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Pick and Place Assembly Technique for Fabrication of Groove Gapwaveguide Resonator

Sadia Farjana[1], A.U. Zaman[2], Peter Enoksson[1]

[1]Micro- and Nanosystems Group, Electronics Materials and Systems Laboratory, Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, 412 96 Göteborg, Sweden.
[2]Department of Signals and Systems, Chalmers University of Technology, SE-412 96 Gothenburg,Sweden

farjana@chalmers.se

Abstract. Gap waveguide are an innovative technology for millimeter-wave RF applications. There are some factors to be considered while using this technology at millimeter wave frequencies or above, particularly for low cost RF applications. Surface mount technology and pick and place machine technique can demonstrate a way to solve this problem. In this paper a groove resonator is presented which is manufactured by using pick and place technique. Brass pins of diameter 1.6mm and height 2.3mm was mounted on a 5mm thick copper plate. Lead free solder paste was used for solder joint.

1. Introduction

Surface-mount technology (SMT) and surface mount device (SMD) is a hot topic in electronic society[1] . SMT is a method for producing electronic circuits in which the components are mounted or placed directly onto the surface of printed circuit boards (PCBs). Pick and place systems or pick and place machines are usually used in the manufacture of surface mount technology (SMT) electronics circuit boards. Using these pick and place systems or pick and place machines, it is possible to accurately place large numbers of small, or large components quickly and precisely onto circuit boards. Practically all of today's mass produced electronics hardware is manufactured using surface mount technology. The associated SMDs provide many advantages over their leaded predecessors in terms of manufacturability and often also performance.

The blend of millimeter-wave communications, arrays with a substantial number of antenna elements, and shorter coverage distances are the likely factors that will allow merging of different technologies with the aim to dramatically improve wireless access and throughput in the upcoming years [2-4]. Even though a lucrative license free spectrum is available at millimeter-wave frequency range, still there are plenty of technological factors and mechanical challenges in designing millimeter-wave RF front-ends. These factors are cost, smaller size requirement, increased system density, packaging and cross-talk suppression, and lower power loss dissipation [5].

Conventional rectangular waveguides, planar transmission lines such as coplanar waveguides, or microstrip lines are well characterized transmission medium which are used in a variety of complex RF component and circuit designs until today. However, there are some factors to be considered while using these conventional technologies at millimeter wave frequencies or above, particularly for low cost RF applications. Most of the millimeter-wave wireless communication systems need analog RF hardware such as waveguide based filters and high gain waveguide based antennas. These waveguide based RF components are usually not produced by pick and place assembly technique and need another more costly manufacturing technique such as metal molding or metal milling. Thus, the total production cost for most of the RF wireless systems cannot be reduced below a certain level around the millimeter-wave frequency range.

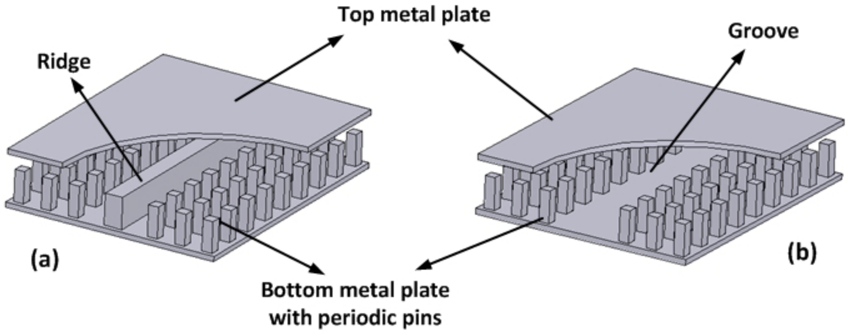
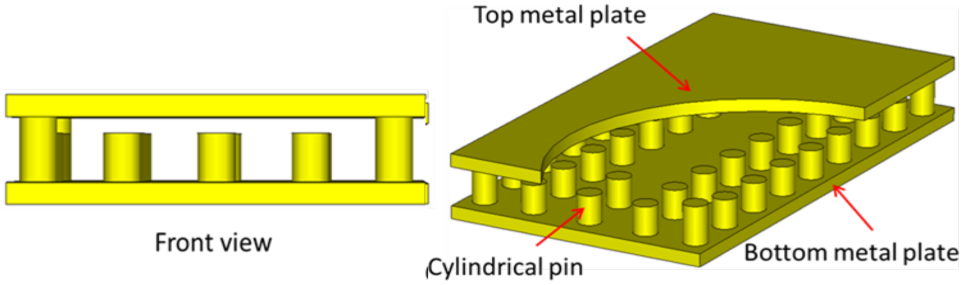


Figure 1. Basic Gap waveguide geometry: a) ridge gap waveguide; b) groove gap waveguide.

