



ISTANBUL COMMERCE
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Difficulties in Patch Antenna Production & Prototyping in Turkey

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1. DIFFICULTIES IN MSPA DESIGN AND PROTOTYPING IN TURKEY

- In today's period, MSPAs are one of the commonly used antenna types. All around the world, study and research groups study on microstrip patch antennas. Since, in terms of structure, it is preferably light, durable and can even be positioned in curved surfaces than other types of antennas. It is also expected that due to the increasing usage of the patch antennas in the wide range this could take over the usage of the conventional antennas for the maximum applications (Singh & Tripathi, 2011).
- Microstrip patch antenna has numerous applications. It is widely used in all areas of civil and military life. Therefore, patch antennas are used in many different fields such as satellite communication, medical, telecommunication, cosmology, public transportation, aviation, aircraft defense systems, and electronic warfare and many applications.

- In recent years, the fluctuation in currency rates and monetary narrowing has caused major problems in antenna design and production in developing countries including Turkey. This situation affected more the small-scale industries and mostly individuals such as students and low-budget researchers.
- Generally, the antenna design starts with substrate selection and built on the substrate. The rareness of high-quality dielectric substrates in the domestic market is one of the main reasons for this situation. There are various difficulties in the design and production of MSPA. Designing a MSPA with compact size, high gain and providing a wideband frequency range is a difficult case i.e. narrow bandwidth, low gain, and low efficiency are major drawbacks of MSPA.

- Moreover, using high dielectric substrates in MSPA reduces the overall performance of MSPA as studied in (Paul, et al., 2015) and high dielectric substrates cause surface wave excitation. When the dielectric constant is decreased the bandwidth of the antenna is increased (Garg & Goen, 2014). To overcome most of these problems, designers use a high-quality substrate with a low dielectric constant and optimization techniques. Thus, low dielectric constant substrates are and expensive in developing countries.

Literature Review & Foundation of The Work

- This study describes the difficulties faced by Turkey and other developing countries in the production of the microstrip patch antenna. The foundation of the study is based on the experience gained during the previous (Oğuz & İmeci, 2017) and (Oğuz et al., 2018) works. Correspondingly, literature scans continued. Economic studies such as (Kandil, Berument, & Dincer, 2007), (Alotaibi, 2016), (Hacıköylü, 2015), (Kandil & Dinçer, 2008), and (Shah, Rajgure, & Tandalekar, 2016) were examined. The impact of fluctuations in foreign exchange and taxes on imports in Turkey was examined. Accordingly, the result of these effects on the production and prototyping process of patch antenna in Turkey has been revealed.

Growing Interest in Microstrip Patch Antenna

- Telecommunication systems are an important part of our daily life. In everyday life, mobile phones are widely used and are part of the telecommunication system. Mobile phones are widely hailed for their technological benefit to mankind, the ease it creates in doing daily chores, and most of all, bridging of information as well as communication gaps among people (Sk, Js, & J., 2019). In this context, the most important part of the telecommunication systems are MSPAs. Patch antennas are highly preferred; the most significant reason for these is that MSPA can be designed according to any condition. In addition, patch antennas are durable and manufactured easier and more affordable than other antennas.

- As they are widely used in many fields, studies and developments on these antennas have increased. They are designed and manufactured in universities, research groups, RF laboratories, small-scale industry and production facilities affiliated to large-scale companies. Accordingly, there are companies that produce and develop RF substrates that are essential in the patch antenna prototyping. By conducting researches, companies develop RF materials for antennas to be used for different purposes. Some of the USA based companies that have developed high-quality materials are Rogers Corp, Taconic and Arlon EMD.

