

Microstrip Antennas in Biomedical Fields

Rabia TOPRAK

Karamanoglu Mehmetbey University

Introduction

Antennas are extremely useful equipments in communication applications. Receiving information taking from a supply and transmitting to another supply is provided by the antenna structures. With these features, antennas are indispensable for telecommunication applications. There are lots of types of the antenna structures. They are horn, microstrip, monopole, dipole, Vivaldi, loop, Bow-Tie, log-periodic and etc. In the designs of antenna, there are important parameters. They are operating frequency, bandwidth, radiation pattern, gain, directivity, impedance, return loss, efficiency, VSWR (Voltage Standing Wave Ratio). These parameters explain the performance of the antenna structures. A radiation pattern defines the variation of the power radiated by an antenna structure as a function of the direction away from the antenna structure. Therefore, gain, directivity and field graphs are generally explain with the radiation pattern. Another parameter is the efficiency of the antenna structure. Efficiency is an important parameter for an antenna structure because of a ratio of the power delivered to the antenna structure relative to the power radiated from the antenna structure (Balanis, 2013).

Microstrip antennas (MAs) consist of a dielectric layer called as substrate between two conduction layer. Copper is generally used as conduction material. Substrate is a material has different dielectric constant and tangent loss. The thickness and dielectric constant value of substrate can be designed differently by different companies. This provides easily the ability of MAs design. MAs are also be able to call as microstrip patch antennas, too. So, MAs are preferred in large search areas (B. J. Kwaha, O. N. Inyang, 2011; Bahrami et al. 2021; Dey & Mittra, 1996; Kanj & Popovic, 2005; Nalam et al., 2014; Peixeiro, 2011; Rabbani & Ghafouri-Shiraz, 2017; Soontornpipit et al., 2004; Top et al., 2020a; Top et al., 2019; Top et al. 2017, 2020b; Uyanik et al., 2020a; S. Yang et al., 2008). The reason of this preference is that they have lots of advantages. One of the advantages is that could directly be printed onto a circuit board. The other is low production cost. Easy design, lightness, large design facility and etc. are possible to sort as another advantages. Disadvantages of MAs are low gain and efficiency values. According to their designs, the efficiency, gain and directivity of microstrip antenna structures are able to increase by applying different methods. Therefore, MAs become attractive for different research applications in the worldwide (Singh & Tripathi, 2011). Every research related to human life is valuable. So, Biomedical/Medical applications are interested in health issues. Sometimes they aim to diagnose and sometimes to treat. Especially as far as human health is concerned, all of biomedical applications

get importance. Biomedical researches and developments are made for purposes that are very different. For examples; Wireless Body Area Network (WBAN), Implantable Medical Devices (IMDs), Wireless Local Area Network and Wearable Medical Devices (WMDs) (Kolokotsa et al., 2002; Paracha et al., 2019; Samal et al., 2019; Simorangkir et al., 2018).

Microstrip Antenna Applications on Cancer Researches

MAAs are highly used in cancer researches. It is possible to say that cancer researches are fairly important because of the effect of death ratios. All over the world people suffer from diseases supplied cancer. Once the statistics are examined, it is seen one of the biggest death ratios about 19% are from diseases supplied cancer (Institution, 2020). Therefore, to diagnose or treat the cancer diseases become quite important. With this aim, in the literature there are several studies. Specially, to solve such health problems, microstrip antenna structures are explained in this book chapter. MAAs are especially chosen to produce solution easily cancer diseases. Because these antenna structures have lots of advantages mentioned above. Also, there are a lot of the types of cancer. They are sortable as breast, brain, pancreatic, kidney, colon cancer and etc. Each type of cancer is a necessary and different research topic.

