(t)]$, Ř will be described by $\alpha \cdot \tilde{a}\,\tilde{a}^T$. First, we assume ˆa is given, and then the RWCB problem can be re-formulated as:

$$\min_w w^T \check{R}\, w \quad \text{subject to} \quad w^T \tilde{a} = 1 \tag{16}$$

This has the solution

$$\hat{w}_{RWCB} = \frac{\check{R}^{-1}\tilde{a}}{\tilde{a}^T R^{-1}\tilde{a}} \tag{17}$$

Since ˆa is a vector in the vicinity of a such that $\alpha \cdot \tilde{a}\ \tilde{a}^T$ is a good fit to Ř, we determine ã as the solution to the following optimization problem

$$\text{Max}_{\alpha,\tilde{a}}\ \alpha \quad \text{subject to} \quad \check{R} - \alpha\,\tilde{a}\,\tilde{a}^T \geq 0$$

$$\| \tilde{a} - a \|^2 \leq \varepsilon$$

4.8.2.5. Amplitude and Phase Estimation (APES)

Explicitly assumes that the signal waveform is known.

$$y(t) = a\,\beta\,\check{S}(t) + e(t), \quad t = 0, \ldots, N-1 \tag{18}$$

Where β is the unknown amplitude of the backscattered signal with waveform Š (t), t = 0, … ,N−1, assumed to be known.

let $\sum_{t=0}^{N-1} \check{S}^2(t) = 1$, the APES consider the following problem:

$$\frac{1}{N}\sum_{t=0}^{N-1}[w^T y(t) - \beta\,\check{S}(t)]^2 \tag{19}$$

Subjected to $w^T a=1$, the beamformer output w T y(t) is required to be as close as possible to the known signal waveform Š(t) The APES beamformer can suppress the noise and interference, and at the same time, protect the signal of interest by enforcing the equality constraint.

Let $g = \frac{1}{N}\sum_{t=0}^{N-1} y(t).\check{S}(t)$, a straightforward calculation shows that the criterion function in the previous equation can be written as:

$$\frac{1}{N}\sum_{t=0}^{N-1}[w^T y(t) - \beta\,\check{S}(t)]^2 = \quad (\frac{\beta}{\sqrt{N}} - \sqrt{N}\,w^T g)^2 + w^T \check{R}\, w - N(w^T g)^2 \qquad (20)$$

So the minimization of (a) with respect to β is given by $B^{\wedge} = N \cdot w^T g$.

Insertion of $B^{\wedge}$ into (a) yields the following minimization problem for the determination of the APES beamformer

$$\min_w w^T Z w \quad \text{subject to} \quad w^T a = 1$$

Where we have defined $Z = \check{R} - N \cdot g g^T$

$\hat{W}_{APES} = \frac{Z^{-1}\check{a}}{\check{a}^T Z^{-1}\check{a}}$ ➔ $B^{\wedge} = N.\frac{Z^{-1}\check{a}}{\check{a}^T Z^{-1} g}$ ➔ the backscattered energy = $B^{\wedge 2}$

4.8.3. Single-Frequency and Time-domain Imaging

Different approaches have been used for microwave imaging of which the two most widespread are the **radar-based** approach and the **tomographic** approach. In the radar-based algorithms, the imaging problem is treated as a linear inverse problem and the resulting images indicate the points of origin for the reflected signals of the incident ultra-wideband pulse used to illuminate the breast. The tomography-based approaches differ from the radar-based approaches in that they seek to reconstruct the distribution of the constitutive parameters of the breast.

Different tomography techniques have been suggested for imaging of the breast, including:

1. single-frequency.
2. Multi-frequency.
3. 3-Time-domain tomography.

The single-frequency (SF) tomographic algorithm illustrated in Figure 4.21 will be compared with a time-domain (TD) tomographic algorithm. While the requirements to the imaging hardware and the computational power is less for the SF algorithm, the TD

algorithm has the advantage of collecting more information about the object since the signals used in this algorithm cover a large frequency band.

The two imaging algorithms both used on a simulated two-dimensional imaging system similar to the imaging system that consist of 20 antennas in a circular setup with a radius of 10 cm and the imaging domain, in which the object to be imaged is positioned, has a radius of 8 cm.

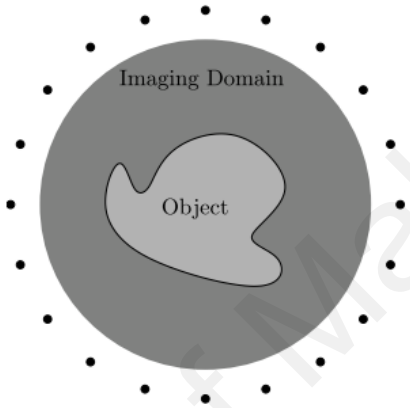


Figure 4.21 Single-Frequency and Time-domain Imaging approach

When performing the measurements with the imaging system, each of the 20 antennas is in turn used as transmitter while the remaining 19 antennas are used as receivers. This leads to a total of 380 measurements of either complex S-parameters (for the single-frequency algorithm) or real-valued time signals (for the TD algorithm).

4.8.3.1. Single-Frequency Imaging Algorithm

The single-frequency imaging algorithm is based on solving the minimization problem:

$$[\underline{K}^2] = \text{argmin} \{ \|\underline{E}^{meas} - \underline{E}^{cala}(\underline{K}^2)\|_2^2 \} = \text{argmin} \{ \| \underline{E}^{res}(\underline{K}^2)\|_2^2 \} \quad (21)$$

using an iterative Newton-type algorithm In the previous equation the vector $\underline{k}^2$ holds the squared complex wave numbers $k^2(r) = \mu_0 \omega^2 \varepsilon(r) + i\mu_0 \omega\sigma(r)$ of the individual cells of the discretized imaging domain. The imaging domain will be divided into square cells with a side length of 2 mm, yielding a total of 4849 cells. The vectors $\underline{S}^{meas}$

and $\underline{S}^{cala}$ holds the measured and calculated S-parameters for the system in the log-phase formulation while $E^{res}(\varepsilon)$ is the residual vector.

4.8.3.2. Time-Domain Imaging Algorithm

The algorithm is based on finding the solution $\underline{k}^2$ to the minimization problem:

$$\underline{k}^2 = \text{argmin}\left\{\int_0^T \sum_{Tx=1}^{20}\sum_{Rx=1}^{20} |S_{Rx,Tx}^{calc}(t', K^2) - S_{Rx,Tx}^{meas}(t')|^2 dt'\right\} \quad (22)$$

The vector $\underline{k}^2$ holds the constitutive parameters of the individual cells in the imaging domain in form of the squared complex wave numbers of the domain. The imaging domain is again divided into 4849 square cells with a side length of 2 mm.

In theory, any pulse can be used in the time-domain algorithm; it has been found that a Gaussian pulse is often the best choice. Such a pulse is characterized by a certain center frequency f_c and a certain full-width half-maximum bandwidth f_{FWHM}. In this case it has been found that the total span of frequencies needed to adequately represent the pulse is from $f_c - f_{FWHM}$ to $f_c + f_{FWHM}$.

For the TD algorithm to perform optimally, the hardware should be capable to function in this frequency span. This is a much more stringent requirement to the hardware than the requirements of the SF algorithm in which the hardware only needs to perform well at a single frequency.

4.8.4. Multistatic Adaptive Microwave Imaging for Early Breast Cancer Detection

MAMI is a two-stage adaptive imaging method. **First**, the data-adaptive RCB algorithm is used spatially to obtain a vector of multiple backscattered waveforms for each probing signal. **Second**, RCB is employed to recover a scalar waveform based on the

estimated vector of waveforms obtained in the first stage. The estimated scalar waveform is used to compute the backscattered energy $p(r_0)$.

4.8.4.1. MAMI stage 1

For notational simplicity, the dependence of on the generic location vector $y_{i,j}(t,r_0)$ is omitted in what follows. Consider the following model for the preprocessed signal vector:

$$y_i(t)=a(t)\, s_i(t)+ e_i(t) \quad , \quad yi(t) \in R^{Mx1} \tag{23}$$

Where $Yi(t)=[y_{i,1}(t)\ldots\ldots\ y_{i,M}(t)]^T$

$S_i(t)$: denotes the backscattered signal (from the focal point at location r_0) corresponding to the probing signal from the i^{th} transmitting antenna. a(t) is referred to as the array steering vector; it is approximately equal to 1_{Mx1} since all the signals have been aligned temporally and their attenuations compensated for. $e_i(t)$ denotes the residual term at point r_0 , which includes the unmodeled noise and interference due to undesired reflections.

There are two assumptions with this model.

A. Assuming that the steering vector varies with *t* , and is nearly a constant with respect to *i*.
B. Assuming that the backscattered signal waveform depends only on *i* but not on j, the j^{th} receiving antenna.

The signal waveform should also vary with both *i* and *j*, due to the frequency-dependent lossy medium within the breast These assumptions simplify the problem slightly and cause little performance degradations when used with robust adaptive algorithms. Due to the errors induced by waveform distortions, antenna location uncertainties, time-

delay round offs, etc., the steering vector $a(t_0)$ will be imprecise in practice, in the sense that the elements of $a(t_0)$ may differ slightly from 23.

Therefore, assuming that the true steering vector $a(t_0)$ lies in the vicinity of the assumed steering vector $\bar{a} = [1,\ldots,1]^T$, and that the only knowledge we have about $a(t_0)$ is that:

$\| a(t_0) - \bar{a}\|^2 \leq \varepsilon$ where ε is used to describe the uncertainty of $a(t_0)$ about $\bar{a}$.

In Stage I, for a given time t_0, $t_0 = 0,\ldots,N-1$, we can estimate the true steering vector $a(t_0)$ via the following covariance fitting approach of RCB:

$$\begin{aligned} &\max_{\sigma^2(t_0),\mathbf{a}(t_0)} \sigma^2(t_0) \\ &\text{subject to } \hat{\mathbf{R}}_Y(t_0) - \sigma^2(t_0)\mathbf{a}(t_0)\mathbf{a}^T(t_0) \geq 0, \\ &\qquad \|\mathbf{a}(t_0) - \bar{\mathbf{a}}\|^2 \leq \epsilon \end{aligned} \tag{24}$$

$$\hat{\mathbf{R}}_Y(t_0) \triangleq \frac{1}{M}\mathbf{Y}(t_0)\mathbf{Y}^T(t_0) \tag{25}$$

$$\mathbf{Y}(t_0) = [\mathbf{y}_1(t_0), \mathbf{y}_2(t_0), \ldots, \mathbf{y}_M(t_0)], \quad \mathbf{Y}(t_0) \in \mathbf{R}^{M\times M} \tag{26}$$

Observe that both of the signal power $\sigma^2(t)$ and the steering vector $a(t_0)$ are treated as unknowns in equation 23. Hence there is a "scaling ambiguity" between these two unknowns in the sense that $(\sigma^2(t_0), a(t_0))$ and $(\sigma^2(t_0)/\alpha, \alpha^{1/2} a(t_0))$ (for any $\alpha > 0$) give the same term

$\sigma^2(t_0)\, a(t_0)\, a^T(t_0)$. To eliminate this ambiguity, we later impose the norm constraint

$$\|\mathbf{a}(t_0)\|^2 = M. \tag{27}$$

For a given $a(t_0)$ the solution of (24):

$$\hat{\sigma}^2(t_0) = \frac{1}{\mathbf{a}^T(t_0)\hat{\mathbf{R}}_Y^{-1}\mathbf{a}(t_0)}. \tag{28}$$

It will be reduced to the following quadratic optimiza-tion problem with quadratic constraint:

$$\min_{\mathbf{a}(t_0)} \mathbf{a}^T(t_0)\hat{\mathbf{R}}_Y^{-1}(t_0)\mathbf{a}(t_0) \quad \text{subject to} \quad \|\mathbf{a}(t_0) - \bar{\mathbf{a}}\|^2 \leq \epsilon. \tag{29}$$

To exclude the trivial solution $a(t_0)=0$, , we need to assume that the uncertainty parameter is sufficiently small

$$\epsilon < ||\bar{\mathbf{a}}||^2.$$

To determine the solution of (26) according to the previous expression we use the Lagrange multiplier methodology and consider the following function:

$$\mathcal{L}(\mathbf{a}(t_0), \lambda) = \mathbf{a}^T(t_0)\hat{\mathbf{R}}_Y^{-1}(t_0)\mathbf{a}(t_0) + \lambda\left(\|\mathbf{a}(t_0) - \bar{\mathbf{a}}\|^2 - \epsilon\right) \quad (30)$$

Where $\lambda \geq 0$ is the real-valued Lagrange multiplier satisfying $\mathbf{R}_Y^{-1}(t_0) + \lambda \mathbf{I} > 0$ so the previous equation with respect to $a(t_0)$. For the unconstrained minimization of Ł$(a(t_0), \lambda)$ for a fixed λ ,the solution is given by:

$$\begin{aligned}\hat{\mathbf{a}}(t_0) &= \left[\frac{\hat{\mathbf{R}}_Y^{-1}(t_0)}{\lambda} + \mathbf{I}\right]^{-1} \bar{\mathbf{a}} \\ &= \bar{\mathbf{a}} - \left[\mathbf{I} + \lambda\hat{\mathbf{R}}_Y(t_0)\right]^{-1} \bar{\mathbf{a}}\end{aligned} \quad (31)$$

Let Ś denote the uncertainty set defined in. It can be shown that the solution $\hat{a}(t_0)$ belongs to the boundary of $\| a(t_0) - \bar{a}\|^2 \leq \varepsilon$ and, hence, satisfies:

$\| \hat{a}(t_0) - \bar{a}\|^2 = \varepsilon$

By using the latest two expressions we can obtain the Lagrange multiplier as the solution to the constraint equation:

$$\mathcal{G}(\lambda) = \left\| \left[\mathbf{I} + \lambda\hat{\mathbf{R}}_Y(t_0)\right]^{-1} \bar{\mathbf{a}} \right\|^2 = \epsilon. \quad (32)$$

Let the eigen decomposition $\check{R}_Y(t_0)$of be:

$$\check{R}_Y(t_0) = UDU^T$$

Where the columns of **U** are the eigenvectors of $\check{R}_Y(t_0)$ and the diagonal elements of the diagonal matrix D, $d_1 \geq d_2 \geq \ldots \geq d_M$ are the corresponding eigen values. Here, the dependencies of U and D on t_0 are omitted for simplicity. Let **b=U* ā** and denote its nth element.

Then equation (32) can be written as:

$$\mathcal{G}(\lambda) = \sum_{n=1}^{M} \frac{|b_n|^2}{(1+\lambda d_n)^2} = \epsilon. \tag{33}$$

Note that $g(\lambda)$ is a monotonically decreasing function of λ . Also, it is clear $g(0) > \varepsilon$ by $\varepsilon < \|\bar{a}\|^2$ and $\lim_{\lambda \to \infty} g(\lambda) = 0 < \varepsilon$nd. Hence, there is a unique solution $\lambda > 0$ to the previous equation can be solved using Newton method.

Inserting λ in (33) we readily determine the solution $\hat{a}(t_0)$ To eliminate the aforementioned "scaling ambiguity," by $\| a(t_0)\|^2 = M$ we replace the solution $\hat{a}(t_0)$ with:

$$\hat{\hat{\mathbf{a}}}_s = \frac{M^{1/2}\hat{\mathbf{a}}_s}{\|\hat{\mathbf{a}}_s\|}. \tag{34}$$

To obtain the signal waveform, we apply a weight vector to the received signal s. The weight vector is determined by using the estimated steering vector $\hat{a}(t_0)$ in the weight vector expression formula of SCB.

The weight vector used in Stage I of MAMI has the form given by:

$$\hat{\mathbf{w}}_{\mathrm{MAMI}_1}(t_0) = \frac{\hat{\mathbf{R}}_Y^{-1}(t_0)\hat{\hat{\mathbf{a}}}(t_0)}{\hat{\hat{\mathbf{a}}}^T(t_0)\hat{\mathbf{R}}_Y^{-1}(t_0)\hat{\hat{\mathbf{a}}}(t_0)} \tag{35}$$

$$= \frac{\|\hat{\mathbf{a}}_s\|}{M^{1/2}} \cdot \frac{(\hat{\mathbf{R}}_s + \frac{1}{\nu}\mathbf{I})^{-1}\bar{\mathbf{a}}}{\bar{\mathbf{a}}^T(\hat{\mathbf{R}}_s + \frac{1}{\nu}\mathbf{I})^{-1}\hat{\mathbf{R}}_s(\hat{\mathbf{R}}_s + \frac{1}{\nu}\mathbf{I})^{-1}\bar{\mathbf{a}}} \tag{36}$$

The equality to obtain (27) is due to inserting (32) and (35) in (36).

The beamformer output can be written as a vector:

$$\hat{\mathbf{s}}(t_0) = \left[\hat{\mathbf{w}}_{\mathrm{MAMI}_1}^T(t_0)\mathbf{Y}(t_0)\right]^T, \quad \hat{\mathbf{s}}(t_0) \in \mathbb{R}^{M\times 1}. \tag{37}$$

$\check{S}(t_0)$ contains the waveform estimates at t_0 of the backscattered signals (from the focal point r_0) due to all the probing signals indexed from 1 to M. Repeating the above process from $t_{0=0}$ to t_0=N-1 , we obtain the complete multiple backscattered signal waveform estimates.

Note that, at this stage, we have obtained M estimates of the backscattered waveforms corresponding to the probing signals sent by each of the transmitting antenna. Since these probing signals are UWB pulses with the same waveform, we can assume that the backscattered signal waveforms from r_0 due to all the probing signals are identical. To estimate the backscattering energy coherently, in the next stage, a scalar waveform is recovered from these estimated M-dimensional signal waveform vectors $\{\check{S}(t0)\}_{t0=0}^{N-1}$.