A Survey On Microstrip Patch Antenna Publications

- Today, microstrip antennas are the most popular antenna type among RF-microwave antennas. They are used in many areas such as land vehicles, spacecraft, planes, radar, satellite and missile systems. Due to its advantages such as low cost, performance, easy installation, and production with modern printed circuit technology, microstrip antennas have become a popular antenna type in microwave antennas. Deschamps used the term microstrip patch antenna for the first time in 1950s. In the following period, the microstrip patch antenna was patented by Gutton & Baissinot. Due to sufficient dielectric materials were not developed, the prototype experiments were carried out later by Howell and Munson in the early 1970s (Balanis, 1996). It is important to briefly mention some of these studies as follows,

- It is important to briefly mention some of these studies as follows,
 - (Carver & Mink, 1981), researchers discussed patch antenna analysis methods such as transmission line and cavity models. Moreover, they used numerical methods such as the method of moments and the finite element method on the microstrip patch antenna.
 - (Sullivan & Schaubert, 1986), authors worked on increasing the limited bandwidth for some applications and applied the aperture coupling feeding technique to the microstrip antennas thus, they managed to increase the bandwidth over %50.
 - (Bhattacharyya, Shafai, & Gary, 1991) obtained new expressions as a result of their studies on radiation patterns, input impedance, and calculation of common and self impedances using the transmission line model.

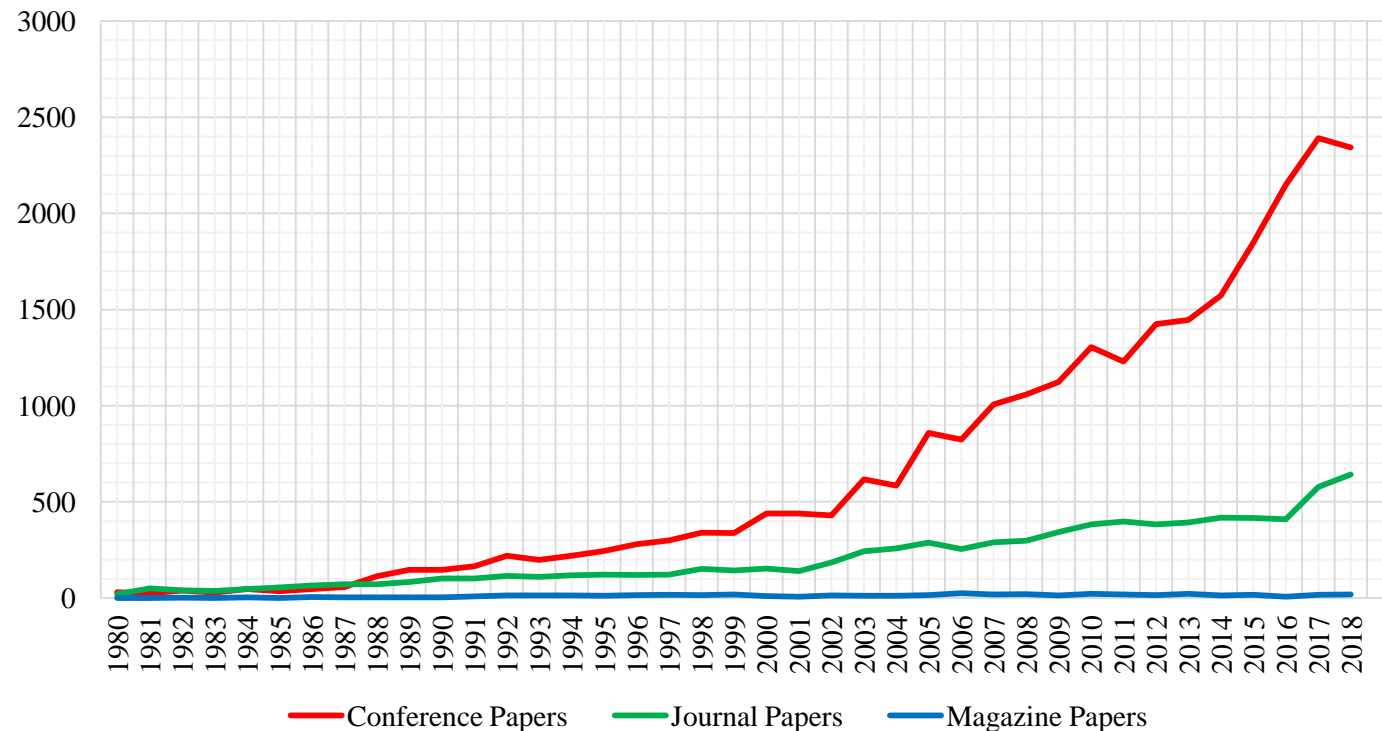


Figure 1 Number of MSPA papers indexed in IEEE Xplore® Digital Library between 1980-2018
Source: (IEEE, 2019)

- As can be seen in Figure 1, according to the data of (IEEE, 2019), there has been a great increase in antenna research and studies since the 1980s. The '80s was the decade when bigger steps were done in substrate design, however, as the frequency demand increases in communication systems, the development of new materials has lead to manufacturers in tightened their specifications, and reducing substrate costs (Pedroza, Zuñiga, & Aguilar, 2010).