Such works are generally related to detect cancer diseases. Because imaging methods are MR (Magnetic Resonance), ultrasound or CT (Computing Tomography) (Alsharif & Kurnaz, 2018; Caliskan et al., 2015; Top et al., 2019). These methods are contained very high frequency bands. For example, X-ray. X-ray is able to affect the atom of human tissue. Although it has low cost, it has low image resolution and the effect of ionizing radiation. MR has high image resolution and nonionizing radiation. But, it is expensive, bulky, noisy and time consuming. Frequency region is very important because of the effect of radiation. The radiation intensity increases at higher frequencies (McKeen, 2016). Also, CT is expensive, bulky and has the effect of ionizing radiation in human body (Alqadami et al., 2019). This could harm the human body at the frequent measurements to detect cancer diseases. So, MAAs have proposed for microwave imaging solutions. Microwave frequency region has no effect on human body. It is called as Microwave Tomography. Medical diagnostic, identification via wireless communication, wireless sensors and etc. applications are continually researching and developing with this aim. Although the proposed antenna types differ, MAAs are mostly preferred.

Microstrip Antenna Applications for the Type of Breast Cancer

All over the world women suffer from breast cancer. One in 8 women gets breast cancer. In men, this rate is 1 in 833 ("Breast Cancer Facts and Statistics," 2022; World Health Organization, 2021). Breast cancer is that has the biggest death rates between women. Early diagnosis is very important and beneficial to treat it. For early diagnosis the most important part is detection to tumorous tissue in breast. Namely, imaging method is almost vital in women life. Because, every woman above 30-years old need to make

check-up twice a year with an imaging method. With this aim, the importance of imaging methods increases day by day. The less radiation intensity used in imaging method is, the more useful women who are measured is. Therefore, Microwave Tomography applications are searched with an increasing demand. Both its application is simple and its cost is low. MAs are developing as an alternative imaging method that has non-ionizing radiation intensity against other imaging methods that has high ionizing radiation intensity level.

Operating frequency and band area are topics examining in antenna structures. Dual-band frequency operation is applied by handling the fundamental resonant mode of the MAs and one of its higher order modes. Dual-band (multi frequency band) operation provides solving the inverse scattering problems. Also, the coupling effect of antenna in an immersion medium is decreased with dual-band operation. Slotting is a method to obtain dual-band in patch of MAs (Al-Joumayly et al., 2010). Short-circuit pin and superstrate methods are another methods to get dual-band operation (Blauert & Kiourti, 2014; Ganeshwaran et al., 2020; Woten & El-Shenawee, 2008). Figure 1 shows some example of MAs slotted and added via in the patch. Figure 1. (a) shows an example of the rectangular patch with three slots and Figure 1. (b) shows an example of the circular patch with slots and via. Superstrate method is used to increase the gain of MAs and to get dual-band operation frequency regions (Faisal & Yoo, 2019a). It is also used to prevent direct contact of the patch with the human tissue. Slotting in the patch and ground plane are methods to increase the gain of MAs (Çalışkan et al., 2015; Toprak et al., 2021). Proposed antennas are used to simulate and measure several 3D measurement set-ups. Some examples are presented in Figure 2. Different breast models are presented at different studies (AbdulSadda et al., 2010; Li et al., 2015).

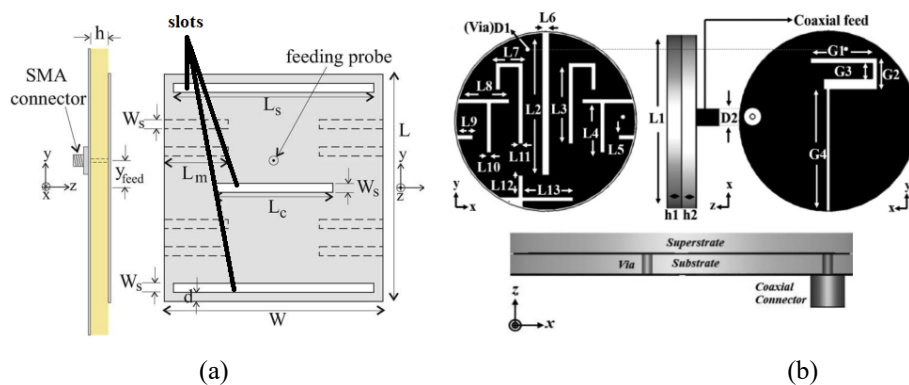


Figure 1. (a) Slotted example of MAs, (b) Slotted and added via example of MAs in the patch (Al-Joumayly et al., 2010; Ganeshwaran et al., 2020)