4.8.4.2. MAMI stage 2

In the second stage of MAMI, the signal waveform vector $\check{S}(t_0)$,t=0,….N-1 , is treated as a snapshot from an M-element (fictitious) "array"

$$\hat{\mathbf{s}}(t) = \mathbf{a}_s s(t) + \mathbf{e}_s(t), \quad t = 0, \ldots, N-1 \tag{38}$$

Whereas is approximately equal to 1_{Mx1} for the same reason as in Stage I. However, the "steering vector" a_s may again be imprecise, and hence RCB is needed again. In (38) s(t) denotes the nominal backscattered signal waveform, due to all probing signals, and each element of $e_s(t)$ contains the differences between the corresponding element in ŝ(t) and s(t) Paralleling the description of Stage I, we estimate s(*t*) via the following RCB formulation:

$$\max_{\tilde{\sigma}^2, \mathbf{a}_s} \tilde{\sigma}^2 \quad \text{subject to} \quad \hat{\mathbf{R}}_s - \tilde{\sigma}^2 \mathbf{a}_s \mathbf{a}_s^T \geq 0, \quad \|\mathbf{a}_s - \bar{\mathbf{a}}\|^2 \leq \tilde{\epsilon}, \tag{39}$$

Where $\bar{\sigma} = 1/N \sum_{t=0}^{N-1} s^2(t)$ is the power of the signal of interest, $\bar{\varepsilon}$ is a user parameter, and $\check{R}_s$ s the following temporal sample covariance matrix:

$$\hat{\mathbf{R}}_s \triangleq \frac{1}{N} \sum_{t=0}^{N-1} \hat{\mathbf{s}}(t) \hat{\mathbf{s}}^T(t). \tag{40}$$

Note that here can use the same assumed steering vector as in Stage I. To eliminate the scaling ambiguity, again imposing the norm constraint

$$||\mathbf{a}_s||^2 = M. \tag{41}$$

Similarly to Stage I, the solution $\hat{a}_s(t)$ to (41) is

$$\hat{a}(t0) = \left(\frac{\check{R}_s^{-1}}{v} + \mathrm{I}\right)^{-1} \bar{a} \tag{42}$$

where *v* is the corresponding Lagrange multiplier used in solving (40) which can be determined similarly to obtaining λ ,similar to (39) we replace $\hat{a}_s(t)$ with:

$$\hat{\hat{\mathbf{a}}}_s = \frac{M^{1/2}\hat{\mathbf{a}}_s}{||\hat{\mathbf{a}}_s||}. \tag{43}$$

Therefore, the adaptive weight vector $\hat{w}_{MAMI}$ for Stage II is determined by a formula similar to (43).

$$\hat{\mathbf{w}}_{\mathrm{MAMI}_2} = \frac{\hat{\mathbf{R}}_s^{-1}\hat{\hat{\mathbf{a}}}_s}{\hat{\hat{\mathbf{a}}}_s^T \hat{\mathbf{R}}_s^{-1}\hat{\hat{\mathbf{a}}}_s} \tag{44}$$

$$= \frac{||\hat{\mathbf{a}}_s||}{M^{1/2}} \cdot \frac{(\hat{\mathbf{R}}_s + \frac{1}{\nu}\mathbf{I})^{-1}\bar{\mathbf{a}}}{\bar{\mathbf{a}}^T(\hat{\mathbf{R}}_s + \frac{1}{\nu}\mathbf{I})^{-1}\hat{\mathbf{R}}_s(\hat{\mathbf{R}}_s + \frac{1}{\nu}\mathbf{I})^{-1}\bar{\mathbf{a}}}$$

The weighted output is the estimate ŝ(t) of s(t):

$$\hat{\mathbf{s}}(t) = \hat{w}_{MAMI2}\, \hat{s}(t)$$

Finally, the backscattered energy for the focal point r_0 is computed as:

$$p(r_0) \triangleq \sum_{t=0}^{N-1} \hat{s}^2(t) \tag{45}$$

4.9. Method of Image Construction

The scattered geometry is simply the 2-D inverse Fourier Transform of the reflectivity of the object in the k_x - k_y plane. Methods of image construction from measurements,

based on the direct application of 2-D inverse Fourier Transform, as well as alternative methods, making use of the so called Central Slice Theorem.

4.9.1. 2-D Inverse Fourier Transform

An image of the geometry of a scattered can be constructed by an inverse 2-D Fourier Transform of the scattered signal in the frequency domain, that is:

$$s(x, y) = \frac{1}{\pi^2} \int_{R^2} S(k_x, k_y) \exp[2j(k_x x + k_y y)] dk_x dk_y \tag{46}$$

This expression gives us a direct method of recovering the image from the measurements. Unfortunately, the discrete version of the previous expression requires uniform rectangular sampling of information in the k_x - k_y domain, while the measurements are usually taken in the $w - \varphi$ domain, which is non-uniform in the k_x - k_y domain.

4.9.1.1. Fihering and Backprojection

An alternative method is Using the fact that $k_x = (w/c)\cos\varphi_i$, and $k_y = (w/c)\sin\varphi_i$ one can rewrite integral:

$$\begin{aligned} s(x, y) &= \frac{1}{\pi^2} \int_{R^2} S(k_x, k_y) \exp[2j(k_x x + k_y y)] dk_x dk_y \\ &= \frac{1}{\pi^2} \int_{-\infty}^{\infty} \int_{0}^{\pi} S_{\varphi_i}(\omega) e^{2j\omega(x\cos\varphi_i + y\sin\varphi_i)} |\omega| d\omega d\varphi_i \end{aligned} \tag{47}$$

where $S\varphi i\,(w) = S(w, \varphi)$ is the slice of the frequency domain image taken at the angle φ_i Using $\rho = \sqrt{x^2 + y^2}$ and $\beta = \text{atan}(y/x)$.

Therefore the shape of the scatterer can be obtained by first filtering the frequency domain slices, that is obtain the filtered signal.

$$s(\rho, \beta) = \frac{1}{\pi^2} \int_{-\infty}^{\infty} \int_{0}^{\pi} S_{\varphi_i}(\omega) e^{2j\omega\rho(\cos\beta\cos\varphi_i + \sin\beta\sin\varphi_i)} |\omega| d\omega d\varphi_i \qquad (48)$$

$$= \frac{1}{\pi^2} \int_{0}^{\pi} d\varphi_i \int_{-\infty}^{\infty} S_{\varphi_i}(\omega) e^{2j\omega\rho\cos(\beta - \varphi_i)} |\omega| d\omega$$

This is just the I-D inverse Fourier transform (using the spatial parameter 2 $\rho\cos(\beta - \varphi)$ of the frequency domain slice, taken at angle φi, and multiplied by $|w|$, Alternatively, it is the spatial domain slice convolved with $h(t) = F^{-1}[|w|]$.

The next step is called *back-projection* of the filtered slices:

$$s(\rho, \beta) = \frac{2}{\pi} \int_{0}^{\pi} d\varphi_i \hat{s}_{\varphi_i}(\rho\cos(\beta - \varphi_i)) \qquad (49)$$

This states that the reconstructed function $s(\rho, \beta)$ is the result of averaging the signal $\acute{S}\varphi i\,(w)\,(\rho\cos(\beta - \varphi_i))$ with respect to φ_i, which. in turn. is the back-projection of the signal $\acute{S}\varphi i\,(x)$along the line in the same direction in which the projection function is obtained in the same direction in which the projection function is obtained. See Figure Thus, the reconstructed pixel is the averaged back-projection of the measurements, taken all around the object. Since the filtered version of the measurements is used, this algorithm is called *filtered back-projection*. From equation (43), the discrete approximation of the reconstructed function $s(\rho, \beta)$ can be obtained as :

$$s(\rho, \beta) = \int_{0}^{\pi} d\varphi_i \hat{s}_{\varphi_i}(\rho\cos(\beta - \varphi_i)) \qquad (50)$$

$$= \frac{\pi}{N} \sum_{n=0}^{N-1} \hat{s}_n(\rho\cos(\beta - \pi n/N))$$

Which can be performed sequentially as a new measurement is obtained. Thus, the filtered back-projection algorithm employs only a series of I-D inverse Fourier

transforms and does not require the complete data set to start reconstruction. This makes the algorithm the best choice for reconstruction of the function from its projections.

4.9.1.2. Back-projection and filtering

The filtered back-projection is not the only way to reconstruct the desired function from the measurements. In fact, equation (50) can be rewritten as:

$$s(x, y) = \frac{1}{\pi^2} \int_{-\infty}^{\infty} \int_{0}^{\pi} S_{\varphi_i}(\omega) e^{2j\omega(x\cos\varphi_i + y\sin\varphi_i)} |\omega| d\omega d\varphi_i \tag{51}$$

Or using the variables β and ρ

$$s(\beta, \rho) = \frac{2}{\pi} F^{-2}(|\omega|) * \int_{0}^{\pi} s_{\varphi_i}(\rho\cos(\beta - \varphi_i)) d\varphi_i \tag{52}$$

And finally,

$$\begin{aligned} s(\beta, \rho) &= \frac{1}{\pi^2} \int_{-\infty}^{\infty} \int_{0}^{\pi} S_{\varphi_i}(\omega) e^{2j\omega\rho(\cos\beta\cos\varphi_i + \sin\beta\sin\varphi_i)} |\omega| d\omega d\varphi_i \\ &= \frac{1}{\pi^2} \int_{-\infty}^{\infty} \int_{0}^{\pi} S_{\varphi_i}(\omega) e^{2j\omega\rho\cos(\beta - \varphi_i)} |\omega| d\omega d\varphi_i \\ &= \frac{2}{\pi} F^{-2}(|\omega|) * \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{0}^{\pi} S_{\varphi_i}(\omega) e^{2j\omega\rho\cos(\beta - \varphi_i)} d\varphi_i \end{aligned} \tag{53}$$

Where * denotes 2-D convolution. The final integral term in (53) represents the back-projection of the signal, restored from the frequency domain measurements without any filtering, i.e.

$$s_{\varphi_i}(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} S_{\varphi_i}(\omega) e^{2j\omega x} d\omega \tag{54}$$

But to restore the true function s(ρ, φi) one has to convolve the result of the back-projection with a point-spread function.

$$F^{-2}(|\omega|) = \rho^{-1}, \quad \rho = \sqrt{x^2 + y^2} \tag{55}$$

This algorithms allows the reconstruction of the image in two steps, one of which requires a two-dimensional convolution with a singular function. Where only a rough image of the body is required, the convolution may be omitted.

CHAPTER FIVE

CONCLUSION

5.1. Conclusion

Breast cancer is the most spread cancer happens for women these days. From every eight women in North America one of them suffering from breast cancer during her lifetime. Next years, it is expected that there will be great number of new cases of invasive breast cancer and about a huge number of deaths in the United States. Breast cancer is most easily treated when detected at an early stage.

Screening mammography is recently the main imaging modality available for the early detection of breast cancer. However, despite developments in mammographic methods, it has a number of limitations. These difficulties manifest themselves in the loss of three dimension data accompanied with projection images, short comes in sensitivity resulting to an unsuitable high rate of "missed" cancers, and in a high difficulty to determine whether a suspicious abnormality is benign or malignant. Such limitations lead to mammographers missing about 10% of all lesions. It is expected that two-thirds of these missed cancers are detected retrospectively by radiologists. Furthermore, approximately two-thirds of lesions checked out to biopsy reveal to be benign, the overall output of breast cancers per breast biopsy being about 10 to 50%. This has result in the investigation of alternative imaging methods, such as magnetic resonance imaging (MRI), ultrasound and computed tomography (CT), for early detection and diagnosis of breast cancer. While many medical imaging studies involved various criteria of breast imaging, these have mainly focused on mammography as well as other image analysis techniques. Also, most medical imaging investigations present a broad

spectrum of medical imaging subjects, with few investigations focused mainly on breast.

Table 5.1 Comparison between Mammography and other frequent methods of breast tumors detection

Population	**Women Aged ≥40 Years**			
Screening Method	**Digital and Film Mammography**	**Magnetic Resonance Imaging (MRI)**	**Clinical Breast Examination (CBE)**	**Breast Self-Examination (BSE)**
Potential Preventable Burden	For younger women and women with dense breast tissue, overall detection is somewhat better with digital mammography rather than film mammography.	Contrast-enhanced MRI has been shown to detect more cases of cancer in very high-risk populations than does mammography.	Indirect evidence suggests that when CBE is the only test available, it may detect a significant proportion of cancer cases.	Adequate evidence suggests that BSE does not reduce breast cancer mortality.
Potential Harms	overdiagnosis occurs with mammography.	Contrast-enhanced MRI requires injection of contrast material. MRI yields many more false-positive results and potentially more overdiagnosis	Contrast-enhanced MRI requires injection of contrast material. MRI yields many more false-positive results and potentially more overdiagnosis than mammography.	Harms of BSE include the same potential harms as for CBE and may be larger in magnitude.
Costs	Digital mammography is more expensive than film.	MRI is much more expensive than mammography.	MRI is not currently used to screen women of average risk.	Costs of BSE are primarily opportunity costs to clinicians.
Current Practice	Still film mammography is more frequent than any other equipment's.	MRI is not currently used to screen women of average risk.	No standard approach or reporting standards are in place	The number of clinicians who teach BSE to patients is unknown; it is likely that few clinicians teach BSE to all women.

Different kinds of methods for detection of breast cancer were reviewed. The results presented in this research reveals that CMI is an appropriate technique for diagnosis and detecting breast tumors in three dimensions. The presented image reconstruction

algorithms, are useful for both system configurations, and are comfortable ways to test the breast for tumors in 3D imaging.

Among the studies focused on breast cancer, some are focused on 2D mammography and others are more medically directed. Hence, they are not related cater to medical physicists, engineers, and scientists who are interested in introducing alternate methods to image the breast.

Table 5.2 Different studies to fabricate breast phantoms

Studies By	**Materials, used to fabricate phantom**	**Simulated Tissues**	**Notes**	**Disadvantages**	**Frequency**
(Guy, 1968)	Black acetylene, catalyst, powder of aluminum, laminac polyester resin	Low water content tissue	variety aluminum powder and black Acetylene to vary dielectric and conductivity values	difficult to fabricate	13.56 - 2450 MHz
(Johnson & Guy, 1972)	a polyester resin, acetylene black and aluminium powder	simulate bone and fat			100–1000 MHz
(Andreuccetti et al., 1988)	polyacrylamide gel as the chief ingredient		optical transparency and gel-like mechanical properties	complicated fabrication methods and chemicals Difficult to obtain.	
(Marchal, Nadi, Tosser, Roussey, & Gaulard, 1989)	polyacrylamide gel as the chief ingredient	high-water content tissues	varying the gelatin concentration to change dielectric value	Are not sTable over a long period of time	10 to 50 MHz
(Sunaga et al., 2003)	gelatin–water material, includes honey syrup and NaCl	simulate human skin	Varying gelatin concentration to change dielectric value	does not allow for heterogeneous phantoms	
(Lagendijk & Nilsson, 1985)	dough’	Fat and bone		difficult to use in a wideband application	451 MHz.
(Robinson, Richardson, Green, & Preece, 1991)	ethanediol, water, salt and gelatin, ethanediol,	Muscles		difficult to use in a wideband application	1000 MHz.
	gelatin and polyethylene powder	Fat			
	utilized silicone rubber with carbon fibre	muscle stimulant	varying the carbon fibres, change dielectric and conductivity value	difficult to use in a wideband application	
(Nikawa et al., 1996)	single polyacrylamide gel material				500 MHz to 3 GHz
(Chang, Fanning, Meaney, & Paulsen, 2000)	polyethyl methacrylate and carbon black	muscle	solid conductive plastic		300 to 900 MHz.

Both the planar and cylindrical configurations identify tumors with similar within-breast SC ratios and accurate detection of tumor site. Further studies conducted on the problems related to practical implementation of CMI will include anatomically realistic numerical breast models which exhibit high resolution MRI scans, same as the model used in two dimensions for the planar structure study, and experimental investigations exploiting tissue phantoms

To study breast cancer detection using different imaging techniques, different types of breast phantoms have been used by different studies, which have been explained in details in chapter four. Table 5.2 indicates different studies used to fabricate breast phantom to be used in different microwave frequencies.

5.2. Advantages of Confocal Microwave Technique over X-Ray Mammography

Confocal microwave pulse system as a technology of ultra-wide band radar provides a complementary (S. C. Hangess et al., 1999a) modulates to X-Ray Mammography with high specificity and sensitivity, a low cost screening method for early detection of breast cancer. This system even can detect small tumors that are not classified, including tumors are close to underarm and those considered as dense breast in radiology. Moreover this approach use safe-limited radio frequency exposure (ANSI/IEEE, 1992), noninvasive, does not need to compress the breast and avoids any exposure to ionizing-radiation. The low cost feature of this technique beside its comfort, safety and ease of use should allow frequent screening of patients and general public.

Microwave imaging technique overcomes the disadvantages of X-Ray Mammography. Although X-Ray Mammography known to be the best technique of breast cancer detection at early stages but this techniques in not known to be the best solution for

women under 50 years old. Thus; many doctors recommend this for older women. Confocal microwave imaging technique is an active microwave system, this method strongly believed to be used for detection of breast tumors at early stages on 1998.

High dielectric difference of lesion free normal breast tissue and malignant cancer tumors, also clear nature of breast tissue makes breast tissues to have unique properties to the microwave spectrum and confocal microwave to be unique and having advantage over ultrasound and X-Ray Mammography modalities Some advantages of confocal microwave techniques over X-Ray Mammography are related to zero ionization radiation exposure of these techniques. Need of having access only to one side of breast makes this technique more comfortable. Thus, this technique is safe, frequent monitoring progress of an individual treatment protocol and public frequent screening by using this technique will be recommended in the future. Small tumor that X-Ray Mammography fail to detect them can be detected by microwave equipment in conjunction to sensor array with studied dynamic range.

5.3. Future Works

First future works after this thesis will be Practical study on Detection of breast tumors using confocal microwave techniques by means of one, two or array of antennas in addition to the employment of any of the previously mentioned algorithms as an attempt to find out the shortage of the algorithm in order to cover it by suggesting an appropriate modification on the algorithm.