- In this sense, this increase is also developing in parallel with the development of high-quality substrates. Furthermore, the rapid progress of telecommunication and satellite communication systems has accelerated the antenna studies. As described in (Patel, Narang, & Jain, 2013), the development of PCB production and the increase of portable devices have led to the need to produce RF circuits cheaper.
- Increased computerization in the 1980s accelerated the antenna design, and the modeling process became easier. Consequently, The researchers worked on techniques and new approaches to increase the bandwidth of patch antennas, reduce losses and increase efficiency.

The Effect of Currency Fluctuation on Antenna Design and Prototyping in Turkey

- The exchange rate is the rate of one currency in another currency. Fluctuations in exchange rates affect the economy. When some countries currency increases or decreases, it brings the changes in the whole business of the country at very much extent (Kandil, Berument, & Dincer, 2007). Therefore, we can say that the increases in currency rate result in a decrease in the import of that country (Duasa, 2009).
- In this context, the unexpected fluctuation in the exchange rate affects industry policies and production in developing countries. This includes patch antenna research. The most important financial effects of patch antenna design and prototyping is the fluctuation in the exchange rate. This situation makes the project budgeting difficult.

- The most important part of patch antenna design and prototyping is the substrate. Unfortunately, high-quality substrates are not available in the domestic market. It can only be obtained through import. In contrast, if the home country currency decreases due to an increase in exchange rate, then the imports of the home country will decrease due to increase in other country prices as well (Alotaibi, 2016).
- Moreover, the special substrates developed by USA based companies to be unavailable for patch antenna prototyping. Undesired fluctuations in the exchange rate also affect the patch antenna printing process. Generally, patch antennas are produced using PCB printing techniques. The operation caps of the PCB printing machines wear out quickly in the antenna printing process.

- The tip heads need to be refreshed periodically. Since the printing tips are not available in the domestic market, they have to be imported through suppliers. In this context, these negative effects caused by unwanted fluctuations in the exchange rate affect researchers, RF laboratories and students in the universities. Consequently, fluctuations in currency slow down Turkey's adapt to this trend.

Effects of Currency Fluctuation on Foreign Trade

- Foreign trade is an important research topic in the field of economy. Many factors affecting foreign trade have been the focus of the attention of economists. One of these factors is the undesired fluctuation in foreign currency. It is widely known by the economist that the unwanted fluctuation in foreign currency affects foreign trade. Multiple applied studies have examined the effects of changes in the exchange rate on imports and exports. To the contrary, there are no supporting findings, conclusive and contributing results were obtained in the literature. By reason of the theoretical results of an undesired alteration in the exchange rate, some of the applied researches reached the expectations in the direction of the expectation and some of them reached the opposite direction due to the increase in exports and decrease in the imports (Arize & Shwiff, 2010). Along with this approach, this section will examine the effects of the fluctuation in foreign currency on microstrip patch antenna production, which is dependent on imports.