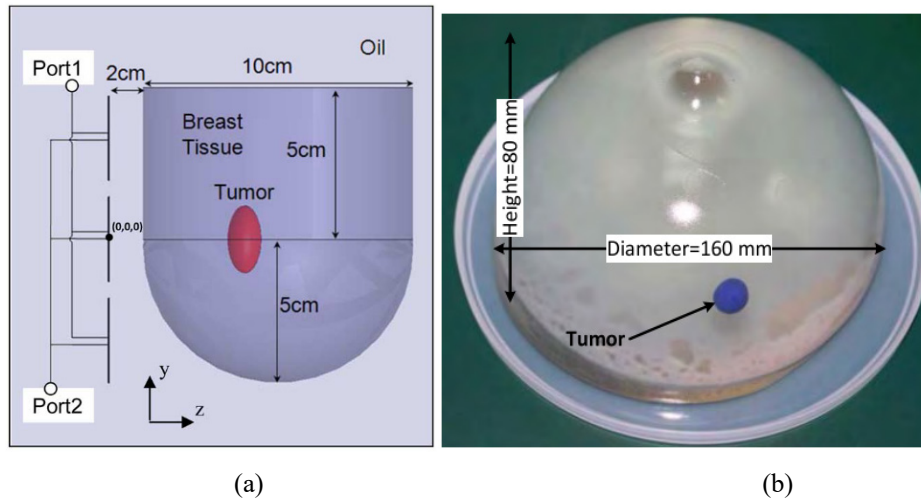


Figure 2. 3D tumorous breast model (a) for simulation, (b) for measurement (Mahmud et al., 2018; Woten & El-Shenawee, 2008)

Another technique to detect breast cancer is to get ultra wide-band (UWB). As differing slot number in the patch, it is possible to make UWB. UWB ensures better return loss and VSWR (Voltage Standing Wave Ratio) value in the measurements. These values are important parameters for evaluating antenna performance (Ul Haq & Khany, 2014). [Microstrip Antenna Applications for the Type of Laryngeal and Trachea/Bronchus/Lung Cancer](#)

In 2019, Türkiye, according to Türkiye Statistical Institute the Larynx and trachea/bronchus/lung tumors caused the most deaths from tumors (Institution, 2020). When deaths from benign and malignant tumors were analyzed according to sub-causes of death, it was seen that 30.2% of the deaths were caused by malignant tumors of the larynx and trachea/bronchus/lung. For imagine these cancer types, MAs are used as microwave imaging method. A study has used MAs as dipole antenna structure. The proposed antenna technique and set-up are quite fast in scanning, computation, and image creation because it needs no additional devices for accurate boundary estimation. Array elements are utilized in MAs structure because of obtaining the dipole antenna structure (Zamani et al., 2018). To do this, by taking the feeding point as the center, a co-design has been made in the patch. So, dipole antenna structure is obtained. Figure 3 shows the antenna structure and its return loss graphs.

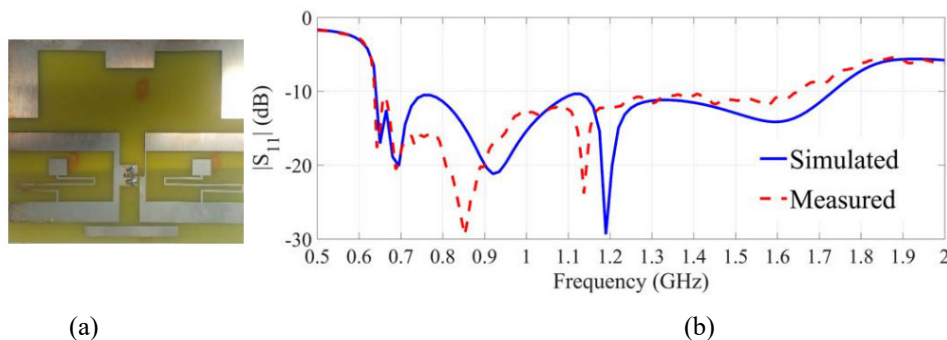


Figure 3. (a) Dipole antenna from MAs, (b) Its return loss (Zamani et al., 2018)

MAs are designed as resonators for imaging lung cancer type. There are different resonator types such as square, circular and etc. Measurements with resonator method are more accurate than other characterization techniques. Resonator method also provides to miniature the proposed technique. Therefore, while smaller resonator structure is got, higher accuracy results are gained (Hardinata et al., 2017).

