Microwaves to hunt tumors

New generation of imaging systems will avoid the breast compression and radiation of traditional mammography

GISELLE SOARES

Information engineer Bruno Sanches carefully places an orange, conical apparatus 15 centimeters (cm) in diameter, which looks similar to the cup of a brassiere, on the table at the University of São Paulo Polytechnic School's Integrated Systems Laboratory (POLI-USP). This is not without good reason: the apparatus is the prototype of a new generation of examination devices that adjust around the breast and capture images at different angles to search for tumors that need to be removed. The Brazilian National Cancer Institute (INCA) estimated 73,600 new cases of breast cancer per year in the country between 2023 and 2025. Breast cancer is the most common tumor among women across all regions of Brazil, with the highest rates in the country's south and southeast regions.

The key characteristic of the new imaging system, a joint project between POLI-USP and the Electrical Engineering Department at the Federal Institute of São Paulo (IFSP), is its microwave function, a new technological approach also studied at universities in the US, Canada, the UK, Sweden, Italy, Japan, and Australia. The mammography devices currently used to detect breast tumors use X-rays, a type of ionizing radiation that can present risks to health.

Although well tolerated by most women, traditional scans can cause discomfort and pain as the equipment's plates compress the breasts. The new device designed by the São Paulo researchers molds to the breast shape and avoids the current painful process. In 2023, 4.4 million mammograms were conducted by the Brazilian Public Health System (SUS).

"We want to offer a complementary alternative to mammography," says Sanches. The engineer believes that the device could be especially useful among women with denser breasts, for which mammography is less sensitive. Density is not related to size but is the proportion of fibrous and glandular tissue in relation to adipose (fat) tissue.

The standard of the American Radiology College (ACR) for imaging scans is to classify the breasts into four density categories: those that are predominantly fatty and less dense, which are easier to scan by mammography; those with sparse areas of fibroglandular tissue; those that are heterogeneously dense, which may hinder the detection of small nodules or tumors; and those that are extremely dense, making the identification of lesions on the mammograph even more difficult. The proposed system may be advantageous for dense breasts, as the electromagnetic properties of the tissues involved are discrepant and can be differentiated.

"The denser the breast, the whiter it appears on the mammogram, making it difficult to identify tumors, which are also white," explains radiologist physician Almir Bitencourt of São Paulo's A.C. Camargo Cancer Center, a leading Brazilian facility for research, diagnosis, and treatment in the area. "In these situations, complementary exams such as ultrasound or magnetic resonance imaging (MRI) are normally recommended."

RADIO WAVES

The prototype developed by USP and IFSP uses an electronic device known as a microwave transceiver that transmits and receives signals through embedded antennae. The transceiver emits ultrabroadband radio waves at a central frequency of 6.4 gigahertz (GHz), which pass through the mammary tissue and return to the device if they encounter denser internal structures, such as possible tumors. The reflected signals are directed to an image processing unit, which uses an algorithm to generate a detailed map of the region (*see infographic on the next page*).

The system currently generates reconstructed two-dimensional images of the breast, but the hardware structure enables adjustments to the vertical position of the platform, allowing the antenna locations to be varied. The equipment can thus scan different sections of the breast, producing 3D images.

In tests on an artificial model, known as the phantom, with materials designed to replicate the electrical properties of mammary tissues, the device was found to detect tumors 1 cm in diameter at a depth of 3 cm, as detailed in a January 2023 article published in the journal *Biomedical Signal Processing and Control*.

The internal structure of the phantom was also designed to simulate breast anatomy, with 0.2 cm of skin, 6 cm of glandular tissue, and 8.6 cm of fat tissue. Breast cancer is classified into four clinical stages according to its extent and severity. Tumors up to 2 cm in diameter that do not reach the lymph nodes are in the initial stage and are less severe.