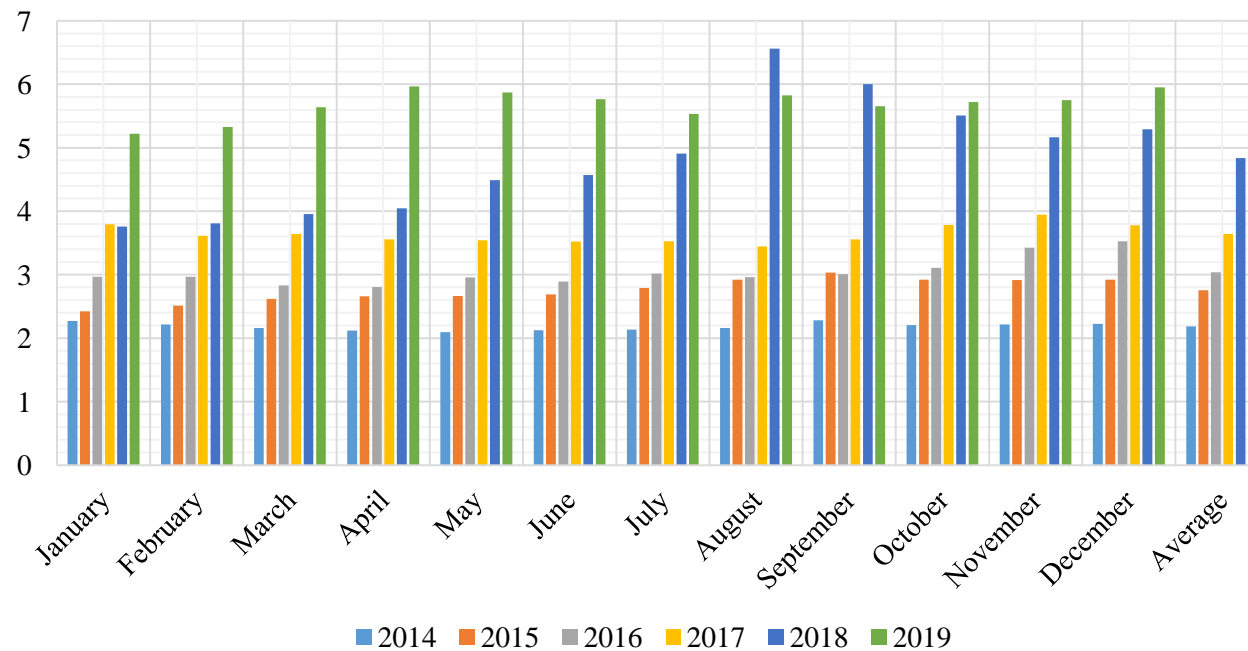


Figure 2 USD/TRY exchange rates between 2014-2019
Source: (Central Bank of Turkey, 2020)

- The data in Figure 2 are based on the exchange rate on the last day of each month. As will be noticed, the fluctuation has stimulated since May 2018. As seen in the general average, the increase continues and almost stable. When this situation is correlated with the growing interest in patch antennas shown in Figure 15; the following situation arises, this negative increase is inversely proportional to the growing interest in MSPAs. This is a concrete indicator of a disadvantage for Turkey.

- The relationship between import-export and the exchange rate is discussed as an important issue in the economy. Occasionally, exchange rates are utilized as tools for understanding the foreign trade deficit in Turkey. Thus, since the 80s growing trade deficit is one of the main obstacles of Turkey's economy besides, the dynamic relationship that exists between foreign trade and exchange rates leads researches to carry out numerous theoretical and empirical studies (Kutlu, 2013). According to the study (Alkan, 2018), there is a bidirectional causality relationship between the balance of imports and exports and the exchange rate. The real exchange rate is not included in the comparison, as the domestic-variant of the high-quality substrates are not available in domestic-industry.

- Countless studies have been conducted in the literature revealing the relationship of interest rates to imports and exports accordingly; this involves foreign trade. However, there are studies in the literature that determine that interest rates affect the exchange rate. Within this context, these circumstances affecting the exchange rate affect the patch antenna industry as in other areas.