MAs with array elements are utilized for electromagnetic imaging. Metamaterial is also used as meta surface element. Cause, backscattering problem is minimized with this method (Zamani et al., 2019). Advantage of this study is better imaging reconstruction. While there is no touch on human torso, imaging method could be easily applied.

A prototype structure, microstrip impedance transformer and antenna have been designed and simulated. In order to deliver the microwave energy into lung tissue at the end of the cable, an antenna has designed. The design must maintain access to the hollow channel at the end to not block the field of view of the CMOS (Complementary metal–oxide–semiconductor) imaging and illumination (Jones et al., 2019). This study is thinkable as lung ablation sensor that designed by using MA structure.

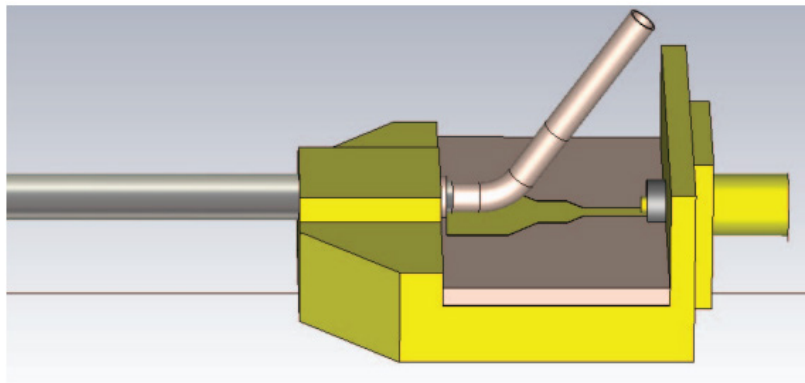


Figure 4. Modelled microstrip and ground structure tray (Jones et al., 2019)

Microstrip Antenna Applications for the Type of Stomach and Colon Cancer

After breast, laryngeal, trachea/bronchus/lung cancer, stomach and colon cancer types have the most death ratios. Both stomach and colon cancer types have about 8% of the death ratio in death ratios supplied benign/malignant tumour in Türkiye (Institution, 2020).

At the detection of colon cancer, colonoscopy is vital. For microwave colonoscopy system, a compact cylindrical U-slot antenna is applied. This antenna with MA structure has 16 L-shaped microstrip lines with two rows. One row is for transmission and other is for reception. L-shaped microstrip feed point is designed to feed U-slot effectively. To make easily colonoscopy, antenna structures wrapped around metal cylinder like a camera. Of course this style is cheaper than a system with a camera. The shape of the antenna provides better input impedance matching when there is human tissue. Antenna performance is tested in liquid phantom (Guardiola et al., 2019).

To measure the reaction of different organ tissue, two layered printed compact dual polarized antenna is designed. Both horizontal and vertical polarization is maintained

with double layer (Sabban, 2011). To prefer double or multiple layer on the design of antenna structure is quite effective method. Therewithal, multiple layer assures the compactness of the MAs.

There are wireless capsule endoscopy systems with MAs. In this system, antennas are the most important element. Flexible substrate is used because of wrapping around the capsule. Proposed antenna type is a loop antenna. Also it is suitable for paediatric application (Miah, Icheln et al., 2018). Another capsule antenna structure is presented by differing the shape of patch (Suzan Miah et al., 2019). In this work, antenna structure is an ultra-wideband conformal loop antenna for the in-body transmission.