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RESULTS

Journals

Academic Radiology

Country: United States

Subject Area: Medicine

Subject Category: Radiology, Nuclear Medicine and Imaging Q2

Publisher: Association of University Radiologists. Publication type: Journals. ISSN: 10766332

Coverage: 1994-2011

H Index: 57

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.195	199	3450
2009	2.092	181	2958
2008	2.021	181	3027

Scope:

Academic Radiology publishes original reports of clinical and laboratory investigations in diagnostic imaging, the diagnostic use of radioactive isotopes, computed tomography, positron emission tomography, magnetic resonance imaging, ultrasound, digital subtraction angiography, and related technique

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,095	0,086	0,106	0,137	0,181	0,160	0,153	0,169	0,200	0,191	0,179	0,188	0,141
Total Documents	151	147	147	333	189	180	223	225	206	207	222	244	183
Total Docs. (3years)	683	527	552	445	627	669	702	592	628	654	638	635	673
Total References	1.774	2.487	2.593	4.721	3.420	3.740	4.961	4.520	4.443	4.868	5.291	5.466	4.663
Total Cites (3years)	456	397	491	525	859	1.040	1.133	1.034	1.289	1.282	1.248	1.265	705
Self Cites (3years)	49	68	73	96	222	149	181	121	182	151	140	177	49
Citable Docs. (3years)	651	492	502	402	561	599	622	528	564	598	585	591	626
Cites / Doc. (4years)	0,70	0,81	1,03	1,16	1,45	1,66	1,81	1,82	2,19	2,16	2,05	2,07	1,16
Cites / Doc. (3years)	0,70	0,81	0,98	1,31	1,53	1,74	1,82	1,96	2,29	2,14	2,13	2,14	1,13
Cites / Doc. (2years)	0,67	0,70	1,04	1,37	1,51	1,69	1,92	1,89	2,15	2,06	2,26	2,10	1,00
References / Doc.	11,75	16,92	17,64	14,18	18,10	20,78	22,25	20,09	21,57	23,52	23,83	22,40	25,48
Cited Docs.	232	196	218	202	356	384	405	350	390	394	395	385	333
Uncited Docs.	451	331	334	243	271	285	297	242	238	260	243	250	340
% International Collaboration	0,00	8,16	10,20	23,42	10,58	8,33	15,70	17,33	14,56	14,01	4,05	15,57	15,30

Advances in Anatomic Pathology

Country: United States

Subject Area: Medicine

Subject Category: Anatomy Q1, Pathology and Forensic Medicine Q1

Publisher: Lippincott Williams & Wilkins Ltd.. Publication type: Journals. ISSN: 15334031, 10724109

Coverage: 1998-2011

H Index: 40

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	3.087	40	1027
2009	3.221	39	933
2008	3.69	39	846

Scope:

An advance in Anatomic Pathology provides targeted coverage of the key developments in anatomic and surgical pathology. It covers subjects ranging from basic morphology to the most advanced molecular biology techniques. The journal selects and efficiently communicates the most important information from recent world literature and offers invaluable assistance in managing the increasing flow of information in pathology.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,080	0,206	0,287	0,313	0,344	0,278	0,285	0,327	0,387	0,362	0,365	0,360	0,304
Total Documents	29	36	34	30	32	33	38	60	53	41	43	44	35
Total Docs. (3years)	32	61	97	99	100	96	95	103	131	151	154	137	128
Total References	1.081	2.140	1.474	1.679	1.810	1.742	2.426	1.971	3.045	1.925	3.244	3.383	2.331
Total Cites (3years)	17	96	198	207	250	191	221	291	356	433	400	398	249
Self Cites (3years)	0	0	0	0	0	0	7	12	8	7	6	10	6
Citable Docs. (3years)	31	60	96	99	96	92	91	103	117	122	111	103	105
Cites / Doc. (4years)	0,55	1,60	2,06	1,96	2,54	2,19	2,27	2,82	2,99	3,45	3,52	3,70	2,31
Cites / Doc. (3years)	0,55	1,60	2,06	2,09	2,60	2,08	2,43	2,83	3,04	3,55	3,60	3,86	2,37
Cites / Doc. (2years)	0,55	1,60	2,14	2,09	2,65	1,97	2,17	2,86	3,07	3,33	4,00	3,92	2,44
References / Doc.	37,28	59,44	43,35	55,97	56,56	52,79	63,84	32,85	57,45	46,95	75,44	76,89	66,60
Cited Docs.	10	31	61	52	69	62	70	75	81	93	90	91	85
Uncited Docs.	22	30	36	47	31	34	25	28	50	58	64	46	43
% International Collaboration	0,00	0,00	0,00	0,00	0,00	0,00	5,26	11,67	9,43	4,88	11,63	11,36	25,71

American Surgeon

Country: United States

Subject Area: Medicine

Subject Category: Surgery Q1

Publisher: Lippincott Williams & Wilkins Ltd.. Publication type: Journals. ISSN: 15559823, 00031348

Coverage: 1951-2011

H Index: 62

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.363	238	5552
2009	1.154	204	5476
2008	1.297	204	5928

Scope:

The Southeastern Surgical Congress owns and publishes THE AMERICAN SURGEON monthly. It is the official journal of the Congress and the Southern California Chapter of the American College of Surgeons, which all members receive each month. The journal brings up to date clinical advances in surgical knowledge in a popular reference format

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,108	0,118	0,130	0,137	0,132	0,135	0,146	0,149	0,139	0,140	0,137	0,126	0,107
Total Documents	261	245	264	308	287	283	240	290	324	312	334	475	256
Total Docs. (3years)	748	772	773	770	817	859	878	810	813	854	926	970	1.121
Total References	4.177	4.612	2.887	3.745	4.243	4.423	4.210	4.748	5.441	4.830	4.779	5.739	3.340
Total Cites (3years)	865	1.061	1.190	1.316	1.236	1.201	1.206	1.267	1.196	1.153	1.091	1.051	549
Self Cites (3years)	40	48	32	41	50	43	24	43	48	51	35	39	26
Citable Docs. (3years)	728	745	744	747	755	780	788	757	744	733	720	672	643
Cites / Doc. (4years)	1,19	1,50	1,64	1,79	1,68	1,69	1,67	1,71	1,65	1,63	1,60	1,57	0,87
Cites / Doc. (3years)	1,19	1,42	1,60	1,76	1,64	1,54	1,53	1,67	1,61	1,57	1,52	1,56	0,85
Cites / Doc. (2years)	0,99	1,26	1,45	1,63	1,42	1,36	1,41	1,57	1,50	1,39	1,37	1,54	0,73
References / Doc.	16,00	18,82	10,94	12,16	14,78	15,63	17,54	16,37	16,79	15,48	14,31	12,08	13,05
Cited Docs.	391	429	464	488	468	473	467	479	465	474	464	449	339
Uncited Docs.	357	343	309	282	349	386	411	331	348	380	462	521	782
% International Collaboration	3,45	0,41	2,27	2,60	1,05	2,47	1,67	6,55	4,32	3,21	2,69	3,16	6,25

Annals of Surgical Oncology

Country: United States

Subject Area: Medicine

Subject Category: Oncology Q1

Publisher: Lippincott Williams & Wilkins Ltd.. Publication type: Journals. ISSN: 10689265, 15344681

Coverage: 1994-2011

H Index: 88

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	4.182	419	11090
2009	4.13	406	9632
2008	3.898	406	8085

Scope:

The Annals of Surgical Oncology is the official journal of The Society of Surgical Oncology and is published for the Society by Springer. The Annals publishes original and educational maunscripts about oncology for surgeons from all specialities in academic and community settings.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,235	0,255	0,321	0,319	0,369	0,520	0,459	0,443	0,403	0,442	0,507	0,461	0,358
Total Documents	161	146	175	174	212	232	179	243	491	584	537	567	676
Total Docs. (3years)	340	406	436	482	495	561	618	623	654	913	1.318	1.612	1.688
Total References	3.327	3.337	3.904	4.540	4.933	4.803	4.271	7.409	13.737	15.912	15.321	15.312	17.424
Total Cites (3years)	669	914	1.236	1.453	1.739	2.205	2.176	2.058	2.313	3.367	5.076	5.822	3.211
Self Cites (3years)	38	54	116	107	122	127	117	159	242	395	526	446	219
Citable Docs. (3years)	301	328	332	365	393	434	465	463	515	776	1.053	1.270	1.260
Cites / Doc. (4years)	2,22	2,79	3,48	3,79	4,41	5,18	4,87	4,58	4,78	4,44	4,79	4,68	2,57
Cites / Doc. (3years)	2,22	2,79	3,72	3,98	4,42	5,08	4,68	4,44	4,49	4,34	4,82	4,58	2,55
Cites / Doc. (2years)	2,18	2,90	3,85	3,97	3,98	4,70	4,33	3,83	4,36	4,23	4,58	4,48	2,38
References / Doc.	20,66	22,86	22,31	26,09	23,27	20,70	23,86	30,49	27,98	27,25	28,53	27,01	25,78
Cited Docs.	225	254	300	340	379	420	467	452	485	717	1.024	1.223	1.047
Uncited Docs.	115	152	136	142	116	141	151	171	169	196	294	389	641
% International Collaboration	5,59	6,16	0,57	8,05	8,96	6,03	10,06	7,41	8,76	9,42	9,68	10,76	12,57

Anticancer Research

Country: Greece

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q3, Oncology Q2

Publisher: International Institute of Anticancer Research. Publication type: Journals. ISSN: 02507005

Coverage: 1981-2011

H Index: 75

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.656	735	12437
2009	1.428	741	11382
2008	1.39	741	11366

Scope:

ANTICANCER RESEARCH is an independent international peer-reviewed journal devoted to the rapid publication of high quality original articles and reviews on all aspects of experimental and clinical oncology. Prompt evaluation of all submitted articles in confidence and rapid publication within 1-2 months of acceptance are guaranteed.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,230	0,215	0,260	0,259	0,231	0,249	0,243	0,232	0,197	0,175	0,174	0,191	0,176
Total Documents	878	832	653	658	778	580	700	763	665	539	751	759	353
Total Docs. (3years)	2.145	2.411	2.474	2.363	2.143	2.089	2.016	2.058	2.043	2.128	1.967	1.955	2.049
Total References	26.890	23.223	19.977	19.065	23.595	17.419	20.756	22.058	20.067	16.536	23.898	22.210	10.401
Total Cites (3years)	3.127	3.539	3.922	3.966	3.583	3.557	3.601	3.703	3.124	3.058	3.030	3.364	2.161
Self Cites (3years)	425	430	385	306	361	286	353	343	286	220	295	258	181
Citable Docs. (3years)	2.126	2.390	2.455	2.352	2.138	2.082	2.007	2.043	1.979	2.055	1.896	1.928	2.011
Cites / Doc. (4years)	1,47	1,49	1,62	1,69	1,68	1,72	1,79	1,76	1,61	1,52	1,55	1,67	1,06
Cites / Doc. (3years)	1,47	1,48	1,60	1,69	1,68	1,71	1,79	1,81	1,58	1,49	1,60	1,74	1,07
Cites / Doc. (2years)	1,39	1,34	1,50	1,55	1,49	1,57	1,82	1,69	1,46	1,48	1,57	1,78	1,07
References / Doc.	30,63	27,91	30,59	28,97	30,33	30,03	29,65	28,91	30,18	30,68	31,82	29,26	29,46
Cited Docs.	1.284	1.436	1.505	1.512	1.408	1.375	1.357	1.418	1.255	1.309	1.225	1.315	1.046
Uncited Docs.	861	975	969	851	735	714	659	640	788	819	742	640	1.003
% International Collaboration	13,90	6,01	0,00	6,99	13,50	18,45	17,29	15,60	23,31	30,80	26,23	16,60	21,53

AP-S International Symposium (Digest) (IEEE Antennas and Propagation Society)

Country: United States

Subject Area: Engineering

Subject Category: Electrical and Electronic Engineering Q4

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Conferences and Proceedings. ISSN: 02724693

Coverage: 1978-1981, 1983-1991, 1993-1998, 2000-2007, 2009

H Index: 30

Scope:

Covers all areas relating to antenna theory, design, and practice: propagation, including theory, effects, and system considerations; analytical and computational electromagnetics, scattering diffraction, and radar cross sections; and all relationships of these areas to applications, including telecommunications, broadcasting, electromagnetic effects on systems, and design and measurement techniques.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,049	0,045	0,049	0,051	0,054	0,055	0,052	0,051	0,045	0,038	0,037	0,028	0,025
Total Documents	0	580	758	793	998	1.147	1.343	533	1.344	0	943	0	0
Total Docs. (3years)	1.741	1.208	1.154	1.338	2.131	2.549	2.938	3.488	3.023	3.220	1.877	2.287	943
Total References	0	2.852	3.747	4.077	5.406	6.385	7.119	2.957	7.356	0	5.271	0	0
Total Cites (3years)	117	114	193	244	624	875	1.139	953	1.123	761	569	338	0
Self Cites (3years)	0	0	81	94	195	263	236	110	180	0	37	0	0
Citable Docs. (3years)	1.730	1.200	1.146	1.330	2.119	2.537	2.926	3.471	3.010	3.209	1.875	2.283	941
Cites / Doc. (4years)	0,07	0,09	0,15	0,16	0,29	0,33	0,37	0,29	0,39	0,26	0,29	0,17	0,07
Cites / Doc. (3years)	0,07	0,10	0,17	0,18	0,29	0,34	0,39	0,27	0,37	0,24	0,30	0,15	0,00
Cites / Doc. (2years)	0,07	0,09	0,20	0,18	0,32	0,37	0,37	0,25	0,33	0,22	0,28	0,00	0,00
References / Doc.	0,00	4,92	4,94	5,14	5,42	5,57	5,30	5,55	5,47	0,00	5,59	0,00	0,00
Cited Docs.	95	95	155	187	405	547	670	627	649	553	372	229	0
Uncited Docs.	1.646	1.113	999	1.151	1.726	2.002	2.268	2.861	2.374	2.667	1.505	2.058	943
% International Collaboration	0,00	0,00	0,00	0,00	10,52	10,55	12,51	14,45	15,03	0,00	16,65	0,00	0,00

Biochimica et Biophysica Acta - Reviews on Cancer

Country: Netherlands

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Biophysics Q1, Cancer Research Q1, Oncology Q1

Publisher: Elsevier BV. Publication type: Journals. ISSN: 0304419X

Coverage: 1974-2011

H Index: 84

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	9.886	49	2791
2009	11.685	43	2271
2008	10.283	43	2100

Scope:

BBA Reviews on Cancer covers the whole field of the biology and biochemistry of cancer, emphasizing oncogenes and tumor suppressor

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	6,205	4,818	2,001	1,060	4,154	5,882	4,494	3,142	1,505	2,101	2,308	2,198	1,407
Total Documents	34	26	25	15	10	27	21	35	31	30	44	51	38
Total Docs. (3years)	119	109	93	85	66	50	52	58	83	87	96	105	125
Total References	965	1.527	2.259	2.017	1.653	3.716	3.445	5.514	5.240	5.292	6.411	6.296	5.903
Total Cites (3years)	1.293	982	595	552	675	731	709	680	634	839	963	1.164	761
Self Cites (3years)	6	1	3	5	1	2	5	6	6	7	5	15	10
Citable Docs. (3years)	104	91	65	54	41	39	50	55	78	80	89	100	123
Cites / Doc. (4years)	12,43	10,89	10,66	10,14	11,49	18,73	14,84	12,83	9,67	10,02	10,45	10,68	6,76
Cites / Doc. (3years)	12,43	10,79	9,15	10,22	16,46	18,74	14,18	12,36	8,13	10,49	10,82	11,64	6,19
Cites / Doc. (2years)	12,02	7,11	8,25	15,92	15,07	19,56	13,54	9,73	7,32	10,90	11,77	10,22	5,76
References / Doc.	28,38	58,73	90,36	134,47	165,30	137,63	164,05	157,54	169,03	176,40	145,70	123,45	155,34
Cited Docs.	95	74	62	57	53	46	45	54	76	79	86	97	113
Uncited Docs.	24	35	31	28	13	4	7	4	7	8	10	8	12
% International Collaboration	11,76	0,00	24,00	13,33	10,00	7,41	19,05	11,43	22,58	6,67	27,27	17,65	7,89

Bioelectromagnetics

Country: United States

Subject Area: Agricultural and Biological Sciences | Biochemistry, Genetics and Molecular Biology

Subject Ctegory: Agricultural and Biological Sciences (miscellaneous) Q1 , Biophysics Q2

Publisher: John Wiley & Sons Inc.. Publication type: Journals. ISSN: 01978462, 1521186X

Coverage: 1980-2011

H Index: 48

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.291	75	2251
2009	2.759	77	2536
2008	2.062	77	1999

Scope: Bioelectromagnetics is published by Wiley-Liss, Inc., for the Bioelectromagnetics Society and is the official journal of the Bioelectromagnetics Society and the European Bioelectromagnetics Association. It is a peer-reviewed, internationally circulated scientific journal that specializes in reporting original data on biological effects and applications of electromagnetic fields that range in frequency from zero hertz (static fields) to the terahertz undulations of visible light. and theories of field-body interactions

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,162	0,178	0,141	0,128	0,124	0,136	0,162	0,151	0,155	0,138	0,141	0,144	0,130
Total Documents	74	72	86	78	90	95	107	90	93	83	86	80	86
Total Docs. (3years)	207	213	207	232	236	254	263	292	292	290	266	262	249
Total References	2.083	1.942	2.613	2.056	3.485	2.311	3.555	2.456	2.346	2.260	2.693	2.282	2.854
Total Cites (3years)	383	419	407	301	423	415	593	607	608	544	639	559	330
Self Cites (3years)	86	81	76	79	111	91	178	115	129	110	112	89	86
Citable Docs. (3years)	204	210	205	230	229	240	242	267	265	260	235	232	225
Cites / Doc. (4years)	1,88	1,87	2,20	1,58	1,81	1,79	2,37	2,31	2,56	2,10	2,63	2,41	1,50
Cites / Doc. (3years)	1,88	2,00	1,99	1,31	1,85	1,73	2,45	2,27	2,29	2,09	2,72	2,41	1,47
Cites / Doc. (2years)	2,03	1,78	1,54	1,21	1,86	1,59	2,47	1,86	2,18	2,12	2,65	2,41	1,34
References / Doc.	28,15	26,97	30,38	26,36	38,72	24,33	33,22	27,29	25,23	27,23	31,31	28,53	33,19
Cited Docs.	132	143	140	137	168	162	186	199	203	194	180	182	150
Uncited Docs.	75	70	67	95	68	92	77	93	89	96	86	80	99
% International Collaboration	8,11	16,67	9,30	19,23	8,89	14,74	17,76	14,44	23,66	21,69	15,12	16,25	12,79

Breast Cancer Research

Country: United States

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1, Oncology Q1

Publisher: Current Science Inc.. Publication type: Journals. ISSN: 14655411, 1465542X

Coverage: 1999-2011

H Index: 67

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	5.785	130	5728
2009	5.326	110	4644
2008	5.052	110	3811

Scope: Breast Cancer Research is an international, peer-reviewed online journal, publishing original research, reviews, commentaries and reports. Research articles of exceptional interest are published in all areas of biology and medicine relevant to breast cancer, including normal mammary gland biology, with special emphasis on the genetic, biochemical, and cellular basis of breast cancer. In addition, the journal publishes clinical studies with a biological basis, including Phase I and Phase II trials.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,040	0,329	0,709	0,687	0,616	0,695	0,712	0,823	0,887	0,940	1,070	0,681
Total Documents	28	92	70	48	104	118	171	102	135	185	154	175	74
Total Docs. (3years)	0	28	120	190	210	222	270	393	391	408	422	474	514
Total References	417	2.854	2.124	1.381	2.048	1.946	2.262	3.878	3.862	7.437	5.707	6.356	0
Total Cites (3years)	0	4	86	431	544	673	927	1.516	1.602	1.871	2.075	2.509	1.343
Self Cites (3years)	0	0	9	10	11	5	22	51	30	103	90	89	0
Citable Docs. (3years)	0	10	64	124	161	203	253	368	367	378	375	412	441
Cites / Doc. (4years)	0,00	0,40	1,34	3,48	3,33	3,65	3,77	4,05	4,22	5,09	5,20	6,06	3,35
Cites / Doc. (3years)	0,00	0,40	1,34	3,48	3,38	3,32	3,66	4,12	4,37	4,95	5,53	6,09	3,05
Cites / Doc. (2years)	0,00	0,40	1,34	3,54	3,03	2,92	3,70	4,25	4,08	5,32	5,45	5,53	2,52
References / Doc.	14,89	31,02	30,34	28,77	19,69	16,49	13,23	38,02	28,61	40,20	37,06	36,32	0,00
Cited Docs.	0	2	43	108	140	172	210	312	317	335	350	381	344
Uncited Docs.	0	26	77	82	70	50	60	81	74	73	72	93	170
% International Collaboration	3,57	5,43	10,00	10,42	9,62	4,24	7,60	26,47	17,04	26,49	22,08	29,71	0,00