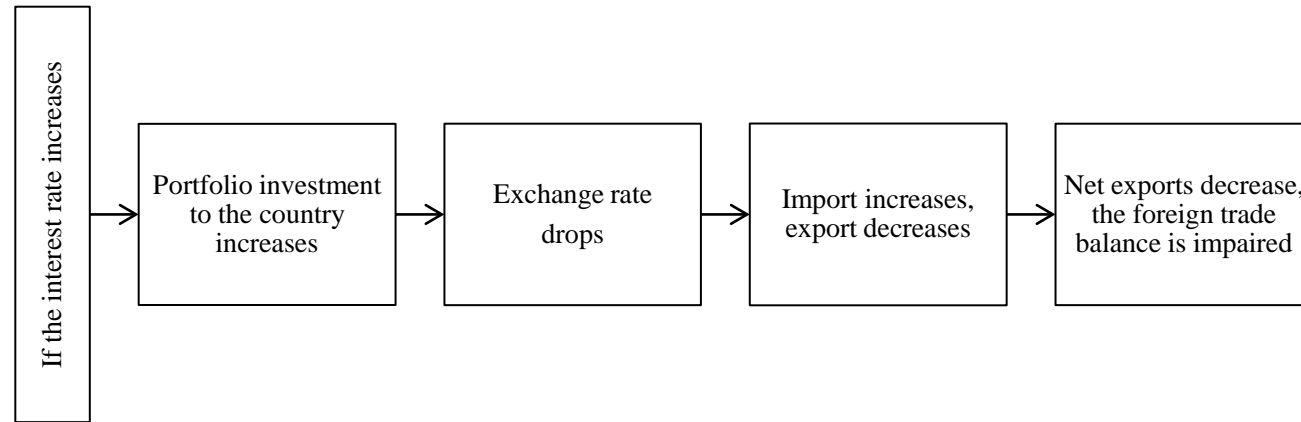


Figure 3 Effects of increase of interest on exchange rate and foreign trade

Source: (Uslu, 2018)

- As graphically presented in Figure 3, the interest rates which grew due to the strict financial policies implemented by the countries may induce more portfolio investment flowing to the developing countries besides, causes the growth in the amount of foreign currency and the decrease in the exchange rates. Determining how the exchange rate fluctuation will affect foreign trade is based on the behavior of imported and exported goods against the exchange rate fluctuation (Göçer & Elmas, 2013).

- As a consequence, it is expected that developing countries exports will decrease then, imports will increase, and foreign trade balance will be negatively affected thus, this situation directly affects the patch antenna industry, whose main foundation is a dielectric substrate. The undesired exchange rate fluctuation affects the foreign trade deficit in Turkey. Consequently, to develop necessary financial policy suggestions regularly, it is beneficial to examine the effects of interest rate and exchange rate on foreign trade.
- Inflation and exchange rates are important issues for countries; many studies have been carried out in this area. This issue has been widely covered in the literature. They have also been correlated with other matters such as foreign trade, unemployment, and growth.

- The connection between the exchange rate and inflation is explained via pass-through. Pass-through can be defined as the variation in the foreign exchange rates of the two trading countries, resulting in the prices of imported goods in local currency (Goldberg & Knetter, 1997). The fact that the effect of the exchange rate change in the short and long term in the changes in inflation shows that inflation is quite susceptible to the exchange rate. Moreover, fluctuations in foreign exchange rates have two direct and indirect effects on domestic prices. The direct effect is through imported final goods and inputs. As a result of the depreciation of the domestic currency against foreign currencies, the price of imported goods and inputs increases, and this increases the domestic prices as the rising prices increase the costs (Kiptui , Ndolo, & Kaminchia, 2005).

- Accordingly, the import share of consumption and the share of imported inputs in the total production cost affect the pass-through effect. The larger the goods imported or the sectors with high import inputs, the greater the pass-through is expected to be in the economy (Central Bank of the Republic of Turkey, 2017). Besides, fluctuations in exchange rates will directly affect domestic prices through the price of goods sold in foreign currency. The indirect effect is realized through the export channel. As the demand for exports increases, since the depreciation of the domestic currency will make the domestic goods cheaper, the import will become expensive, and the import demand will decrease. In this case, domestic demand will shift to exported and imported substitute goods. Different factors that determine the pass-through between the exchange rate and prices alter according to the periods and conditions. It is observed that the pass-through is higher in small open-economy economies with high import dependency and low income (Kaygısız, 2018).

Dielectric Substrate Market & Industry Analysis

- For many years, in industrial countries, designers and manufacturers have been working together to fabricate dielectric substrates at affordable prices. Despite this, as proposed in (Santhanam, 1999), results that would reduce costs have not been resolved. While this is the case, this matter affects developing countries more. High-quality substrates can only be obtained through imports; therefore, their costs are high. Another issue that plays an important role in this circumstance is the matter of tax and financial obligations in imports. According to a study in (Hacıköylü, 2015), there are at least 15 tax items and financial liabilities encountered while imports in Turkey. Some of the tax and financial liabilities are shown in the study in (Hacıköylü, 2015); customs duty, value added tax, special consumption tax, stamp duty, anti-dumping tax, banderole fee, countervailing charges in respect of import, additional financial obligation, housing development fund, resource utilization support fund, and environmental contribution.