Microstrip Antenna Applications on Heart Failure Diseases

Circulatory system diseases are any conditions that affect your heart or blood vessels. Circulatory system is also called your cardiovascular system. It keeps blood moving in your body. Diseases originating from the circulatory system have the highest mortality rate in the world today. The biggest ratio in this rate is from heart failure diseases (Institution, 2020; World Health Organization, 2020). Especially coronary artery occlusion is vital in the development and progress of heart failures. At the early stage, the detection of cardiac occlusion could be able to save lots of people life.

MAs in the detection of heart failure diseases are researching and development. A microstrip patch antenna has been designed at ISM (Industrial, Scientific, Medical) frequency band. A 3D heart model is developed by using the human tissue phantom receipt. This study focuses on the different patch shapes. Therefore, the performance of the proposed antenna is increased to detect coronary artery occlusion (Top, 2017; Top, Gultekin, & Uzer, 2017; Uyanik et al., 2020b). To detect heart failure at early stage, a compact antenna array with wideband performance is designed and tested in a study. The performance of the proposed antenna is tested in an artificial torso phantom. In the study, the proposed antenna with microstrip structure is designed as a loop antenna structure. So, wideband operation is provided (S.Ahdi Rezaeieh et al., 2015). Figure 5 shows the proposed antenna structure. Wideband frequency operation ensures the fine resolution of reconstruction. Another study suggests a leadless pacemaker by proposing a prototype rectenna. They propose a dipole antenna that is planar. Proposed antenna has a fractal geometry that is inductively doubled with rectangular strips. Fractal geometry is for minimization of the antenna structure. The performance of the proposed antenna is tested and measured with an ovine which is alive. The results of measurements are successful to pace a live heart using wearable conformal antenna array (Asif et al., 2019). Another leadless pacemaker by using MAs is suggested by differing dimensions of patch and ground plane (Abbas et al., 2022).

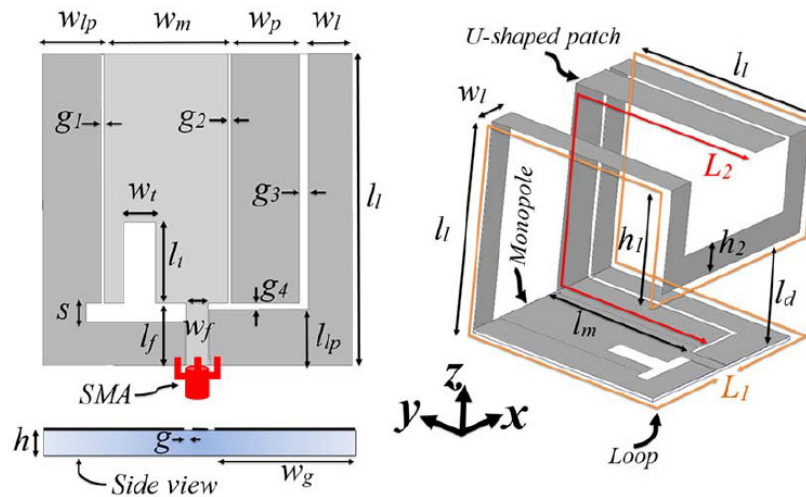


Figure 5. The proposed antenna structure for detection cardiac occlusion at early stage (S.Ahdi Rezaeieh et al., 2015)

A unidirectional and wideband antenna is proposed to image thorax. Reflector structure is utilized for resonance-based. Patch part is designed for reflection. So dimension of the proposed antenna is minimized. Multiple antenna structures could be located adjacent to each other with no experiencing any impedance mismatch or frequency shift. Figure 6 shows the proposed antenna structure. It is seen from the picture that antenna structure provides easily transfer electromagnetic energy to thorax (Sasan Ahdi Rezaeieh et al., 2018).