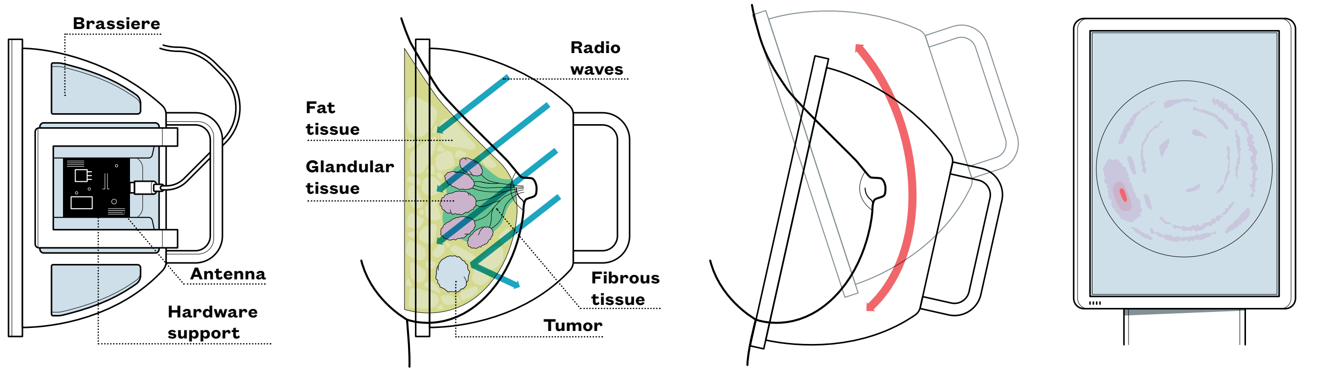
X-ray mammography, which is recommended for the diagnosis of suspicious alterations at any age in both men and women, can identify lesions smaller than 1 cm, along with the initial signs of breast cancer, known as microcalcifications. "Currently, no other method identifies microcalcifications with the same accuracy," says Bitencourt of the A.C. Camargo Center.

The microwave examination, although less accurate in its current version, may put a stop to the ionizing radiation used in traditional devices. "X-ray mammography needs shielded spaces, while the microwave-based technology does not emit ionizing radiation, making it safer and more accessible," says electrical engineer Fatima Salete Correra, also of POLI-USP, who did not participate in the research. Low-cost, portable devices may provide benefits, particularly in regions where access to breast scans is more challenging.

The team's previous experience with the miniaturized integrated circuit known by the abbreviation SAMPA (serialized analog-digital multipurpose Asic), developed with the support of FAPESP, helped in the development of components for integration into the portable pro-

How the new scan works

The device is positioned at different angles around the breast to obtain the best possible image



1 The prototype uses a microwave transceiver with embedded antennae and a silicone rubber brassiere for dry coupling, with no need for conducting gel

2 The transceiver emits ultrabroadband radio waves, which pass through the mammary tissue and return to the device if they find denser internal structures

3 To generate a more comprehensive, clearer image, the device is positioned on different parts of the breast, without the need to compress it

4 A processing unit receives the reflected signals, and with the help of its own algorithm, it generates a two-dimensional map of the region examined

SOURCE BRUNO SANCHES (USP)

totype. "Knowledge about how to design and build highly sensitive amplifiers, analog-digital converters, and signal processors was essential to our development of chips for use in health care," explains Sanches, of the Polytechnic School. Created by researchers from USP, UNICAMP, and the Aeronautics Technology Institute (ITA), the SAMPA Chip has been in use since 2020 at one of the four particle detectors of the Large Hadron Collider (LHC), operated by the European Organization for Nuclear Research (CERN) on the French–Swiss border.

The next step for the São Paulo team will be to test the performance of the prototype on phantoms reflecting different breast sizes and tumor types. Companies have yet to show interest in collaborating on the project. In other countries, devices of this type are already in more advanced stages of development. In a review article published in December 2024 in *IEEE Access*, researchers from USP and IFSP compared the performance of 12 prototypes and observed how they present different levels of sensitivity (ability to correctly identify the presence of a tumor) and specificity (ability to present a negative result with no tumor present).

Some demonstrated high levels of precision, such as the device at McMaster University, Canada, which was found to identify tumors of 2.4 mm, although the exam took five hours (*see the infographic in the online version of this article*). One of the most advanced devices, created at the University of Bristol in England, is known as Maria (multistatic array processing for radio-wave image acquisition). In a clinical trial involving 389 women with an average age of 47, the sixth version of the device correctly identified 47% of malignant lesions, which falls well short of the percentage for conventional mammography, whose correct identification rate was 92%, as detailed in the *British Journal of Radiology* in a January 2024 article.

Although the scan received positive evaluations from the women who underwent it, the authors of the study, led by radiologist Richard Sidebottom of the Royal Marsden NHS Foundation Trust, concluded that diagnosis by microwaves cannot yet be considered fully effective. Among the participants, 94% preferred this procedure to the traditional scan, primarily because there was no breast compression or ionizing radiation. Nine out of ten women reported greater comfort during diagnosis. ●

Prototype of the microwave imaging system designed by USP and IFSP

The scientific articles consulted for this report are listed in the online version.

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