Breast Cancer Research and Treatment

Country: Netherlands

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1, Oncology Q1

Publisher: Kluwer Academic Publishers. Publication type: Journals. ISSN: 01676806, 15737217

Coverage: 1981-2011

H Index: 79

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	4.859	535	11164
2009	4.696	394	9695
2008	5.684	394	9299

Scope: Breast Cancer Research and Treatment provides the surgeon, radiotherapist, medical oncologist, endocrinologist, epidemiologist, immunologist or cell biologist investigating problems in breast cancer a single forum for communication. The journal creates a `market place for breast cancer topics which cuts across all the usual lines of disciplines, providing a site for presenting pertinent investigations and for discussing critical questions relevant to the entire field. It seeks to develop a new focus and new perspectives for all those concerned with breast cancer.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,380	0,454	0,554	0,273	0,247	0,276	0,511	0,547	0,585	0,574	0,576	0,631	0,481
Total Documents	166	151	589	180	227	180	236	249	265	369	453	663	705
Total Docs. (3years)	469	479	495	906	920	996	587	643	665	750	883	1.087	1.485
Total References	5.780	5.763	5.068	5.856	7.840	6.453	7.570	8.327	9.928	13.557	16.272	21.850	22.929
Total Cites (3years)	1.086	1.232	1.424	1.407	1.467	1.670	1.811	2.165	2.275	2.798	3.314	4.495	3.358
Self Cites (3years)	92	69	80	44	65	56	103	85	136	147	209	453	455
Citable Docs. (3years)	453	466	483	897	909	979	572	617	629	704	812	976	1.260
Cites / Doc. (4years)	2,40	2,75	2,89	1,95	1,79	1,86	2,09	3,38	3,47	3,92	4,03	4,47	2,64
Cites / Doc. (3years)	2,40	2,64	2,95	1,57	1,61	1,71	3,17	3,51	3,62	3,97	4,08	4,61	2,67
Cites / Doc. (2years)	2,07	2,45	2,49	1,23	1,31	2,56	3,12	3,52	3,49	3,81	4,10	4,72	2,53
References / Doc.	34,82	38,17	8,60	32,53	34,54	35,85	32,08	33,44	37,46	36,74	35,92	32,96	32,52
Cited Docs.	333	354	383	429	438	480	449	500	544	633	726	908	1.088
Uncited Docs.	136	125	112	477	482	516	138	143	121	117	157	179	397
% International Collaboration	15,06	10,60	10,53	26,67	18,50	13,33	25,00	22,89	27,92	29,27	26,49	25,94	25,53

Ca-A Cancer Journal for Clinicians

Country: United States

Subject Area: Medicine

Subject Category: Oncology Q1

Publisher: Lippincott Williams & Wilkins Ltd.. Publication type: Journals. ISSN: 00079235, 15424863

Coverage: 1957-2011

H Index: 83

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	94.262	18	9801
2009	87.925	23	8528
2008	74.575	23	7522

Scope: CA: A Cancer Journal for Clinicians is a peer-reviewed journal of the American Cancer Society providing cancer care professionals with up-to-date information on all aspects of cancer diagnosis, treatment, and prevention. Published six times per year, CA is the most widely circulated oncology journal in the world, with a circulation of approximately 88,000, including primary care physicians; medical, surgical, and radiation oncologists; nurses; other health care and public health professionals; and students in various health care fields.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	2,462	2,320	3,346	3,075	3,558	4,124	5,267	7,061	8,856	11,662	11,518	11,620	9,895
Total Documents	32	35	42	39	42	28	34	43	41	34	39	38	21
Total Docs. (3years)	104	103	104	109	116	123	109	104	105	118	118	114	111
Total References	1.338	1.354	1.316	1.307	1.443	1.637	1.477	1.857	1.943	1.848	2.218	2.410	840
Total Cites (3years)	1.224	1.340	1.489	1.750	1.782	2.067	2.454	3.374	3.838	4.881	4.699	5.374	3.499
Self Cites (3years)	5	12	6	3	16	21	15	13	18	18	20	28	7
Citable Docs. (3years)	67	69	66	72	68	71	66	68	62	62	59	63	63
Cites / Doc. (4years)	18,27	16,75	19,51	21,88	24,36	26,30	30,83	43,53	49,03	64,19	82,77	74,28	47,87
Cites / Doc. (3years)	18,27	19,42	22,56	24,31	26,21	29,11	37,18	49,62	61,90	78,73	79,64	85,30	55,54
Cites / Doc. (2years)	21,31	22,52	25,74	26,58	28,61	36,80	41,54	65,93	80,17	78,73	96,58	103,43	61,57
References / Doc.	41,81	38,69	31,33	33,51	34,36	58,46	43,44	43,19	47,39	54,35	56,87	63,42	40,00
Cited Docs.	73	73	59	55	65	62	68	60	61	64	64	77	63
Uncited Docs.	31	30	45	54	51	61	41	44	44	54	54	37	48
% International Collaboration	9,38	28,57	14,29	10,26	2,38	10,71	8,82	9,30	12,20	8,82	15,38	10,53	4,76

Cancer Epidemiology Biomarkers and Prevention

Country: United States

Subject Area: Medicine

Subject Category: Epidemiology Q1

Publisher: American Association for Cancer Research. Publication type: Journals. ISSN: 10559965

Coverage: 1991-2011

H Index: 118

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	4.19	337	18052
2009	4.31	429	16984
2008	4.77	429	15330

Scope:

Cancer Epidemiology, Biomarkers & Prevention publishes original, peer-reviewed research on cancer causation, mechanisms of carcinogenesis, prevention, and survivorship.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,517	0,575	0,714	0,886	0,763	0,888	0,747	0,650	0,731	0,711	0,665	0,636	0,488
Total Documents	167	203	207	256	257	337	522	460	476	520	507	391	226
Total Docs. (3years)	462	520	553	577	666	720	850	1.116	1.319	1.458	1.456	1.503	1.418
Total References	6.324	7.716	6.906	8.930	8.305	11.744	18.739	16.894	16.594	19.083	18.680	13.777	7.714
Total Cites (3years)	1.565	2.104	2.383	3.212	3.412	3.612	4.111	4.743	5.838	6.500	6.027	5.907	3.411
Self Cites (3years)	133	241	200	282	252	312	570	505	529	566	459	344	197
Citable Docs. (3years)	427	479	518	549	631	672	788	1.018	1.187	1.287	1.299	1.346	1.285
Cites / Doc. (4years)	3,67	4,43	4,58	5,83	5,49	5,62	5,57	5,00	4,96	5,11	4,82	4,60	2,77
Cites / Doc. (3years)	3,67	4,39	4,60	5,85	5,41	5,38	5,22	4,66	4,92	5,05	4,64	4,39	2,65
Cites / Doc. (2years)	3,48	4,38	4,25	5,59	5,00	4,79	4,44	4,49	4,74	4,74	4,25	4,06	2,57
References / Doc.	37,87	38,01	33,36	34,88	32,32	34,85	35,90	36,73	34,86	36,70	36,84	35,24	34,13
Cited Docs.	358	425	465	507	573	616	723	958	1.132	1.238	1.219	1.241	1.055
Uncited Docs.	104	95	88	70	93	104	127	158	187	220	237	262	363
% International Collaboration	19,76	13,30	0,00	2,73	31,52	26,71	37,36	38,26	34,24	35,19	31,36	38,36	33,19

Cochrane Database of Systematic Reviews

Country: United States

Subject Area: Medicine

Subject Category: Medicine (miscellaneous) Q1

Publisher: John Wiley & Sons Inc.. Publication type: Journals. ISSN: 1469493X

Coverage: 2000-2011

H Index: 63

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	6.186	749	27366
2009	5.653	602	23102
2008	5.182	602	19444

Scope:

The Cochrane Database of Systematic Reviews (CDSR) is the leading resource for systematic reviews in health care. The CDSR includes all Cochrane Reviews (and protocols) prepared by Cochrane Review Groups in The Cochrane Collaboration. Each Cochrane Review is a peer-reviewed systematic review that has been prepared and supervised by a Cochrane Review Group (editorial team) in The Cochrane Collaboration according to the Cochrane Handbook for Systematic Reviews of Interventions or Cochrane Handbook for Diagnostic Test Accuracy Reviews

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,000	0,079	0,098	0,110	0,139	0,141	0,171	0,096	0,142	0,169	0,175	0,174
Total Documents	0	1.008	508	453	382	520	529	802	1.785	1.584	1.897	659	337
Total Docs. (3years)	0	0	1.008	1.516	1.969	1.343	1.355	1.431	1.851	3.116	4.171	5.266	4.140
Total References	0	22.073	24.198	23.964	22.037	31.384	34.615	48.230	98.893	90.648	114.764	41.219	0
Total Cites (3years)	0	0	667	1.152	2.119	2.042	1.794	2.190	1.745	4.629	9.178	11.231	5.972
Self Cites (3years)	0	0	0	0	0	0	0	0	0	0	508	0	0
Citable Docs. (3years)	0	0	1.008	1.516	1.969	1.343	1.354	1.430	1.849	3.115	4.170	5.266	4.140
Cites / Doc. (4years)	0,00	0,00	0,66	0,76	1,08	1,37	1,28	1,42	0,89	1,38	2,11	2,30	1,43
Cites / Doc. (3years)	0,00	0,00	0,66	0,76	1,08	1,52	1,32	1,53	0,94	1,49	2,20	2,13	1,44
Cites / Doc. (2years)	0,00	0,00	0,66	0,76	1,06	1,66	1,26	1,52	1,06	1,61	2,08	1,98	1,45
References / Doc.	0,00	21,90	47,63	52,90	57,69	60,35	65,43	60,14	55,40	57,23	60,50	62,55	0,00
Cited Docs.	0	0	300	505	814	658	678	904	759	1.412	2.281	2.711	1.836
Uncited Docs.	0	0	708	1.011	1.155	685	677	527	1.092	1.704	1.890	2.555	2.304
% International Collaboration	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,12	11,99	26,99	0,15	0,00

Critical Reviews in Oncology/Hematology

Country: Ireland

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1, Hematology Q1, Oncology Q1

Publisher: Elsevier Scientific Publishers Ireland. Publication type: Journals. ISSN: 10408428

Coverage: 1983-2011

H Index: 69

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	4.689	76	3986
2009	5.269	87	3690
2008	4.589	87	3237

Scope:

Critical Reviews in Oncology/Hematology publishes scholarly, critical reviews in all fields of oncology and hematology, and reviews and original research articles in the field of geriatric oncology. Most of the reviews are written on invitation. All reviews and original research articles are subject to peer review before final acceptance.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,348	0,267	0,294	0,434	0,555	0,503	0,559	0,621	0,826	0,713	0,715	0,591	0,450
Total Documents	66	71	93	105	122	75	89	87	93	106	102	117	141
Total Docs. (3years)	98	133	182	230	269	320	302	286	251	269	286	301	325
Total References	5.757	6.355	6.941	9.349	10.063	8.745	9.096	8.590	8.408	8.704	7.962	7.001	5.804
Total Cites (3years)	143	163	320	572	893	1.037	1.174	1.205	1.315	1.364	1.594	1.420	770
Self Cites (3years)	7	10	11	15	16	16	8	28	34	26	31	24	27
Citable Docs. (3years)	86	118	161	215	252	306	290	277	244	264	280	281	273
Cites / Doc. (4years)	1,66	1,50	2,04	2,57	3,21	3,44	3,96	4,47	4,62	5,21	5,52	4,99	2,93
Cites / Doc. (3years)	1,66	1,38	1,99	2,66	3,54	3,39	4,05	4,35	5,39	5,17	5,69	5,05	2,82
Cites / Doc. (2years)	1,78	1,28	2,08	3,13	3,43	3,23	3,71	5,11	5,18	4,95	5,85	4,80	2,34
References / Doc.	87,23	89,51	74,63	89,04	82,48	116,60	102,20	98,74	90,41	82,11	78,06	59,84	41,16
Cited Docs.	54	72	105	154	198	240	243	231	224	239	258	249	222
Uncited Docs.	44	61	77	76	71	80	59	55	27	30	28	52	103
% International Collaboration	7,58	8,45	11,83	16,19	16,39	13,33	56,18	19,54	22,58	26,42	17,65	21,37	18,44

Current Oncology

Country: Canada

Subject Area: Medicine

Subject Category: Oncology Q2

Publisher: Multimed, Inc.. Publication type: Journals. ISSN: 11980052

Coverage: 1998-2011

H Index: 14

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	4.386	86	2519
2009	4.088	82	2389
2008	4.116	82	2219

Scope:

Controversies and Hypotheses Clinical guidelines and consensus statements Short Communications: These should be no longer than six double-spaced typewritten pages, including key references. Letters to the Editor: Comments on papers published in Current Oncology or on any other matters of interest to oncology. These should not be more than two pages long (including the literature) and their publication is based only on the decision of the Editor, who occasionally asks experts on the merit of the contents.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,044	0,047	0,056	0,042	0,046	0,048	0,037	0,039	0,053	0,104	0,174	0,206	0,140
Total Documents	37	36	19	16	25	17	17	36	28	61	67	115	43
Total Docs. (3years)	48	85	121	92	71	60	58	59	70	81	125	156	243
Total References	699	754	558	551	719	566	747	1.093	821	1.878	1.941	2.704	1.286
Total Cites (3years)	0	6	15	6	16	10	6	11	15	76	146	242	208
Self Cites (3years)	0	0	4	1	4	1	2	0	1	8	2	8	6
Citable Docs. (3years)	36	65	95	77	63	56	54	53	57	63	97	125	199
Cites / Doc. (4years)	0,00	0,09	0,16	0,12	0,24	0,14	0,11	0,22	0,23	0,96	1,32	1,86	1,08
Cites / Doc. (3years)	0,00	0,09	0,16	0,08	0,25	0,18	0,11	0,21	0,26	1,21	1,51	1,94	1,05
Cites / Doc. (2years)	0,00	0,09	0,20	0,10	0,24	0,13	0,10	0,13	0,34	1,39	1,67	1,76	0,93
References / Doc.	18,89	20,94	29,37	34,44	28,76	33,29	43,94	30,36	29,32	30,79	28,97	23,51	29,91
Cited Docs.	0	3	13	6	13	10	5	9	10	31	60	84	91
Uncited Docs.	48	82	108	86	58	50	53	50	60	50	65	72	152
% International Collaboration	0,00	0,00	0,00	6,25	8,00	5,88	23,53	13,89	21,43	14,75	7,46	5,22	11,63

Electronics and Communications in Japan

Country: United States

Subject Area: Computer Science | Engineering | Mathematics | Physics and Astronomy

Subject Category: Applied Mathematics Q4, Computer Networks and Communications Q4, Electrical and Electronic Engineering Q4, Physics and Astronomy (miscellaneous) Q4, Signal Processing Q4

Publisher: Scripta Technica. Publication type: Journals. ISSN: 19429533

Coverage: 2008-2011

H Index: 2

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	N/A	N/A	N/A
2009	0.141	0	84
2008	0.067	0	73

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,025	0,026	0,030
Total Documents	0	0	0	0	0	0	0	0	0	29	81	81	62
Total Docs. (3years)	0	0	0	0	0	0	0	0	0	0	29	110	191
Total References	0	0	0	0	0	0	0	0	0	417	1.191	1.110	886
Total Cites (3years)	0	0	0	0	0	0	0	0	0	0	1	13	13
Self Cites (3years)	0	0	0	0	0	0	0	0	0	0	0	0	1
Citable Docs. (3years)	0	0	0	0	0	0	0	0	0	0	29	109	189
Cites / Doc. (4years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,12	0,07
Cites / Doc. (3years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,12	0,07
Cites / Doc. (2years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,12	0,06
References / Doc.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	14,38	14,70	13,70	14,29
Cited Docs.	0	0	0	0	0	0	0	0	0	0	1	11	12
Uncited Docs.	0	0	0	0	0	0	0	0	0	0	28	99	179
% International Collaboration	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,47	2,47	0,00

Endocrine-Related Cancer

Country: United Kingdom

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1, Endocrinology Q1, Endocrinology, Diabetes and Metabolism Q1, Oncology Q1

Publisher: Society for Endocrinology. Publication type: Journals. ISSN: 13510088

Coverage: 1994-2011

H Index: 72

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	4.432	111	3909
2009	4.282	103	3434
2008	5.236	103	3080

Scope: Endocrine-Related Cancer offers a global forum for basic, clinical and experimental investigations which concern hormones and cancer in human and animal subjects. Endocrine-Related Cancer publishes all aspects of basic, translational and clinical research in hormone-dependent cancers, and in cancers of endocrine organs. The journal publishes reviews, together with original research papers of exceptional quality. Case reports are only considered if they are of extraordinary interest and reveal a new mechanism of disease

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,162	0,253	0,645	1,185	2,062	1,209	0,914	0,863	0,956	0,882	0,823	0,623	0,586
Total Documents	63	20	30	28	57	65	98	106	93	93	106	114	40
Total Docs. (3years)	110	142	114	113	78	115	150	220	269	297	292	292	313
Total References	3.043	2.341	2.301	2.601	3.929	5.403	6.257	7.338	5.044	5.586	6.021	6.866	2.103
Total Cites (3years)	92	173	379	647	621	708	783	1.225	1.558	1.772	1.567	1.420	901
Self Cites (3years)	14	16	3	12	14	32	46	69	45	58	38	56	25
Citable Docs. (3years)	90	121	107	108	68	106	139	215	263	292	286	286	305
Cites / Doc. (4years)	1,02	1,39	2,91	4,96	7,05	7,03	6,62	5,72	5,88	6,17	5,71	5,47	2,93
Cites / Doc. (3years)	1,02	1,43	3,54	5,99	9,13	6,68	5,63	5,70	5,92	6,07	5,48	4,97	2,95
Cites / Doc. (2years)	1,03	1,62	4,18	6,83	9,10	4,92	5,38	5,84	5,58	5,63	4,54	4,70	2,85
References / Doc.	48,30	117,05	76,70	92,89	68,93	83,12	63,85	69,23	54,24	60,06	56,80	60,23	52,58
Cited Docs.	43	71	87	96	61	90	127	194	243	267	261	260	258
Uncited Docs.	67	71	27	17	17	25	23	26	26	30	31	32	55
% International Collaboration	14,29	0,00	0,00	7,14	29,82	16,92	23,47	22,64	40,86	33,33	28,30	30,70	47,50