Recently evolved Gap waveguide are considered as an innovative technology for millimeter-wave RF applications [6,7,8]. As described in [8] and shown in Fig. 1, the basic gap waveguide structure consists of two metal parts; the bottom part consists of periodic metal pins or fingers and the top part is a smooth metal plate. Unlike the traditional rectangular waveguide, the top and bottom metal parts in any of these gap waveguide geometries do not need metal connections or electrical contacts. This opens up a completely new opportunity for designing and manufacturing RF components based on gap waveguide technology. It is expected that the bottom plate having a base metal and protruding fingers or ridge section can be produced very cheap by stamping on a soft thin metal sheet or by die-casting technique. These new manufacturing techniques will make the gap waveguide components relatively cheaper than the conventional rectangular waveguide based components. Nevertheless, the incompatibility of these manufacturing techniques with the pick and place assembly technique will still present a major bottleneck in integrating the digital electronics, RF electronics and the waveguide components in most of the millimeter wave wireless systems. Thus, the total production cost will not be reduced below a certain level. To overcome this issue, we present the concept of manufacturing a millimeter-wave RF waveguide component by using the pick and place assembly technique in this work. In the gap waveguide design, the size of the basic building blocks such as the metal pins, the metal ridge etc. falls in the range of typical size of the conventional SMDs. Pre-produced gap waveguide building blocks or basic components in large scale volume will make it possible to assemble these components by pick-and-place methodology. These pre-produced gap waveguide building blocks can be picked and placed on top of a carrier substrate and can be connected conductively to the conducting layer of the substrate. If several of these pre-produced components are picked and placed or put in a desired arrangement, a complete RF waveguide component can be formed. Thus making the manufacturing very adorable to different needs. The top metal plate for such gap waveguide component can be a simple metal plate or another substrate with ground plane. This new concept of pick and place type waveguides has the potential to revolutionize the millimeter wave RF industry completely and will pave the way for low cost millimeter wave RF products such as millimeter wave massive MIMO modules.

2. Groove gap waveguide resonator

To verify the performance of the low loss gap waveguide technology, it is important to characterize its loss in an accurate way. One way to do that is to measure the attenuation of a very long line (several wavelengths), which will be impractically long in order to measure the low losses accurately. As an alternative, losses can be better characterized in terms of Q-factors of resonators. One such groove gap resonator working at 30 GHz band is shown in figure 2(a) and 2(b).



(a) (b)

Figure 2. Schematic of a 30 GHz groove resonator. (a) Side view, (b) perspective view with part of the top plate cut away for clarify.

The dimensions of this groove gap resonator are shown in Table 1. The simulation result of the resonator is shown in Fig. 3. For a two-port resonator S21 is the transmission coefficient of the resonator (ratio of the voltage transmitted to the incident voltage). For Q factor evaluation, weak coupling has been considered in this case. The material used in simulation is copper. The simulated Q value at 27.75 GHz was found to be 1,800. In this paper we present a groove resonator that has been manufactured by using pick and place machine to realize this design. Pins have been mounted on the bottom plate by using the reflow soldering technique.

Table 1. Dimensional details of the groove gap resonator

Parameters (mm)	**Operating Frequency 30 GHz**
Pin Height	2.6
Pin Diameter	1.8
Gap between two pins	2.6
Resonator Length	19.2
Resonator width	2.6
Air Gap	.75

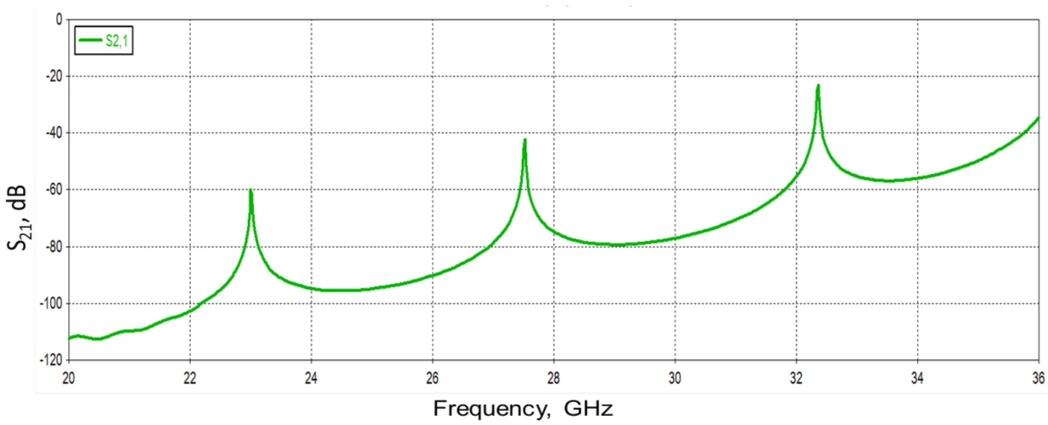


Figure 3. Simulation result of the 30 GHz groove resonator with several resonance peaks within the frequency band of interest.