- Considering this situation, it turns out that the importing high-quality substrate is major financial stress in the patch antenna design and prototyping projects. Substrate suppliers appear to have variable substrate prices. The main reason for this condition is that the substrate stocks are limited. Manufacturers determine the stock according to the demand in the market. In the study (Oğuz & İmeci, 2017), a high-quality R/T Duroid 6002 substrate was used. The corresponding substrate was about the size of A4 and bought for \$100. The purchased substrate was used in the prototype of 5 different patch antennas.

Table 1 Price comparison of high-quality RF substrates

Name of the substrate	Dielectric constant	Dimensions	Thickness	Price
Rogers Corp RT/duroid 5870	2.33	202 x 228mm	0.254mm	\$73.09
Taconic TLX-9	2.5	305 x 457mm	0.760mm	\$109.25
Rogers Corp CuClad 217	2.17	228 x 305mm	0.380mm	\$95.38

Source: (R.F. Elettronica, 2020)

- Table 1 shows the current high-grade dielectric substrate prices have taken on (R.F. Elettronica, 2020). As shown in the table, high-grade substrates are quite costly. As discussed before, it is directly associated with the negative impact of the currency fluctuation on patch antenna design and prototyping. Furthermore, it was observed that the import of dielectric substrates was affected by the price increase caused by the exchange rate fluctuation. This situation displays an increase in project costs in developing countries, including Turkey.

Suppliers

- As covered in previous slides, when designing the microstrip patch antenna at specific radio frequencies, the essential point is choosing a substrate that determines microstrip patch antennas performance. Besides, substrate is a foundation on which MSPA is manufactured and it takes an essential part in microstrip antenna performance. The substrate in patch antennas is mainly required for the physical support of the MSPA, which is sometimes challenging. Thus, the substrate consists of a dielectric material that affects the electrical performance of the patch antenna. Commonly, for microstrip patch antennas, the special dielectric substrates are used. The price of these dielectric substrates is higher than the basic FR4 epoxy substrate. The production and supply of special dielectric substrates are carried out by well-established companies.

- The vast majority of these well-established companies (active more than 60 years) are of USA based companies. Therefore, substrates can be supplied through these companies; besides, there is a quota/limit which suppliers can provide. When financial liabilities in the import and undesired currency fluctuations added to this matter, the patch antenna production and prototyping in Turkey has negatively affected.

Table 2 List of high-grade dielectric suppliers & corresponding products

Suppliers	High-grade dielectric laminates
Arlon	FoamClad 100, DiClad series, CuClad series, IsoClad series, 25N, 25FR, AD Series, AR Series, CLTE, CLTE-LC, CLTE-XT, PIM Laminates, MultiClad HF Series
CLP Industries Ltd	MW laminates
GE	GETEK, GETEK II
Hitachi	MCL-LX-67F
Krempel	Akaflex, PCL, KCL, GHE
Isola Group	Astra™, IS680, Gigaver 210/410
Neltec	NL9000, N9000 Laminate system, NY, NX Series, NH Series, N4000-13 Series, N9000-13 RF, NH9450, N9350 Series
Polyflon	Norclad, Polyguide, CuFlon

(continued)

Table 2 (continued)

Suppliers	High-grade dielectric laminates
Rogers Corporation	RO3000 series, RO3200 series, RO4000 series, RO4500 series, RO4500™, RO4730™, LoPro™, Ultralam 2000 series, RT/duroid 5000 series, RT/duroid 5880LZ, RT/duroid 6000 series, RT/duroid 6006/6010, TMM series, RO3730 Series, RO4360™ HF Laminates, SYRON 7100
Sheldahl	ComClad HF
Taconic	TLX series, TLC series, TSM-30, TLY series, TLP series, TLE series, TacLam series, RF-30, RF-35, TLF-35 & TLF-34, TRF-41 & TRF-43 & TRF-45 series