European Journal of Cancer

Country: Netherlands

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1 , Hematology Q1 , Oncology Q1

Publisher: Elsevier BV. Publication type: Journals. ISSN: 09598049

Coverage: 1990-2011

H Index: 125

Scope:

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.138	116	1008
2009	1.1	83	842
2008	0.985	83	759

The European Journal of Cancer (including EJC Supplements), is an international comprehensive oncology journal that publishes original research, editorial comments, review articles and news on experimental oncology, clinical oncology (medical, paediatric, radiation, surgical), translational oncology, and on cancer epidemiology and prevention. The Journal now has online submission for authors.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,414	0,407	0,474	0,421	0,411	0,446	0,496	0,591	0,687	0,652	0,589	0,575	0,520
Total Documents	331	418	582	443	377	386	363	431	349	351	460	393	344
Total Docs. (3years)	1.542	1.331	1.237	1.331	1.443	1.402	1.206	1.126	1.180	1.143	1.131	1.160	1.204
Total References	11.625	11.773	13.712	13.132	11.383	12.531	15.716	16.240	12.718	12.846	17.238	15.420	7.453
Total Cites (3years)	3.332	3.165	3.543	3.782	4.146	4.390	4.231	4.685	5.040	5.245	4.812	5.118	3.485
Self Cites (3years)	111	112	180	135	155	160	112	164	146	140	187	165	81
Citable Docs. (3years)	1.322	1.137	1.073	1.198	1.307	1.262	1.077	998	1.085	1.090	1.096	1.126	1.160
Cites / Doc. (4years)	2,52	2,83	3,29	3,24	3,35	3,52	3,65	4,43	4,53	4,69	4,62	4,56	2,91
Cites / Doc. (3years)	2,52	2,78	3,30	3,16	3,17	3,48	3,93	4,69	4,65	4,81	4,39	4,55	3,00
Cites / Doc. (2years)	2,18	2,50	3,24	2,83	2,95	3,67	4,02	4,57	4,67	4,39	4,20	4,58	3,07
References / Doc.	35,12	28,17	23,56	29,64	30,19	32,46	43,29	37,68	36,44	36,60	37,47	39,24	21,67
Cited Docs.	927	889	844	859	918	885	874	877	928	922	921	955	902
Uncited Docs.	615	442	393	472	525	517	332	249	252	221	210	205	302
% International Collaboration	21,15	16,27	17,87	22,35	32,10	20,47	24,52	31,09	34,96	34,76	32,39	37,66	22,09

IEEE Antennas and Wireless Propagation Letters

Country: United States

Subject Area: Computer Science | Engineering

Subject Category: Computer Networks and Communications Q1, Electrical and Electronic Engineering Q1

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Journals. ISSN: 15361225

Coverage: 2002-2011

H Index: 39

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.031	297	1713
2009	1.3	341	1586
2008	1.312	341	1246

Scope:

A rapid-dissemination publication containing short manuscripts on new research results and technical developments in the areas of antennas and wireless propagation.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,000	0,000	0,000	0,103	0,117	0,144	0,160	0,133	0,145	0,105	0,095	0,216
Total Documents	0	0	0	65	103	102	133	147	173	208	367	322	175
Total Docs. (3years)	0	0	0	0	65	168	270	338	382	453	528	748	897
Total References	0	0	0	574	897	901	1.242	1.435	1.740	2.154	4.177	3.713	2.138
Total Cites (3years)	0	0	0	0	71	224	506	622	913	869	1.069	1.679	920
Self Cites (3years)	0	0	0	0	18	22	42	53	56	77	149	190	112
Citable Docs. (3years)	0	0	0	0	61	160	262	332	378	447	523	742	887
Cites / Doc. (4years)	0,00	0,00	0,00	0,00	1,16	1,40	1,93	2,04	2,49	2,05	2,19	2,30	1,04
Cites / Doc. (3years)	0,00	0,00	0,00	0,00	1,16	1,40	1,93	1,87	2,42	1,94	2,04	2,26	1,04
Cites / Doc. (2years)	0,00	0,00	0,00	0,00	1,16	1,40	1,67	1,72	2,23	1,78	1,89	2,22	0,94
References / Doc.	0,00	0,00	0,00	8,83	8,71	8,83	9,34	9,76	10,06	10,36	11,38	11,53	12,22
Cited Docs.	0	0	0	0	24	86	167	210	262	296	354	517	431
Uncited Docs.	0	0	0	0	41	82	103	128	120	157	174	231	466
% International Collaboration	0,00	0,00	0,00	67,69	13,59	16,67	87,22	25,17	27,75	21,15	16,08	15,53	21,71

IEEE Microwave and Wireless Components Letters

Country: United States

Subject Area: Engineering

Subject Category: Electrical and Electronic Engineering Q1

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Journals. ISSN: 15311309

Coverage: 1999-2011

H Index: 71

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.759	227	3705
2009	1.913	274	3341
2008	2.302	274	3664

Scope:

Covers research and engineering encompassing microwaves, millimeter waves, and guided wave structures. Emphasis on components, devices, circuits, guided wave structures, systems, and applications covering the electromagnetic spectrum from microwaves to infrared. Experimental, theoretical and applications papers are included

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,110	0,148	0,184	0,171	0,200	0,185	0,169	0,219	0,270	0,368	0,241	0,237	0,435
Total Documents	126	122	123	131	175	184	303	214	303	278	278	231	148
Total Docs. (3years)	359	371	383	371	376	429	490	662	701	820	795	859	787
Total References	1.063	1.005	1.000	1.027	1.460	1.558	2.671	1.979	2.784	2.608	2.709	2.182	1.234
Total Cites (3years)	275	432	607	587	691	842	1.098	1.510	2.134	2.327	2.239	2.570	942
Self Cites (3years)	55	60	65	51	78	85	93	108	208	247	246	240	105
Citable Docs. (3years)	359	371	383	335	304	263	359	566	696	813	784	847	774
Cites / Doc. (4years)	0,77	1,07	1,45	1,70	2,13	2,83	3,14	2,76	3,33	2,87	2,89	3,07	1,23
Cites / Doc. (3years)	0,77	1,16	1,58	1,75	2,27	3,20	3,06	2,67	3,07	2,86	2,86	3,03	1,22
Cites / Doc. (2years)	0,82	1,24	1,52	1,89	2,52	2,94	3,03	2,28	2,91	2,72	2,76	2,86	1,24
References / Doc.	8,44	8,24	8,13	7,84	8,34	8,47	8,82	9,25	9,19	9,38	9,74	9,45	8,34
Cited Docs.	140	188	214	222	223	263	335	452	527	589	571	650	436
Uncited Docs.	219	183	169	149	153	166	155	210	174	231	224	209	351
% International Collaboration	69,05	57,38	78,05	62,60	12,57	15,22	42,24	79,44	91,42	72,30	12,23	16,88	13,51

IEEE Microwave Magazine

Country: United States

Subject Area: Engineering

Subject Category: Engineering (miscellaneous) Q1

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Journals. ISSN: 15273342

Coverage: 2000-2011

H Index: 30

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.752	56	664
2009	0.896	52	478
2008	1.494	52	542

Scope:

The magazine is intended to serve primarily as a source of information of interest to professionals in the field of microwave theory and techniques. In addition, it also strives to introduce this field to others, including professionals in other technical and scientific fields; policy makers; financial, legal and management communities and public

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,000	0,220	0,134	0,167	0,149	0,131	0,154	0,152	0,132	0,070	0,091	0,124
Total Documents	0	14	26	44	30	40	46	72	82	92	94	142	99
Total Docs. (3years)	0	0	14	40	84	100	114	116	158	200	246	268	328
Total References	0	144	386	429	379	372	356	391	634	1.054	1.298	1.772	971
Total Cites (3years)	0	0	19	62	125	217	231	236	267	187	207	364	149
Self Cites (3years)	0	0	0	2	3	5	1	2	7	25	19	25	16
Citable Docs. (3years)	0	0	14	39	79	93	105	102	121	151	187	215	256
Cites / Doc. (4years)	0,00	0,00	1,36	1,59	1,58	2,24	2,47	2,31	2,71	1,70	1,21	1,70	0,61
Cites / Doc. (3years)	0,00	0,00	1,36	1,59	1,58	2,33	2,20	2,31	2,21	1,24	1,11	1,69	0,58
Cites / Doc. (2years)	0,00	0,00	1,36	1,59	1,62	1,93	2,51	1,99	1,25	1,19	1,02	1,82	0,57
References / Doc.	0,00	10,29	14,85	9,75	12,63	9,30	7,74	5,43	7,73	11,46	13,81	12,48	9,81
Cited Docs.	0	0	8	19	34	44	46	33	42	56	79	97	72
Uncited Docs.	0	0	6	21	50	56	68	83	116	144	167	171	256
% International Collaboration	0,00	7,14	3,85	4,55	0,00	10,00	2,17	8,33	7,32	9,78	10,64	8,45	5,05

IEEE MTT-S International Microwave Symposium Digest

Country: United States

Subject Area: Engineering | Physics and Astronomy

Subject Category: Condensed Matter Physics Q2, Electrical and Electronic Engineering Q1

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Conferences and Proceedings. ISSN: 0149645X

Coverage: 1980-1981, 1983-1985, 1987-2010

H Index: 38

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,061	0,077	0,099	0,084	0,101	0,095	0,102	0,100	0,097	0,125	0,089	0,082	0,114
Total Documents	442	465	534	537	592	486	534	568	525	380	430	446	0
Total Docs. (3years)	1.341	1.335	1.366	1.441	1.536	1.663	1.615	1.612	1.588	1.627	1.473	1.335	1.256
Total References	3.204	3.215	3.964	4.213	4.556	3.724	4.453	4.447	4.506	3.471	3.933	4.115	0
Total Cites (3years)	266	545	894	780	1.039	1.524	1.778	1.263	1.366	1.328	1.405	1.285	437
Self Cites (3years)	0	182	209	183	314	218	263	183	164	129	158	160	0
Citable Docs. (3years)	1.332	1.329	1.360	1.435	1.527	1.654	1.606	1.602	1.513	1.552	1.399	1.326	1.248
Cites / Doc. (4years)	0,20	0,39	0,58	0,49	0,66	0,86	1,01	0,77	0,93	0,88	0,94	0,88	0,34
Cites / Doc. (3years)	0,20	0,41	0,66	0,54	0,68	0,92	1,11	0,79	0,90	0,86	1,00	0,97	0,35
Cites / Doc. (2years)	0,21	0,46	0,72	0,53	0,73	1,01	1,19	0,77	0,79	0,92	1,06	1,02	0,38
References / Doc.	7,25	6,91	7,42	7,85	7,70	7,66	8,34	7,83	8,58	9,13	9,15	9,23	0,00
Cited Docs.	196	346	520	450	554	733	774	640	639	630	635	625	315
Uncited Docs.	1.145	989	846	991	982	930	841	972	949	997	838	710	941
% International Collaboration	0,00	0,00	0,00	0,00	11,82	14,61	16,48	17,96	23,81	19,47	14,65	15,47	0,00

IEEE Transactions on Antennas and Propagation

Country: United States

Subject Area: Computer Science | Engineering

Subject Category: Computer Networks and Communications Q1, Electrical and Electronic Engineering Q1

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Journals. ISSN: 0018926X

Coverage: 1969-2011

H Index: 92

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.728	528	13627
2009	2.011	508	14253
2008	2.479	508	15884

Scope:

IEEE Transactions on Antennas and Propagation is one of the most cited journals, ranking number sixteen in telecommunications in 2004

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,096	0,094	0,116	0,117	0,110	0,124	0,156	0,173	0,162	0,206	0,144	0,133	0,291
Total Documents	248	276	248	245	429	447	543	405	498	522	519	548	348
Total Docs. (3years)	805	834	822	772	769	922	1.121	1.419	1.395	1.446	1.425	1.539	1.589
Total References	3.974	4.712	3.902	4.003	7.339	8.031	9.741	8.076	9.776	10.655	10.849	11.527	7.819
Total Cites (3years)	623	745	1.063	975	1.049	1.571	2.644	3.421	4.179	4.003	4.399	5.216	2.341
Self Cites (3years)	25	111	138	142	229	264	528	551	657	694	647	707	437
Citable Docs. (3years)	805	834	822	751	742	886	1.084	1.370	1.343	1.389	1.358	1.473	1.530
Cites / Doc. (4years)	0,77	0,90	1,45	1,37	1,54	1,74	2,41	2,49	3,13	2,89	3,36	3,56	1,60
Cites / Doc. (3years)	0,77	0,89	1,29	1,30	1,41	1,77	2,44	2,50	3,11	2,88	3,24	3,54	1,53
Cites / Doc. (2years)	0,78	0,74	1,16	1,13	1,36	1,68	2,40	2,35	3,05	2,68	3,19	3,28	1,43
References / Doc.	16,02	17,07	15,73	16,34	17,11	17,97	17,94	19,94	19,63	20,41	20,90	21,03	22,47
Cited Docs.	303	368	436	417	404	550	740	956	1.023	1.035	1.059	1.156	880
Uncited Docs.	502	466	386	355	365	372	381	463	372	411	366	383	709
% International Collaboration	7,26	44,57	70,16	54,69	24,01	18,79	20,63	27,16	20,08	19,92	22,54	22,45	22,99

IEEE Transactions on Biomedical Engineering

Country: United States

Subject Area: Engineering

Subject Category: Biomedical Engineering Q2

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Journals. ISSN: 00189294

Coverage: 1963-2011

H Index: 91

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.782	316	10397
2009	2.154	336	10947
2008	2.496	336	10943

Scope:

Basic and applied papers dealing with biomedical engineering and applied biophysics. Papers range from practical/clinical applications through experimental science and technological development to formalized mathematical theory. Indexed in PubMed® and Medline®, products of the United States National Laboratory of Medicine.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,137	0,131	0,136	0,161	0,140	0,139	0,174	0,205	0,160	0,172	0,143	0,138	0,140
Total Documents	172	235	176	197	162	271	249	319	277	342	338	326	286
Total Docs. (3years)	474	503	584	583	608	535	630	682	839	845	938	957	1.006
Total References	4.457	5.481	4.213	4.564	3.634	6.969	6.628	8.916	7.404	9.127	8.137	9.117	8.425
Total Cites (3years)	584	748	927	998	1.071	1.219	1.806	2.118	2.688	2.515	2.814	2.776	1.370
Self Cites (3years)	6	55	83	122	103	136	134	193	156	167	139	141	112
Citable Docs. (3years)	463	493	568	567	590	524	618	674	825	828	917	940	988
Cites / Doc. (4years)	1,26	1,52	1,81	1,85	1,92	2,40	2,96	3,16	3,46	3,42	3,24	3,12	1,55
Cites / Doc. (3years)	1,26	1,52	1,63	1,76	1,82	2,33	2,92	3,14	3,26	3,04	3,07	2,95	1,39
Cites / Doc. (2years)	1,14	1,46	1,49	1,49	1,75	2,17	2,84	3,05	2,64	2,74	2,87	2,55	1,24
References / Doc.	25,91	23,32	23,94	23,17	22,43	25,72	26,62	27,95	26,73	26,69	24,07	27,97	29,46
Cited Docs.	272	316	335	388	376	377	478	524	635	635	716	720	587
Uncited Docs.	202	187	249	195	232	158	152	158	204	210	222	237	419
% International Collaboration	10,47	28,94	30,68	53,30	27,78	37,27	57,43	66,77	26,71	24,27	26,92	22,39	28,67

IEEE Transactions on Geoscience and Remote Sensing

Country: United States

Subject Area: Earth and Planetary Sciences | Engineering

Subject Category: Computers in Earth Sciences Q1, Electrical and Electronic Engineering Q1, Geochemistry and Petrology Q1, Geophysics Q1

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Journals. ISSN: 01962892

Coverage: 1980-2011

H Index: 105

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.47	375	14006
2009	2.234	366	11678
2008	3.157	366	14614

Scope:

This publication focuses on the theory, concepts, and techniques of science and engineering as applied to sensing the earth, oceans, [...