3. Experimental details

A copper plate of 5 mm thickness was used as top and bottom plate and cylindrical brass pins of diameter 1.6 mm and height 2.3 mm were used for mounting. Before applying solder paste, flux was applied on the bottom plate. Lead free solder paste Sn96.5Ag3Cu was used as solder paste. The solder paste was applied by using a pump dispenser. Then a manual pick and place machine (for mass production automated machine will be used) was used to place the pins on the bottom plate. After placing the pins, the copper plate was placed in a reflow oven (PortoFlow S Solectro) for reflow soldering. During reflow soldering four different temperature zone i.e. preheat zone, soak zone, and reflow zone and cooling zone was set. The device was keep in the preheat zone for 200 s at 160 ˚C then kept in the soak zone for 240 s and then keep at reflow temperature 270 ˚C for 160 s and then in the cooling zone for 80 s. The reason for using four different temperature zone is described in section 4. Top plate was fixed with the bottom plate by using four screws.

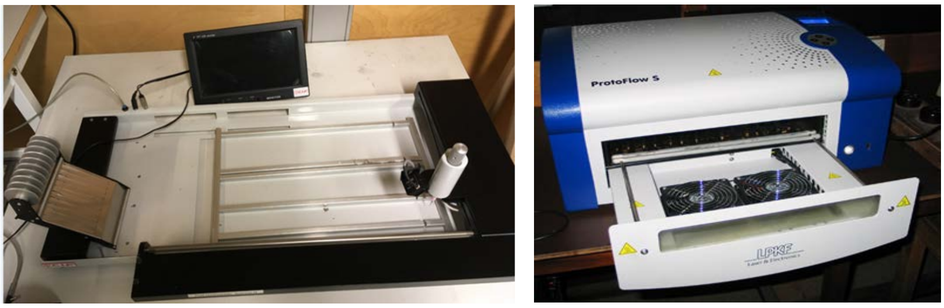


Figure 4. (a) Pick and Place Machine, (b) Reflow Oven.

4. Discussion

First step of mounting resonator pins are to put solder paste to the bottom plate. In PCB production a screen or stencil printer are used. In our case a pump was used to apply solder paste on pre marked positions. After that a manual pick and place machine was used and the pins were placed in the required position by using a alignment camera. Fig 5 shows the image of a groove resonator manufactured by using the pick and place machine. It has been observed that the reflow temperature can affect the pin position. If the reflow temperature is too high then the solder paste can start to flow and displace the pins. Different reflow profile has been checked and it has been observed that reflow profile mentioned in section 3 was most suitable for this device which gave better joint and better pin alignment. The reflow process is a combination of preheat, thermal soak, reflow, cooling stage. In our case the thickness of the bottom plate was 5mm, which was thicker than normal PCBs. However, it has been mentioned in [11] that the gap waveguide components can survive relatively large dimensional tolerance (compared to the conventional rectangular waveguide components) and ± 15μm of variation in pin position, pin height and pin size is not going to degrade the electrical performance of the gap waveguide components. This opens up the opportunity to use commercial pick and place assembly machines for fabricating gap waveguide based RF components.

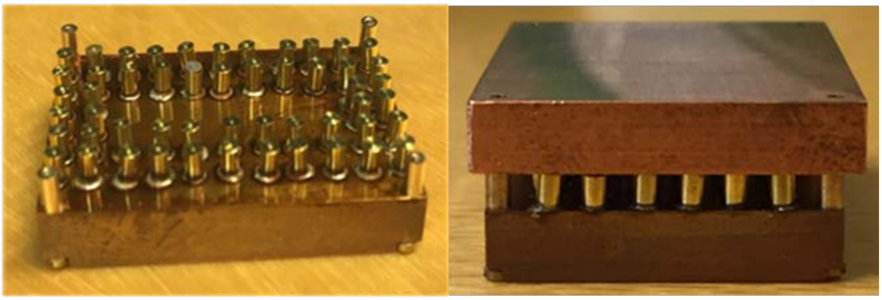


Figure 5. Groove resonator manufactured by pick and place machine (a) without top plate (b) with top plate.

5. Conclusion

Gap waveguides is a new RF technology platform enabling RF system solutions to meet market demands. On the other hand conventional surface mount is ruling the electronic packaging world. In this paper we present a groove gap resonator, which is manufactured using a pick and place machine. This new technique is not only cost effective but time saving, versatile and easy to manufacture. A manual pick and place machine was used to assembly the resonator pins. After several trials it has been observed that this process is workable and the use of automatic pick and place machine can only improve the assembly quality.

Acknowledgements

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