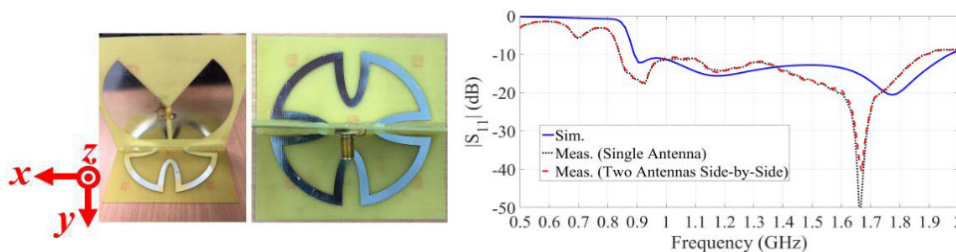


Figure 6. The proposed antenna structure (left) and its return loss graph (right) (Sasan Ahdi Rezaeieh et al., 2018)

MAAs are examined for cancer and heart failure diseases above. There are different MAAs in the literature to produce different solution for biomedical areas. For example, wearable microstrip antenna is designed for detection brain cancer. Proposed antenna structure has small dimensions and compatible for measuring in the brain structure. Patch part is from pentagon shaped and ground plane is modified. This design supplies the increase of current flow (Raihan, Alam Bhuiyan, Hasan, Chowdhury, & Farhin, 2017). MAAs are very preferable to detect brain cancer type (Mahmoud & Montaser, 2021; Rodrigues et al., 2021).

Telemetry applications are very searchable subject in medical. So MAAs are used frequently to apply telemetry applications (Basir & Yoo, 2019; Faisal & Yoo, 2019b; Wireless, 2018; Xia et al., 2020). MAAs are popular antenna types for other biomedical applications (Alkhaibari et al., 2017; Hasan et al., 2018; Iqbal et al., 2019; Lin et al., 2018; Nalam et al., 2014; Nesusudha & Fairry, 2018; Rahaman & Delwar Hossain, 2019;

Saha et al., 2018; Shadid et al., 2018; Xia et al., 2020; Z. J. Yang & Xiao, 2018a, 2018b). It is possible to rise MA examples in biomedical areas.

Conclusion

When the examples are examined, the importance of MAs is come out. Ease of design of microstrip antennas, which was also emphasized above, provide a huge research facility/possibility. The variety of substrate material used in designs provides design richness. According to the aim of design, it is usable both robust and flexible materials. Thickness and dimensions of it are able to adjusted as desired. There are many companies that produce PCBs. On account of the situation, it could be found in desired thickness.

The patch of MAs is able to design desire shapes. A flower, symbol, geometric shapes and letters are able to use. Moreover, one or more slot could make a slit in the patch structure. The shape of slot may differ. These differences are used for various aims. For example, to minimize the dimensions of antenna, to obtain wideband, ultra wideband, to increase the gain of antenna, to determine the directivity of antenna, to increase the efficiency of the antenna, to adapt the impedance matching and etc. The via used for antenna designs especially provides to decrease the dimensions of antenna structure. To minimize the antenna structure, generally via is utilized. But there is a disadvantage of it. Impedance matching may be a problem because of solder on ports. The ground plane of MAs has different shapes. Modified ground plane generally uses to obtain wideband or ultra wideband operations. Shape of it could be a geometric shape, letter or any other design. Using multiple layer called as superstrate is a different design method. Same or different substrate materials are designed by superimposing. It is generally used to increase the gain of antenna. Gain value is important because of effecting the directivity of antenna. Moreover, it is able to prefer for minimization and wideband operation.

MAs are possible to transform a loop or reflector antennas after designs. Similarly, the surface of patch is able to cover another different material for the aim of hypothesis. Metamaterial is another design and research subject in this area. There are several successful studies with metamaterial used. All of the examples and explanations are shown that MAs are very charming candidates for biomedical applications. Despite all the work, MAs continues to be developed at the moment. MAs are sometimes a biosensor, sometimes an implantable device and sometimes a wearable device. The importance of them is vital in biomedical applications.

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About the Author

Rabia TOPRAK, PhD, is a Research Assistant of Electrical and Electronics Engineering at Karamanoglu Mehmetbey University in Karaman, Türkiye. She holds a PhD in Electrical and Electronics Engineering from Konya Technical University and a MSc in Electrical and Electronics Engineering from Selcuk University. Her main areas of interest are antenna structures, microstrip antennas, biomedical applications of antenna structures and electromagnetic fields.

E-mail: rabiatorp@kmu.edu.tr, **ORCID:** 0000-0002-3306-1163.

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