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,100	0,096	0,152	0,153	0,145	0,146	0,148	0,142	0,118	0,129	0,129	0,115	0,128
Total Documents	284	257	287	272	346	269	294	310	376	383	469	293	421
Total Docs. (3years)	523	650	761	828	816	905	887	909	873	980	1.069	1.228	1.145
Total References	6.614	6.065	6.509	6.208	7.880	7.258	7.688	8.028	10.534	11.067	10.742	8.627	8.221
Total Cites (3years)	487	958	1.593	1.902	2.088	2.487	2.420	2.639	2.759	3.681	3.579	3.623	1.705
Self Cites (3years)	16	138	313	379	404	361	368	309	640	715	659	613	455
Citable Docs. (3years)	522	649	760	821	803	851	836	860	857	958	1.031	1.099	1.004
Cites / Doc. (4years)	0,93	1,53	2,21	2,41	2,61	2,96	3,03	3,04	3,44	4,08	3,58	3,47	1,75
Cites / Doc. (3years)	0,93	1,48	2,10	2,32	2,60	2,92	2,89	3,07	3,22	3,84	3,47	3,30	1,70
Cites / Doc. (2years)	0,89	1,26	2,05	2,15	2,46	2,55	2,91	2,60	3,07	3,57	3,17	3,10	1,61
References / Doc.	23,29	23,60	22,68	22,82	22,77	26,98	26,15	25,90	28,02	28,90	22,90	29,44	19,53
Cited Docs.	218	346	493	567	609	642	636	654	673	810	834	894	663
Uncited Docs.	305	304	268	261	207	263	251	255	200	170	235	334	482
% International Collaboration	6,69	29,57	58,54	52,57	31,50	23,42	51,02	75,48	73,67	50,91	24,73	35,84	17,34

IEEE Transactions on Microwave Theory and Techniques

Country: United States

Subject Area: Engineering

Subject Category: Electrical and Electronic Engineering Q1

Publisher: Institute of Electrical and Electronics Engineers. Publication type: Journals. ISSN: 00189480

Coverage: 1969-2011

H Index: 107

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.015	444	14395
2009	2.076	385	14800
2008	2.711	385	16941

Scope:

Microwave theory, techniques, and applications as they relate to components, devices, circuits, and systems involving the generation, transmission, and detection of microwaves.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,108	0,137	0,193	0,182	0,190	0,194	0,226	0,285	0,294	0,386	0,254	0,194	0,305
Total Documents	378	404	380	386	333	320	474	516	342	394	627	458	264
Total Docs. (3years)	1.122	1.113	1.153	1.162	1.170	1.099	1.039	1.127	1.310	1.332	1.252	1.363	1.479
Total References	6.052	6.339	5.428	7.546	5.908	6.705	8.444	10.206	6.749	7.825	12.986	10.697	4.803
Total Cites (3years)	896	1.236	1.941	2.008	2.187	2.649	3.317	3.578	4.953	4.428	4.334	3.753	1.453
Self Cites (3years)	44	205	259	351	311	356	523	631	483	535	768	517	227
Citable Docs. (3years)	1.119	1.111	1.152	1.147	1.141	1.060	1.005	1.092	1.269	1.285	1.189	1.299	1.415
Cites / Doc. (4years)	0,80	1,14	1,71	1,76	2,14	2,46	3,23	3,17	3,86	3,64	3,77	3,23	1,12
Cites / Doc. (3years)	0,80	1,11	1,68	1,75	1,92	2,50	3,30	3,28	3,90	3,45	3,65	2,89	1,03
Cites / Doc. (2years)	0,73	1,06	1,60	1,57	1,85	2,41	3,39	3,28	3,51	3,19	3,11	2,62	0,89
References / Doc.	16,01	15,69	14,28	19,55	17,74	20,95	17,81	19,78	19,73	19,86	20,71	23,36	18,19
Cited Docs.	432	563	680	692	745	753	763	837	1.013	1.006	951	962	715
Uncited Docs.	690	550	473	470	425	346	276	290	297	326	301	401	764
% International Collaboration	21,69	13,37	39,21	77,72	20,42	18,44	45,78	92,64	88,89	66,24	18,98	27,07	16,29

Indian Journal of Biochemistry and Biophysics

Country: India

Subject Area: Biochemistry, Genetics and Molecular Biology

Subject Category: Biochemistry Q4, Biophysics Q3

Publisher: Scientific Publishers. Publication type: Journals. ISSN: 03011208

Coverage: 1972-2011

H Index: 19

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	0.824	58	696
2009	0.574	59	696
2008	0.579	59	603

Scope:

Started in 1964, this journal publishes original research articles in the following areas: structure-function relationships of biomolecules; biomolecular recognition, protein-protei

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,108	0,089	0,071	0,077	0,073	0,063	0,053	0,049	0,040	0,052	0,049	0,060	0,056
Total Documents	66	70	70	59	59	52	64	57	67	59	71	58	28
Total Docs. (3years)	229	209	200	206	199	188	170	175	173	188	183	197	188
Total References	2.097	2.259	1.984	1.767	2.232	1.515	1.968	1.870	2.430	2.282	2.547	1.872	1.036
Total Cites (3years)	110	88	76	88	75	68	77	65	71	94	115	165	122
Self Cites (3years)	2	9	13	8	7	12	15	12	19	15	11	10	2
Citable Docs. (3years)	228	206	192	195	184	172	154	163	164	180	171	186	178
Cites / Doc. (4years)	0,48	0,44	0,46	0,51	0,46	0,44	0,49	0,39	0,49	0,48	0,58	0,92	0,63
Cites / Doc. (3years)	0,48	0,43	0,40	0,45	0,41	0,40	0,50	0,40	0,43	0,52	0,67	0,89	0,69
Cites / Doc. (2years)	0,48	0,28	0,38	0,48	0,27	0,38	0,56	0,27	0,50	0,63	0,56	0,96	0,84
References / Doc.	31,77	32,27	28,34	29,95	37,83	29,13	30,75	32,81	36,27	38,68	35,87	32,28	37,00
Cited Docs.	68	56	55	67	49	52	48	49	45	60	67	87	68
Uncited Docs.	161	153	145	139	150	136	122	126	128	128	116	110	120
% International Collaboration	3,03	14,29	11,43	10,17	13,56	7,69	15,63	14,04	7,46	16,95	12,68	10,34	0,00

International Journal of Cancer

Country: United States

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1, Medicine (miscellaneous) Q1, Oncology Q1

Publisher: John Wiley & Sons Inc.. Publication type: Journals. ISSN: 00207136, 10970215

Coverage: 1966-2011

H Index: 137

Scope:

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	4.926	588	40185
2009	4.722	740	37606
2008	4.734	740	36277

The International Journal of Cancer (official journal of the International Union Against Cancer - UICC) appears 24 times per year.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,786	0,806	0,916	0,878	0,807	0,811	0,817	0,759	0,756	0,732	0,726	0,758	0,620
Total Documents	735	708	698	737	696	721	730	902	784	819	795	633	781
Total Docs. (3years)	2.095	2.170	2.134	2.141	2.143	2.131	2.154	2.147	2.353	2.416	2.505	2.398	2.247
Total References	18.918	20.429	24.770	27.620	26.247	27.585	28.537	35.131	32.741	32.315	32.380	26.001	30.353
Total Cites (3years)	7.391	8.274	8.998	9.269	9.523	9.676	10.081	10.183	10.699	11.084	11.537	11.464	6.732
Self Cites (3years)	433	458	443	508	481	474	437	549	516	484	458	351	285
Citable Docs. (3years)	2.019	2.089	2.043	2.033	2.025	1.983	1.975	1.948	2.126	2.181	2.269	2.191	2.056
Cites / Doc. (4years)	3,66	3,94	4,34	4,42	4,72	4,80	5,03	5,11	5,03	5,02	4,98	5,10	3,29
Cites / Doc. (3years)	3,66	3,96	4,40	4,56	4,70	4,88	5,10	5,23	5,03	5,08	5,08	5,23	3,27
Cites / Doc. (2years)	3,47	3,92	4,41	4,34	4,66	4,76	5,18	5,17	4,96	5,12	5,10	5,04	3,32
References / Doc.	25,74	28,85	35,49	37,48	37,71	38,26	39,09	38,95	41,76	39,46	40,73	41,08	38,86
Cited Docs.	1.747	1.838	1.841	1.847	1.890	1.890	1.927	1.903	2.035	2.102	2.180	2.112	1.796
Uncited Docs.	348	332	293	294	253	241	227	244	318	314	325	286	451
% International Collaboration	28,16	32,77	26,93	28,77	31,61	32,04	34,38	35,25	36,22	37,85	42,26	34,12	25,48

International Journal of Hyperthermia

Country: United Kingdom

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q2 , Radiology, Nuclear Medicine and Imaging Q1

Publisher: Taylor & Francis. Publication type: Journals. ISSN: 02656736, 14645157

Coverage: 1985-2011

H Index: 43

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.929	75	2082
2009	2.412	67	1417
2008	2.339	67	1386

Scope:

The official journal of the Society for Thermal Medicine, the European Society for Hyperthermic Oncology, and the Asian Society of Hyperthermic Oncology; Rapid Communications† and Letters on hyperthermia which fall largely into the following three categories: Clinical Studies. Whole body, regional or local treatment, practical considerations in therapy, clinical trials, physiological effects, heat treatment in combination with other modalities, thermal ablation and treatment optimization. - Biological Studies.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,171	0,139	0,151	0,224	0,220	0,232	0,216	0,218	0,255	0,266	0,195	0,218	0,240
Total Documents	40	45	40	48	46	62	66	66	61	70	79	81	53
Total Docs. (3years)	180	145	133	125	133	134	156	174	194	193	197	210	230
Total References	1.177	1.161	1.265	2.002	1.853	2.668	2.855	1.928	2.677	3.228	2.741	3.941	2.263
Total Cites (3years)	217	137	147	213	222	305	328	424	513	509	425	622	340
Self Cites (3years)	50	28	24	33	47	48	64	54	105	123	63	165	81
Citable Docs. (3years)	152	131	125	121	128	131	151	166	178	175	176	188	206
Cites / Doc. (4years)	1,43	1,18	1,15	1,59	1,69	2,15	2,22	2,71	3,04	2,67	2,71	3,22	1,79
Cites / Doc. (3years)	1,43	1,05	1,18	1,76	1,73	2,33	2,17	2,55	2,88	2,91	2,41	3,31	1,65
Cites / Doc. (2years)	1,20	0,92	1,15	1,90	1,83	2,21	1,92	2,42	3,05	2,40	2,55	3,10	1,38
References / Doc.	29,43	25,80	31,63	41,71	40,28	43,03	43,26	29,21	43,89	46,11	34,70	48,65	42,70
Cited Docs.	96	72	63	75	89	107	108	138	145	131	128	157	134
Uncited Docs.	84	73	70	50	44	27	48	36	49	62	69	53	96
% International Collaboration	12,50	4,44	0,00	12,50	23,91	16,13	10,61	9,09	13,11	10,00	15,19	9,88	13,21

Journal of Electromagnetic Waves and Applications

Country: Netherlands

Subject Area: Engineering

Subject Category: Electrical and Electronic Engineering Q1

Publisher: VSP. Publication type: Journals. ISSN: 15693937, 09205071

Coverage: 1994-2011

H Index: 29

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.376	237	1432
2009	1.551	248	1835
2008	3.134	248	1893

Scope: The journal"s scope is broad and includes the following topics: Wave propagation theory; Remote sensing; Inverse scattering; Geophysical subsurface probing, inversion techniques; Propagation in random media; Oceanography-radar reflection; Meteorology; Ionospheric effects on wave propagation; Ionospheric modifications and heating; Atmospherics; Antenna theory and applications; Transients; Radar measurements and applications; Active experiments using space vehicles; Extra-terrestrial remote sensing; Electromagnetic interferometry;

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,062	0,056	0,056	0,053	0,055	0,055	0,050	0,052	0,074	0,711	0,086	0,093	0,871
Total Documents	145	168	129	126	112	123	146	177	199	252	221	224	133
Total Docs. (3years)	314	362	431	442	423	367	361	381	446	522	628	672	697
Total References	1.409	1.221	1.092	1.435	1.457	1.427	1.903	2.405	3.045	5.003	3.904	4.262	2.838
Total Cites (3years)	131	116	141	129	140	161	152	252	730	1.538	1.021	1.004	1.032
Self Cites (3years)	26	14	14	28	28	30	32	56	179	225	202	224	325
Citable Docs. (3years)	314	362	431	442	423	365	358	378	443	520	626	672	697
Cites / Doc. (4years)	0,42	0,32	0,34	0,32	0,33	0,39	0,41	0,65	1,44	2,51	1,47	1,41	1,26
Cites / Doc. (3years)	0,42	0,32	0,33	0,29	0,33	0,44	0,42	0,67	1,65	2,96	1,63	1,49	1,48
Cites / Doc. (2years)	0,41	0,28	0,30	0,26	0,37	0,47	0,45	0,62	2,02	3,69	1,53	1,62	2,07
References / Doc.	9,72	7,27	8,47	11,39	13,01	11,60	13,03	13,59	15,30	19,85	17,67	19,03	21,34
Cited Docs.	83	77	90	89	81	94	87	129	286	407	405	435	443
Uncited Docs.	231	285	341	353	342	273	274	252	160	115	223	237	254
% International Collaboration	24,14	26,79	17,83	11,11	17,86	19,51	28,77	11,86	7,04	8,73	10,41	9,38	9,02

Journal of International Medical Research

Country: United Kingdom

Subject Area: Medicine

Subject Category: Medicine (miscellaneous) Q2

Publisher: Cambridge Medical Publications. Publication type: Journals. ISSN: 03000605

Coverage: 1973-2011

H Index: 29

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.068	228	1419
2009	0.938	192	1065
2008	0.821	192	1024

Scope:b A leading international journal for rapid publication of original medical, pre-clinical and clinical research on a page charge basis. Original full length pre-clinical, clinical and medical research articles are welcome. Also welcome are short preliminary studies, pilot studies, reviews, unusual case reports, and studies on new indications and new formulations of established products, pharmacoeconomics, managed care and post-marketing surveillance. Symposium proceedings, summaries of presentations or clinical data on a specific topic are welcome for publication as Supplements

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,081	0,096	0,111	0,115	0,099	0,102	0,102	0,091	0,102	0,093	0,095	0,109	0,073
Total Documents	40	44	77	95	81	91	92	92	113	194	240	232	77
Total Docs. (3years)	157	128	124	161	216	253	267	264	275	297	399	547	666
Total References	789	923	1.576	2.054	1.826	1.914	2.285	2.048	2.788	4.713	5.783	7.274	2.380
Total Cites (3years)	91	103	118	162	175	227	264	267	273	296	439	708	370
Self Cites (3years)	2	3	0	1	8	7	6	5	2	10	11	26	12
Citable Docs. (3years)	152	126	118	152	203	245	261	260	269	290	377	517	636
Cites / Doc. (4years)	0,60	0,77	0,96	1,17	0,85	0,94	1,11	1,00	0,99	1,04	1,18	1,32	0,61
Cites / Doc. (3years)	0,60	0,82	1,00	1,07	0,86	0,93	1,01	1,03	1,01	1,02	1,16	1,37	0,58
Cites / Doc. (2years)	0,63	0,71	0,85	0,96	0,83	0,78	0,95	1,01	0,98	0,99	1,12	1,28	0,51
References / Doc.	19,73	20,98	20,47	21,62	22,54	21,03	24,84	22,26	24,67	24,29	24,10	31,35	30,91
Cited Docs.	54	44	53	72	86	118	131	126	127	141	204	307	225
Uncited Docs.	103	84	71	89	130	135	136	138	148	156	195	240	441
% International Collaboration	7,50	9,09	3,90	3,16	4,94	4,40	4,35	10,87	8,85	10,31	4,58	6,03	10,39

Journal of Magnetic Resonance Imaging

Country: United States

Subject Area: Medicine

Subject Category: Radiology, Nuclear Medicine and Imaging Q1

Publisher: John Wiley & Sons Inc.. Publication type: Journals. ISSN: 10531807, 15222586

Coverage: 1991-2011

H Index: 92

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.747	355	10041
2009	2.77	383	9376
2008	2.658	383	8199

Scope:

The Journal of Magnetic Resonance Imaging (JMRI) is an international journal devoted to the timely publication of basic and clinical research, educational and review articles, and other information related to the diagnostic applications of magnetic resonance.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,257	0,245	0,283	0,356	0,382	0,399	0,378	0,341	0,342	0,323	0,330	0,324	0,242
Total Documents	265	232	252	189	197	252	233	315	391	398	400	370	253
Total Docs. (3years)	531	645	692	749	673	638	638	682	800	939	1.104	1.189	1.168
Total References	7.073	6.234	6.291	5.713	5.020	6.826	5.962	9.444	12.263	12.203	11.177	10.818	7.782
Total Cites (3years)	1.462	1.671	1.998	2.209	2.139	2.210	1.973	2.122	2.419	2.838	3.294	3.600	2.091
Self Cites (3years)	239	254	304	242	191	191	157	200	321	336	378	335	232
Citable Docs. (3years)	510	619	666	721	648	612	601	652	775	912	1.071	1.143	1.131
Cites / Doc. (4years)	2,87	2,62	3,01	3,03	3,43	3,56	3,47	3,44	3,24	3,28	3,12	3,13	1,94
Cites / Doc. (3years)	2,87	2,70	3,00	3,06	3,30	3,61	3,28	3,25	3,12	3,11	3,08	3,15	1,85
Cites / Doc. (2years)	2,89	2,48	2,79	2,81	3,14	3,46	2,90	3,02	2,67	2,99	3,01	2,91	1,72
References / Doc.	26,69	26,87	24,96	30,23	25,48	27,09	25,59	29,98	31,36	30,66	27,94	29,24	30,76
Cited Docs.	404	493	534	561	524	496	489	533	621	731	848	913	739
Uncited Docs.	127	152	158	188	149	142	149	149	179	208	256	276	429
% International Collaboration	23,40	20,26	25,00	19,58	23,35	21,03	18,45	20,95	24,55	27,39	31,25	24,59	25,69

Journal of Mammary Gland Biology and Neoplasia

Country: United States

Subject Area: Biochemistry, Genetics and Molecular Biology

Subject Category: Cancer Research Q1

Publisher: Kluwer Academic/Plenum Publishers. Publication type: Journals. ISSN: 10833021, 15737039

Coverage: 1996-2011

H Index: 60

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	5.446	31	1841
2009	4.074	23	1637
2008	4.167	23	1524

Scope: Journal of Mammary Gland Biology and Neoplasia provides researchers within and outside the field of mammary gland biology with an integrated source of information derived from studies of the development, function, and pathology of the mammary gland. This quarterly journal offers comprehensive analyses of all aspects of the field, considering the fundamental biology and pathology of the mammary gland including, but not restricted to mammary development, the biology of breast cancer, lactation, milk proteins, bioactive agents in milk, hormonal regulation, growth factors, signal transduction, nutrition, and genetics.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,725	0,834	1,025	1,023	0,969	0,867	0,940	0,987	1,192	0,984	0,876	0,770	0,618
Total Documents	41	38	42	36	37	34	33	25	29	46	59	35	24
Total Docs. (3years)	115	118	118	121	116	115	107	104	92	87	100	134	140
Total References	2.508	2.241	3.151	2.500	2.937	2.808	2.092	2.113	2.334	4.195	2.078	3.867	2.167
Total Cites (3years)	238	295	383	376	395	431	428	393	397	331	405	510	345
Self Cites (3years)	25	43	15	28	21	25	8	10	10	9	30	16	7
Citable Docs. (3years)	114	117	112	114	104	104	96	94	83	77	90	101	107
Cites / Doc. (4years)	2,09	2,45	3,49	3,61	3,61	4,16	4,48	4,82	4,86	4,53	4,66	4,99	3,33
Cites / Doc. (3years)	2,09	2,52	3,42	3,30	3,80	4,14	4,46	4,18	4,78	4,30	4,50	5,05	3,22
Cites / Doc. (2years)	2,05	2,44	3,14	2,92	3,82	3,44	3,66	3,74	4,04	3,92	4,21	5,11	3,02
References / Doc.	61,17	58,97	75,02	69,44	79,38	82,59	63,39	84,52	80,48	91,20	35,22	110,49	90,29
Cited Docs.	78	87	90	97	83	89	85	82	78	68	88	84	82
Uncited Docs.	37	31	28	24	33	26	22	22	14	19	12	50	58
% International Collaboration	7,32	5,26	2,38	13,89	13,51	17,65	9,09	20,00	17,24	4,35	11,86	25,71	16,67

Journal of Medical Physics

Country: India

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Biophysics Q3, Radiology, Nuclear Medicine and Imaging Q2