Source: (Trackwise Designs Ltd, 2013)

- Table 2 shows the list of high-grade dielectric suppliers and products. Common benefits of high-grade substrates are given below;
 - Fitting the requirements of various microwave applications.
 - Uniform thickness, a precise dielectric constant and low dissipation through the entire layer.
 - The low moisture conduction minimizes the phase shift with frequency.
 - The thermally stable dielectric constant that simplifies circuit design and optimizes circuit performance. (Reduces material and fabrication costs).
 - Lead-free, solder friendly, fire retardant and halogen-free (green laminates).
- The majority of these well-established suppliers have active for more than 60 years. However, since the 80s, their development in the field of the dielectric substrate has increased

Basic Cost of Prototyping

- As in all manufacturing processes, the cost is important in microstrip patch antenna production. Moreover, in this section, the basic cost is given for a single coaxial fed patch antenna. Basic cost includes the cost of the dielectric substrate forming the antenna, cost of labor and SMA connector. Nevertheless, the cost of the milling machine and operation nozzles or the cost of consumed energy is not included. Thus, only the cost of labor and cost of microstrip patch antenna components added to the calculation.

- The basic cost is given below;
 - Cost of high-grade Rogers RT/Duroid 6002 substrate about A4 paper size: 100\$.
 - Cost of FR4 substrate about A4 paper size: 20 – 40 (Inefficient for some cases however optional, besides can be used instead of the high-quality dielectric substrate).
 - Production cost: 100 (depends on the size)(set of operation heads cost around 400€).
 - Cost of SMA connector: 5.

The data is collected for the antenna in (Oğuz & İmeci, 2017) and prices has taken from (R.F. Elettronica, 2020).

- The total basic cost approximately varies between ₺125 and ₺725 (depends on the dielectric substrate used in the patch antenna and rate of foreign currency). The most important factor affecting the cost of microstrip patch antenna production is the variable cost of the dielectric substrate. Furthermore, high-grade dielectric substrates can only be obtained by import. Hence, this situation is directly related to foreign currency (in this case the US dollar) moreover, it is excessively affected by the undesired exchange rate fluctuation.

CONCLUSION

- The popularity of microstrip antennas is rising lately. The most important reason for this is that microstrip patch antennas can be developed for various purposes. There is a tremendous interest in MSPAs because they are lightweight compared to other antenna types, they can be produced in almost any size and shape, they are durable and can be produced in almost any condition with traditional PCB manufacturing methods. They are frequently used in countless fields such as wireless communication, medical and military fields. Specifically, they are essential for wearable technologies. For this reason, numerous researches and developments are carried out on microstrip patch antennas in universities, laboratories, research groups, and private corporations.

- One of the most important parts of the production and development process of microstrip patch antennas is the dielectric substrate and is also the essential element of patch antennas. Since the performance parameters of the patch antenna are built on the properties of the dielectric substrate, It is very important to be able to obtain high characteristic dielectric substrates moreover, dielectric substrates from the domestic market are insufficient for projects that require a high-grade characteristic. High-grade substrates are generally produced, developed and distributed by the USA originated companies. Therefore, the supply of substrate depends on imports besides Turkey and developing countries are directly affected.

- Supplying dielectric substrates have become more challenging than before, due to unexpected fluctuations in exchange rates, monetary narrowing, and unexpected COVID-19 pandemics. High-grade dielectric substrates can only be obtained by import. Access to high-grade substrates has practically stopped when the COVID-19 pandemic is added to the unexpected fluctuation in the exchange rate and monetary problems. Besides Turkey and developing countries, this unusual situation slows down the semiconductor and IT industries all over the world. Due to the measures taken at the factories, the workforce has been divided, and production is carried out on duty.

- Furthermore, services in logistics have been limited. Such situations increased the price of the existing good while increasing the cost. As a summary, risky disruptions happen in the supply chain. Within this context, in this study, the difficulties affecting microstrip patch antenna production and design process in Turkey were examined by making the necessary literature research and benefiting from the author's microstrip antenna design and manufacturing process experience.

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Thank you for your time!

Any questions ?