Publisher: Medknow Publications. Publication type: Journals. Coverage: 2006-2011

H Index: 6

Scope: JOURNAL OF MEDICAL PHYSICS is the official journal of Association of Medical Physicists of India (AMPI). The association has been bringing out a quarterly publication since 1976. Till the end of 1993, it was known as Medical Physics Bulletin, which then became Journal of Medical Physics. The main objective of the Journal is to serve as a vehicle of communication to highlight all aspects of the practice of medical radiation physics. The areas covered include all aspects of the application of radiation physics to biological sciences, radiotherapy, radiodiagnosis, nuclear medicine, dosimetry and radiation protection. Papers / manuscripts dealing with the aspects of physics related to cancer therapy / radiobiology also fall within the scope of the journal.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,038	0,039	0,036	0,037	0,078
Total Documents	0	0	0	0	0	0	0	22	28	30	40	38	17
Total Docs. (3years)	0	0	0	0	0	0	0	0	22	50	80	98	108
Total References	0	0	0	0	0	0	0	422	368	531	568	717	346
Total Cites (3years)	0	0	0	0	0	0	0	0	4	11	36	36	44
Self Cites (3years)	0	0	0	0	0	0	0	0	2	2	4	7	5
Citable Docs. (3years)	0	0	0	0	0	0	0	0	18	42	68	85	95
Cites / Doc. (4years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,22	0,26	0,53	0,50	0,40
Cites / Doc. (3years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,22	0,26	0,53	0,42	0,46
Cites / Doc. (2years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,22	0,26	0,46	0,49	0,46
References / Doc.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	19,18	13,14	17,70	14,20	18,87	20,35
Cited Docs.	0	0	0	0	0	0	0	0	4	7	25	23	29
Uncited Docs.	0	0	0	0	0	0	0	0	18	43	55	75	79
% International Collaboration	0,00	0,00	0,00	0,00	0,00	0,00	0,00	27,27	21,43	26,67	15,00	18,42	11,76

Journal of Medical Screening

Country: United Kingdom

Subject Area: Medicine

Subject Category: Public Health, Environmental and Occupational Health Q1

Publisher: RSM Press. Publication type: Journals. ISSN: 09691413, 14755793

Coverage: 1994-2010

H Index: 37

Scope:

Journal of Medical Screening is concerned with all aspects of medical screening, particularly the publication of research that advances screening theory and practice. The journal aims to increase awareness of the principles of screening (quantitative and statistical aspects), screening techniques and procedures and methodologies from all specialties. An essential subscription for physicians, clinicians and academics with an interest in screening, epidemiology and public health

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,222	0,176	0,238	0,206	0,216	0,276	0,260	0,230	0,162	0,269	0,178	0,196	0,165
Total Documents	51	51	51	47	35	45	43	63	42	45	40	49	13
Total Docs. (3years)	142	143	157	153	149	133	127	123	151	148	150	127	134
Total References	831	603	990	875	902	1.123	852	915	1.001	830	844	785	190
Total Cites (3years)	197	212	234	232	255	240	238	225	191	249	249	205	115
Self Cites (3years)	15	18	28	29	10	17	11	16	20	16	26	14	5
Citable Docs. (3years)	107	108	119	117	115	105	104	99	119	119	123	109	107
Cites / Doc. (4years)	1,84	1,98	2,13	1,88	2,21	2,26	2,30	2,55	1,83	2,13	2,17	1,88	1,26
Cites / Doc. (3years)	1,84	1,96	1,97	1,98	2,22	2,29	2,29	2,27	1,61	2,09	2,02	1,88	1,07
Cites / Doc. (2years)	1,75	1,81	1,77	1,82	2,14	2,07	2,30	2,07	1,35	1,90	2,26	1,47	1,03
References / Doc.	16,29	11,82	19,41	18,62	25,77	24,96	19,81	14,52	23,83	18,44	21,10	16,02	14,62
Cited Docs.	82	76	92	89	94	77	78	79	88	98	101	78	56
Uncited Docs.	60	67	65	64	55	56	49	44	63	50	49	49	78
% International Collaboration	25,49	13,73	19,61	14,89	11,43	35,56	25,58	12,70	28,57	11,11	15,00	20,41	7,69

Journal of the National Cancer Institute

Country: United Kingdom

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1, Oncology Q1

Publisher: Oxford University Press. Publication type: Journals. ISSN: 00278874

Coverage: 1948-2011

H Index: 234

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.493	34	961
2009	2.141	34	873
2008	1.802	34	863

Scope:

The Journal of the National Cancer Institute (print ISSN: 0027-8874, online ISSN: 1460-2105) publishes peer-reviewed original research from around the world and is internationally acclaimed as the source for the most up-to-date news and information from the rapidly changing fields of cancer research and treatment. For the past several years, the JNCI has been ranked as the most-cited original-research cancer journal by the Institute of Scientific Information in its annual Journal Citation Reports

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	1,102	1,242	1,714	1,822	1,896	2,049	2,157	2,061	1,916	1,745	1,633	1,661	1,444
Total Documents	478	455	451	412	507	525	482	396	400	415	371	384	205
Total Docs. (3years)	1.238	1.333	1.348	1.384	1.318	1.370	1.444	1.514	1.403	1.278	1.211	1.186	1.170
Total References	10.221	9.369	8.351	8.368	8.453	8.251	7.808	8.371	7.203	7.619	7.149	7.651	5.070
Total Cites (3years)	5.643	6.902	8.399	8.594	8.065	7.372	7.968	8.515	8.110	7.966	7.161	6.677	3.743
Self Cites (3years)	165	193	215	203	180	166	163	168	169	150	136	157	67
Citable Docs. (3years)	773	836	865	798	648	554	566	596	671	722	683	564	479
Cites / Doc. (4years)	7,30	8,08	9,38	10,74	11,42	12,61	13,87	14,62	12,34	11,39	11,50	11,10	6,92
Cites / Doc. (3years)	7,30	8,26	9,71	10,77	12,45	13,31	14,08	14,29	12,09	11,03	10,48	11,84	7,81
Cites / Doc. (2years)	7,15	8,27	8,96	11,32	13,35	13,12	13,30	14,01	11,61	9,05	10,51	13,83	7,05
References / Doc.	21,38	20,59	18,52	20,31	16,67	15,72	16,20	21,14	18,01	18,36	19,27	19,92	24,73
Cited Docs.	738	802	834	812	776	767	793	806	767	744	729	677	596
Uncited Docs.	500	531	514	572	542	603	651	708	636	534	482	509	574
% International Collaboration	8,79	17,80	17,07	18,69	19,33	18,29	19,92	19,19	17,25	18,07	22,64	22,14	21,46

Journal of the National Cancer Institute

Country: United Kingdom

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1 , Oncology Q1

Publisher: Oxford University Press. Publication type: Journals. ISSN: 00278874

Coverage: 1948-2011

H Index: 234

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	14.697	135	36186
2009	14.069	132	35795
2008	14.933	132	35371

Scope: The Journal of the National Cancer Institute (print ISSN: 0027-8874, online ISSN: 1460-2105) publishes peer-reviewed original research from around the world and is internationally acclaimed as the source for the most up-to-date news and information from the rapidly changing fields of cancer research and treatment. For the past several years, the JNCI has been ranked as the most-cited original-research cancer journal by the Institute of Scientific Information in its annual Journal Citation Report

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	1,102	1,242	1,714	1,822	1,896	2,049	2,157	2,061	1,916	1,745	1,633	1,661	1,444
Total Documents	478	455	451	412	507	525	482	396	400	415	371	384	205
Total Docs. (3years)	1.238	1.333	1.348	1.384	1.318	1.370	1.444	1.514	1.403	1.278	1.211	1.186	1.170
Total References	10.221	9.369	8.351	8.368	8.453	8.251	7.808	8.371	7.203	7.619	7.149	7.651	5.070
Total Cites (3years)	5.643	6.902	8.399	8.594	8.065	7.372	7.968	8.515	8.110	7.966	7.161	6.677	3.743
Self Cites (3years)	165	193	215	203	180	166	163	168	169	150	136	157	67
Citable Docs. (3years)	773	836	865	798	648	554	566	596	671	722	683	564	479
Cites / Doc. (4years)	7,30	8,08	9,38	10,74	11,42	12,61	13,87	14,62	12,34	11,39	11,50	11,10	6,92
Cites / Doc. (3years)	7,30	8,26	9,71	10,77	12,45	13,31	14,08	14,29	12,09	11,03	10,48	11,84	7,81
Cites / Doc. (2years)	7,15	8,27	8,96	11,32	13,35	13,12	13,30	14,01	11,61	9,05	10,51	13,83	7,05
References / Doc.	21,38	20,59	18,52	20,31	16,67	15,72	16,20	21,14	18,01	18,36	19,27	19,92	24,73
Cited Docs.	738	802	834	812	776	767	793	806	767	744	729	677	596
Uncited Docs.	500	531	514	572	542	603	651	708	636	534	482	509	574
% International Collaboration	8,79	17,80	17,07	18,69	19,33	18,29	19,92	19,19	17,25	18,07	22,64	22,14	21,46

Journal of the National Cancer Institute. Monographs

Country: United States

Subject Area: Medicine

Subject Category: Medicine (miscellaneous) Q1

Publisher: Oxford University Press. Publication type: Journals. ISSN: 10526773

Coverage: 1992-2001, 2003-2008, 2010

H Index: 56

Scope:Manuscripts from key conferences dealing with cancer and closely related research fields, or a related group of papers on specific subjects of importance to cancer research, are considered for publication, with the understanding that they have not been published previously and are submitted exclusively to the Journal of the National Cancer Institute Monographs. All material submitted for consideration will be subject to review, when appropriate, by at least one outside reviewer and one member of the Editorial Board of the Journal of the National Cancer Institute

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,422	0,408	0,615	0,517	0,827	0,724	0,606	0,741	0,509	0,427	0,403	0,427	0,287
Total Documents	46	11	46	0	19	35	48	16	9	23	0	37	0
Total Docs. (3years)	99	95	77	103	57	65	54	102	99	73	48	32	60
Total References	1.349	1.086	1.192	0	843	2.798	888	75	187	692	0	721	0
Total Cites (3years)	227	230	256	325	322	293	298	593	458	295	129	112	82
Self Cites (3years)	0	0	0	0	0	0	0	0	0	0	0	0	0
Citable Docs. (3years)	99	91	73	98	56	64	54	102	99	73	47	31	57
Cites / Doc. (4years)	2,29	2,12	3,93	3,28	4,82	5,96	5,31	5,81	5,69	5,23	3,94	3,30	1,80
Cites / Doc. (3years)	2,29	2,53	3,51	3,32	5,75	4,58	5,52	5,81	4,63	4,04	2,74	3,61	1,44
Cites / Doc. (2years)	3,45	1,73	3,06	4,00	4,44	5,58	5,52	3,99	3,64	1,76	2,42	2,41	1,23
References / Doc.	29,33	98,73	25,91	0,00	44,37	79,94	18,50	4,69	20,78	30,09	0,00	19,49	0,00
Cited Docs.	69	60	55	76	50	53	46	92	85	59	36	24	41
Uncited Docs.	30	35	22	27	7	12	8	10	14	14	12	8	19
% International Collaboration	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	21,74	0,00	10,81	0,00

Magnetic Resonance Imaging

Country: Netherlands

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine | Physics and Astronomy

Subject Category: Biophysics Q2, Condensed Matter Physics Q1, Radiology, Nuclear Medicine and Imaging Q1, Structural Biology Q2

Publisher: Elsevier BV. Publication type: Journals. ISSN: 0730725X

Coverage: 1982, 1984-2011

H Index: 64

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.042	176	4697
2009	2.026	162	4670
2008	1.871	162	4330

Scope:

MRI is the first international multidisciplinary journal encompassing physical, life, and clinical science investigations as they relate to the development and use of magnetic resonance imaging. MRI is dedicated to both basic research and medical applications, providing a single forum for communication among radiologists, physicists, chemists, biochemists, biologists, engineers, internists, pathologists, physiologists, computer scientists, and mathematicians.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,160	0,199	0,222	0,229	0,194	0,170	0,187	0,201	0,214	0,219	0,228	0,224	0,193
Total Documents	182	153	194	99	178	195	153	163	184	187	164	180	140
Total Docs. (3years)	503	510	516	529	446	471	472	526	511	500	534	535	531
Total References	4.176	3.732	3.723	2.244	3.906	4.777	3.157	4.475	4.771	5.138	5.294	5.724	2.995
Total Cites (3years)	718	756	922	945	716	771	770	950	942	985	1.108	1.177	735
Self Cites (3years)	80	81	80	45	68	68	41	67	70	66	77	78	46
Citable Docs. (3years)	494	496	507	520	444	467	464	516	500	492	512	515	510
Cites / Doc. (4years)	1,45	1,49	1,86	1,77	1,80	1,81	1,69	1,95	1,91	2,07	2,14	2,31	1,43
Cites / Doc. (3years)	1,45	1,52	1,82	1,82	1,61	1,65	1,66	1,84	1,88	2,00	2,16	2,29	1,44
Cites / Doc. (2years)	1,43	1,36	1,87	1,52	1,37	1,50	1,43	1,71	1,69	2,02	2,14	2,16	1,28
References / Doc.	22,95	24,39	19,19	22,67	21,94	24,50	20,63	27,45	25,93	27,48	32,28	31,80	21,39
Cited Docs.	272	302	333	343	297	293	311	349	333	327	368	387	305
Uncited Docs.	231	208	183	186	149	178	161	177	178	173	166	148	226
% International Collaboration	14,29	16,99	16,49	6,06	15,73	18,97	25,49	17,79	24,46	16,58	17,07	25,00	15,00

Microwave and Optical Technology Letters

Country: United States

Subject Area: Engineering

Subject Category: Electrical and Electronic Engineering Q1

Publisher: John Wiley & Sons Inc.. Publication type: Journals. ISSN: 08952477, 10982760

Coverage: 1988-2011

H Index: 47

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	0.656	781	4012
2009	0.682	845	4141
2008	0.743	845	4114

Scope:

Microwave and Optical Technology Letters provides quick publication (3 to 6 month turnaround) of the most recent findings and achievements

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,073	0,064	0,073	0,070	0,075	0,072	0,070	0,077	0,073	0,091	0,065	0,063	0,137
Total Documents	484	488	544	576	616	667	713	775	946	969	866	733	678
Total Docs. (3years)	954	1.139	1.311	1.516	1.608	1.736	1.859	1.996	2.155	2.434	2.690	2.781	2.568
Total References	4.316	4.443	5.016	5.355	5.557	6.018	6.729	7.663	9.426	9.444	9.030	8.148	7.853
Total Cites (3years)	393	441	631	736	907	1.100	1.250	1.400	1.858	2.042	2.315	2.466	1.215
Self Cites (3years)	160	159	205	247	219	260	286	351	493	537	603	537	500
Citable Docs. (3years)	954	1.139	1.311	1.510	1.594	1.714	1.835	1.974	2.135	2.408	2.646	2.726	2.518
Cites / Doc. (4years)	0,41	0,35	0,47	0,46	0,51	0,62	0,66	0,67	0,84	0,81	0,86	0,87	0,45
Cites / Doc. (3years)	0,41	0,39	0,48	0,49	0,57	0,64	0,68	0,71	0,87	0,85	0,87	0,90	0,48
Cites / Doc. (2years)	0,46	0,38	0,50	0,53	0,63	0,61	0,68	0,73	0,91	0,84	0,91	0,96	0,51
References / Doc.	8,92	9,10	9,22	9,30	9,02	9,02	9,44	9,89	9,96	9,75	10,43	11,12	11,58
Cited Docs.	219	262	353	416	471	594	652	713	866	987	1.084	1.105	725
Uncited Docs.	735	877	958	1.100	1.137	1.142	1.207	1.283	1.289	1.447	1.606	1.676	1.843
% International Collaboration	13,64	14,75	11,21	14,24	12,34	11,99	11,36	16,52	13,64	10,73	10,28	12,28	10,32

Molecular Oncology

Country: Netherlands

Subject Area: Biochemistry, Genetics and Molecular Biology

Subject Category: Cancer Research Q1 , Genetics Q1 , Molecular Medicine Q1

Publisher: Elsevier BV. Publication type: Journals. ISSN: 15747891, 18780261

Coverage: 2007-2011

H Index: 17

Scope: Molecular Oncology highlights new discoveries, approaches, as well as technical developments, in basic, clinical and discovery-driven translational research. Topics include: Key biological processes such as cell cycle; DNA repair; apoptosis; invasion and metastasis; angiogenesis and lymphangiogenesis; cell signaling and interactive networks; immune response. - Emerging technologies (genomics, proteomics, functional genomics, metabolomics, tissuearrays, imaging), and model systems. Biomarkers: diagnosis, prognosis, stratification and efficacy. Cancer genetics, epigenetics, and genomic instability. Minimal residual disease, pre-malignant lesions. Cancer micro-environment. Molecular pathology.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,442	0,359	0,959	0,571
Total Documents	0	0	0	0	0	0	0	0	40	51	51	44	40
Total Docs. (3years)	0	0	0	0	0	0	0	0	0	40	91	142	146
Total References	0	0	0	0	0	0	0	0	1.548	1.908	2.421	3.575	1.706
Total Cites (3years)	0	0	0	0	0	0	0	0	0	64	134	454	306
Self Cites (3years)	0	0	0	0	0	0	0	0	0	10	13	34	6
Citable Docs. (3years)	0	0	0	0	0	0	0	0	0	25	61	102	117
Cites / Doc. (4years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,56	2,20	4,45	2,73
Cites / Doc. (3years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,56	2,20	4,45	2,62
Cites / Doc. (2years)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,56	2,20	4,12	2,63
References / Doc.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	38,70	37,41	47,47	81,25	42,65
Cited Docs.	0	0	0	0	0	0	0	0	0	19	47	91	88
Uncited Docs.	0	0	0	0	0	0	0	0	0	21	44	51	58
% International Collaboration	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	15,00	25,49	19,61	22,73	25,00

New England Journal of Medicine

Country: United States

Subject Area: Medicine

Subject Category: Medicine (miscellaneous) Q1

Publisher: Massachusetts Medical Society. Publication type: Journals. ISSN: 00284793, 15334406

Coverage: 1947-2011

H Index: 589

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	53.484	345	227674
2009	0.728	49	690
2008	0.845	49	706

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	1,957	2,109	2,467	2,840	3,151	3,878	3,439	3,572	3,431	3,441	3,467	3,903	3,412
Total Documents	1.324	1.240	1.110	1.184	1.618	1.606	1.331	1.888	1.885	1.808	1.829	1.817	1.113
Total Docs. (3years)	3.881	3.952	3.865	3.674	3.534	3.912	4.408	4.555	4.825	5.104	5.581	5.522	5.454
Total References	19.007	17.033	17.792	16.446	17.665	18.684	17.337	18.044	18.241	19.011	18.256	17.296	10.423
Total Cites (3years)	31.983	36.123	39.326	41.972	46.010	52.097	53.755	58.543	57.059	56.771	57.331	61.174	36.190
Self Cites (3years)	376	387	476	382	483	532	517	633	583	568	529	559	419
Citable Docs. (3years)	1.852	1.864	1.791	1.693	1.592	1.693	1.943	2.053	2.063	1.946	1.920	1.911	1.850
Cites / Doc. (4years)	17,27	19,28	21,55	23,86	27,21	29,86	28,69	29,26	27,65	27,61	29,97	31,18	18,56
Cites / Doc. (3years)	17,27	19,38	21,96	24,79	28,90	30,77	27,67	28,52	27,66	29,17	29,86	32,01	19,56
Cites / Doc. (2years)	16,72	18,87	21,54	26,12	29,68	29,63	25,82	27,88	29,27	28,15	29,85	34,42	19,61
References / Doc.	14,36	13,74	16,03	13,89	10,92	11,63	13,03	9,56	9,68	10,51	9,98	9,52	9,36
Cited Docs.	1.938	2.044	2.059	2.065	2.078	2.209	2.440	2.519	2.528	2.550	2.530	2.557	2.251
Uncited Docs.	1.943	1.908	1.806	1.609	1.456	1.703	1.968	2.036	2.297	2.554	3.051	2.965	3.203
% International Collaboration	6,19	9,84	20,90	18,33	19,84	20,92	27,50	14,62	15,07	14,33	14,82	13,26	14,38

Oncologist Research

Country: United States

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q1, Hematology Q1

Publisher: AlphaMed Press Inc. Publication type: Journals. ISSN: 1549490X, 10837159

Coverage: 1996-2011

H Index: 80

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	0.826	43	854
2009	6.701	131	5337
2008	6.630	131	4676

Scope:

The Oncologist is devoted to medical and practice issues for surgical, radiation, and medical oncologists and is designed specifically for the busy practitioner entrusted with the care of adult or pediatric cancer patients. With emphasis on clear, concise interpretation, this international peer-reviewed journal publishes original papers, reviews, and commentaries addressing the multimodality diagnosis, treatment, and quality of life of the cancer patient. Manuscripts are reviewed by two or more experts in the field and, when accepted, are published with haste—generally within 12 weeks.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,082	0,166	0,271	0,442	0,525	0,633	0,702	0,685	0,691	0,787	0,823	0,834	0,460
Total Documents	67	97	116	113	89	125	121	153	180	189	167	205	139
Total Docs. (3years)	181	204	230	280	326	318	327	335	399	454	522	536	561
Total References	2.206	3.283	3.430	4.409	4.071	5.795	5.153	7.475	8.937	8.544	7.967	7.322	5.349
Total Cites (3years)	71	145	422	806	1.171	1.213	1.598	1.784	2.116	2.669	3.159	3.198	1.440
Self Cites (3years)	1	8	11	20	15	28	35	42	54	58	51	55	22
Citable Docs. (3years)	158	168	178	218	246	248	267	285	329	376	425	441	471
Cites / Doc. (4years)	0,45	0,82	1,93	3,32	4,34	4,93	5,40	6,01	6,34	6,95	7,10	6,94	3,54
Cites / Doc. (3years)	0,45	0,86	2,37	3,70	4,76	4,89	5,99	6,26	6,43	7,10	7,43	7,25	3,06
Cites / Doc. (2years)	0,49	1,15	2,76	4,15	4,42	5,18	5,76	6,08	6,05	7,46	7,66	6,38	2,42
References / Doc.	32,93	33,85	29,57	39,02	45,74	46,36	42,59	48,86	49,65	45,21	47,71	35,72	38,48
Cited Docs.	41	67	119	172	208	208	239	269	308	364	409	417	358
Uncited Docs.	140	137	111	108	118	110	88	66	91	90	113	119	203
% International Collaboration	2,99	3,09	12,93	8,85	5,62	8,80	16,53	9,15	17,22	14,29	10,78	15,61	15,11

Physics in Medicine and Biology

Country: United Kingdom

Subject Area: Engineering | Medicine | Physics and Astronomy | Health Professions

Subject Category: Biomedical Engineering Q1, Physics and Astronomy (miscellaneous) Q1, Radiological and Ultrasound Technology Q1, Radiology, Nuclear Medicine and Imaging Q1

Publisher: Institute of Physics Publishing. Publication type: Journals. ISSN: 13616560, 00319155

Coverage: 1956-2011

H Index: 101

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	3.056	536	16658
2009	1.045	29	211
2008	0.698	29	178

Scope: Subject coverage. The application of theoretical and practical physics to medicine, physiology and biology. Topics covered are: all areas of radiotherapy physics; radiation dosimetry; biomedical imaging image reconstruction and kinetic modeling; image analysis and computer-aided detection; other radiation medicine applications; therapies biomedical optics; radiation protection; radiobiology; body composition .

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,142	0,142	0,176	0,178	0,207	0,193	0,215	0,227	0,258	0,250	0,225	0,246	0,310
Total Documents	261	307	267	364	332	442	450	524	535	522	547	543	345
Total Docs. (3years)	667	739	853	835	938	963	1.138	1.224	1.416	1.509	1.581	1.604	1.612
Total References	6.830	7.653	6.575	9.288	8.690	11.660	12.101	16.426	15.343	16.015	15.585	16.013	11.246
Total Cites (3years)	1.101	1.276	1.652	1.762	2.129	2.453	3.318	3.852	4.802	4.528	5.014	5.043	3.036
Self Cites (3years)	333	338	399	452	431	540	606	745	839	919	875	930	655
Citable Docs. (3years)	647	711	816	795	902	925	1.100	1.189	1.392	1.492	1.564	1.576	1.577
Cites / Doc. (4years)	1,70	1,86	2,06	2,18	2,32	2,68	3,00	3,22	3,48	3,16	3,31	3,14	1,97
Cites / Doc. (3years)	1,70	1,79	2,02	2,22	2,36	2,65	3,02	3,24	3,45	3,03	3,21	3,20	1,93
Cites / Doc. (2years)	1,51	1,75	1,94	2,24	2,26	2,61	2,98	3,15	3,12	2,84	3,26	3,10	1,85
References / Doc.	26,17	24,93	24,63	25,52	26,17	26,38	26,89	31,35	28,68	30,68	28,49	29,49	32,60
Cited Docs.	425	469	549	574	643	677	816	919	1.106	1.184	1.268	1.285	1.086
Uncited Docs.	242	270	304	261	295	286	322	305	310	325	313	319	526
% International Collaboration	19,92	19,87	20,22	24,45	27,41	26,70	24,44	21,18	22,80	22,61	23,95	22,65	29,57

Proceedings of the National Academy of Sciences of the United States of America

Country: United States

Subject Area: Multidisciplinary

Subject Category: Multidisciplinary Q1

Publisher: National Academy of Sciences. Publication type: Journals. ISSN: 00278424, 10916490

Coverage: 1947-1951, 1961-2011

H Index: 442

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	9.771	3764	482679
2009	4.321	56	3754
2008	3.981	56	3401

Scope: PNAS is one of the world's most-cited multidisciplinary scientific serials. Since its establishment in 1914, it continues to publish cutting-edge research reports, commentaries, reviews, perspectives, colloquium papers, and actions of the Academy. Coverage in PNAS spans the biological, physical, and social sciences. PNAS is published weekly in print, and daily online in PNAS Early Edition. The PNAS impact factor is 9.38 and the Eigenfactor is 1.7 for 2008. PNAS is available by subscription

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	5,178	5,214	4,750	4,440	3,995	3,707	3,323	2,976	2,744	2,419	2,432	2,206	1,754
Total Documents	2.830	2.702	2.815	3.118	2.922	3.334	3.456	3.634	3.776	3.919	4.239	4.237	2.456
Total Docs. (3years)	8.473	8.437	8.416	8.347	8.635	8.855	9.374	9.712	10.424	10.866	11.329	11.934	12.395
Total References	102.016	97.474	103.052	112.507	107.512	121.186	127.161	132.552	142.937	138.933	151.256	154.834	91.068
Total Cites (3years)	83.083	86.152	88.420	87.258	86.694	92.223	96.358	96.586	98.716	100.718	103.852	108.945	68.164
Self Cites (3years)	3.081	3.111	3.297	3.272	3.175	3.302	3.421	3.250	3.451	3.432	3.496	3.429	2.046
Citable Docs. (3years)	8.127	7.981	7.900	7.750	8.024	8.235	8.754	9.065	9.668	10.072	10.385	10.835	11.118
Cites / Doc. (4years)	10,22	10,63	11,00	11,26	10,87	11,31	11,23	10,84	10,60	10,18	10,20	10,30	6,33
Cites / Doc. (3years)	10,22	10,79	11,19	11,26	10,80	11,20	11,01	10,65	10,21	10,00	10,00	10,05	6,13
Cites / Doc. (2years)	9,98	10,68	10,86	10,90	10,40	10,73	10,64	10,03	9,78	9,53	9,49	9,64	5,71
References / Doc.	36,05	36,07	36,61	36,08	36,79	36,35	36,79	36,48	37,85	35,45	35,68	36,54	37,08
Cited Docs.	7.878	7.836	7.874	7.802	8.075	8.334	8.794	9.039	9.634	10.072	10.403	10.938	10.684
Uncited Docs.	595	601	542	545	560	521	580	673	790	794	926	996	1.711
% International Collaboration	26,40	29,50	28,60	27,29	31,28	31,16	32,90	33,82	35,65	37,02	39,09	38,14	38,80

Review of Scientific Instruments

Country: United States `

Subject Area: Physics and Astronomy

Subject Category: Physics and Astronomy (miscellaneous) Q2

Publisher: American Institute of Physics. Publication type: Journals. ISSN: 00346748

Coverage: 1930-2011

H Index: 90

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.598	1145	21869
2009	1.521	657	19371
2008	1.738	657	19770

Scope: Review of Scientific Instruments, published by the American Institute of Physics, is devoted to scientific instruments, apparatus, and techniques. Its contents include original and review articles on instruments in physics, chemistry, and the life sciences; and sections on new instruments and new materials. One volume is published annually. Conference proceedings are occasionally published and supplied in addition to the Journal"s scheduled monthly issues.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,149	0,139	0,151	0,148	0,150	0,136	0,123	0,149	0,135	0,178	0,105	0,116	0,125
Total Documents	863	834	813	892	966	1.049	781	999	726	1.151	669	1.162	551
Total Docs. (3years)	2.084	2.302	2.316	2.510	2.539	2.671	2.907	2.796	2.829	2.506	2.876	2.546	2.982
Total References	14.312	14.407	12.557	1.158	16.699	17.276	15.440	17.062	15.489	19.724	15.003	20.844	12.848
Total Cites (3years)	2.427	2.517	3.131	2.783	3.142	3.683	3.933	4.256	3.673	3.942	3.326	3.471	1.354
Self Cites (3years)	408	380	429	21	454	699	329	696	310	675	293	527	138
Citable Docs. (3years)	2.082	2.302	2.316	2.477	2.475	2.603	2.866	2.781	2.813	2.481	2.848	2.512	2.945
Cites / Doc. (4years)	1,17	1,09	1,33	1,13	1,26	1,40	1,41	1,47	1,35	1,61	1,20	1,30	0,60
Cites / Doc. (3years)	1,17	1,09	1,35	1,12	1,27	1,41	1,37	1,53	1,31	1,59	1,17	1,38	0,46
Cites / Doc. (2years)	1,16	1,13	1,34	1,12	1,26	1,31	1,36	1,50	1,18	1,59	1,21	1,10	0,46
References / Doc.	16,58	17,27	15,45	1,30	17,29	16,47	19,77	17,08	21,33	17,14	22,43	17,94	23,32
Cited Docs.	1.030	1.096	1.237	1.146	1.267	1.432	1.530	1.569	1.392	1.399	1.360	1.375	838
Uncited Docs.	1.054	1.206	1.079	1.364	1.272	1.239	1.377	1.227	1.437	1.107	1.516	1.171	2.144
% International Collaboration	20,05	22,66	21,65	16,59	23,91	26,02	20,36	24,12	22,59	28,15	25,56	27,02	22,14

Science

Country: United States

Subject Area: Multidisciplinary

Subject Category: Multidisciplinary Q1

Publisher: American Association for the Advancement of Science. Publication type: Journals. ISSN: 00368075

Coverage: 1880-1881, 1883-2011

H Index: 678

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	31.364	862	469704
2009	29.747	897	444643
2008	28.103	897	409290

Scope:

Thank you for visiting the Web site of Science -- the world's leading journal of original scientific research, global news, and commentary. In this section we offer some basic information specific to the magazine and its Web content. For more detailed information about the functions available across the Science Web sites, we invite you to visit the For Readers section of our global site help

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	11,483	10,233	8,951	8,250	8,421	7,349	6,110	4,962	4,330	4,292	4,883	5,721	5,425
Total Documents	2.409	2.478	2.599	2.630	2.524	2.591	2.535	2.373	2.393	2.400	2.452	2.425	1.338
Total Docs. (3years)	8.098	8.095	7.712	7.486	7.707	7.753	7.745	7.650	7.499	7.301	7.166	7.245	7.277
Total References	41.369	34.694	38.326	39.015	33.661	32.689	32.472	32.707	32.181	33.580	34.567	34.431	20.238
Total Cites (3years)	76.655	77.540	74.942	75.378	78.570	84.680	86.715	81.214	77.816	76.067	78.997	84.509	50.898
Self Cites (3years)	1.312	1.129	1.203	1.264	1.181	1.081	990	1.008	930	997	884	992	531
Citable Docs. (3years)	3.287	3.391	3.386	3.500	3.370	3.707	4.025	4.314	4.476	4.166	3.718	3.074	2.835
Cites / Doc. (4years)	23,32	22,88	22,62	22,55	22,63	22,87	22,25	20,97	17,89	18,62	20,70	24,07	17,19
Cites / Doc. (3years)	23,32	22,87	22,13	21,54	23,31	22,84	21,54	18,83	17,39	18,26	21,25	27,49	17,95
Cites / Doc. (2years)	22,92	21,84	20,13	21,49	23,56	22,04	18,43	18,22	16,17	17,75	24,45	28,86	17,22
References / Doc.	17,17	14,00	14,75	14,83	13,34	12,62	12,81	13,78	13,45	13,99	14,10	14,20	15,13
Cited Docs.	4.090	4.113	4.160	4.238	4.503	4.663	4.673	4.538	4.455	4.475	4.510	4.520	4.106
Uncited Docs.	4.008	3.982	3.552	3.248	3.204	3.090	3.072	3.112	3.044	2.826	2.656	2.725	3.171
% International Collaboration	11,66	5,49	0,81	2,47	16,52	17,41	20,83	21,53	21,19	22,00	23,37	23,63	23,84

Technology in Cancer Research and Treatment

Country: United States

Subject Area: Biochemistry, Genetics and Molecular Biology | Medicine

Subject Category: Cancer Research Q3, Radiology, Nuclear Medicine and Imaging Q1

Publisher: Adenine Press. Publication type: Journals. ISSN: 15330346

Coverage: 2002-2011

H Index: 32

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	1.814	62	1235
2009	2.023	55	1037
2008	1.951	55	1009

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,000	0,000	0,000	0,000	0,107	0,193	0,188	0,255	0,304	0,242	0,188	0,205	0,163
Total Documents	0	0	0	62	66	72	79	71	111	61	56	68	32
Total Docs. (3years)	0	0	0	0	62	128	200	217	222	261	243	228	185
Total References	0	0	0	2.383	3.135	3.208	3.878	2.980	2.453	2.316	1.665	2.423	979
Total Cites (3years)	0	0	0	0	61	226	389	529	662	560	477	443	197
Self Cites (3years)	0	0	0	0	2	8	21	14	35	20	14	41	18
Citable Docs. (3years)	0	0	0	0	59	121	190	206	212	250	233	220	174
Cites / Doc. (4years)	0,00	0,00	0,00	0,00	1,03	1,87	2,05	2,44	2,97	2,47	2,31	2,09	1,31
Cites / Doc. (3years)	0,00	0,00	0,00	0,00	1,03	1,87	2,05	2,57	3,12	2,24	2,05	2,01	1,13
Cites / Doc. (2years)	0,00	0,00	0,00	0,00	1,03	1,87	2,11	2,60	2,67	1,71	1,95	1,81	1,04
References / Doc.	0,00	0,00	0,00	38,44	47,50	44,56	49,09	41,97	22,10	37,97	29,73	35,63	30,59
Cited Docs.	0	0	0	0	33	92	140	163	166	153	145	141	95
Uncited Docs.	0	0	0	0	29	36	60	54	56	108	98	87	90
% International Collaboration	0,00	0,00	0,00	4,84	9,09	11,11	13,92	14,08	11,71	14,75	23,21	27,94	21,88

Ultrasound in Medicine and Biology

Country: Netherlands

Subject Area: Medicine

Subject Category: Radiology, Nuclear Medicine and Imaging Q1

Publisher: Elsevier BV. Publication type: Journals. ISSN: 03015629

Coverage: 1973-2011

Year	Impact Factor (IF)	Total Articles	Total Cites
2010	2.493	214	6695
2009	2.021	168	5723
2008	2.395	168	6868

H Index: 77

Scope: Ultrasound in Medicine and Biology (UMB) is the official journal of the World Federation for Ultrasound in Medicine and Biology. The journal publishes original contributions on significant advances in clinical diagnostic, interventional and therapeutic applications, new and improved clinical techniques, the physics, engineering and technology of ultrasound in medicine and biology, and the interactions between ultrasound and biological materials, including bioeffects.

Indicators	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
SJR	0,102	0,105	0,084	0,090	0,118	0,202	0,233	0,194	0,202	0,191	0,182	0,199	0,183
Total Documents	148	1.057	190	177	193	179	191	206	226	223	225	226	176
Total Docs. (3years)	965	986	1.372	1.395	1.424	560	549	563	576	623	655	674	674
Total References	3.816	4.807	5.271	5.028	5.415	5.114	5.429	5.621	6.886	6.865	7.003	7.709	5.427
Total Cites (3years)	790	906	922	1.107	1.304	1.408	1.408	1.598	1.447	1.549	1.636	1.939	999
Self Cites (3years)	225	278	195	214	333	240	266	241	244	257	209	306	174
Citable Docs. (3years)	952	976	1.358	1.381	1.412	550	540	549	561	603	631	649	647
Cites / Doc. (4years)	0,83	1,08	0,63	0,98	1,06	1,16	2,61	3,00	2,84	2,63	2,62	2,87	1,60
Cites / Doc. (3years)	0,83	0,93	0,68	0,80	0,92	2,56	2,61	2,91	2,58	2,57	2,59	2,99	1,54
Cites / Doc. (2years)	0,61	1,84	0,48	0,61	2,25	2,44	2,46	2,46	2,34	2,37	2,57	2,83	1,40
References / Doc.	25,78	4,55	27,74	28,41	28,06	28,57	28,42	27,29	30,47	30,78	31,12	34,11	30,84
Cited Docs.	296	326	337	373	396	431	391	440	425	436	483	505	410
Uncited Docs.	669	660	1.035	1.022	1.028	129	158	123	151	187	172	169	264
% International Collaboration	12,84	2,08	7,89	11,86	18,65	10,06	19,37	14,08	13,72	14,80	18,67	21,68	19,32