A COMPARISON OF THIN FILM AND THICK FILM KU-BAND AMPLIFIERS

Anthony M. Pavio and Lisa L. Cook

Texas Instruments Incorporated

ABSTRACT

The use of thick film fabrication methods, to achieve a low cost microwave design media, will be discussed. A variety of common components and transmission lines were assembled and evaluated in order to assess the performance differences between these circuits and their thin film counterparts. One of the key components evaluated, which exhibited excellent performance, was a Ku-Band GaAs FET amplifier.

EXPERIMENTAL RESULTS

It has been common practice in the microwave industry to discount the use of thick film fabrication methods as a viable MIC construction technique. This attitude has prevailed because of a variety of reasons such as conductor loss and line width definition. However, during the past five years a viable copper process was introduced and the quality of gold conductor paste was improved substantially making thick film process technology much more attractive. The problem encountered with fine-line geometries and line width definition have also subsided. Most importantly the cost of thick film circuits is vastly lower than thin film, providing that prudent design rules are followed. Hence, selecting this technology can be a reasonable choice if component performance is not sacrificed. The most common objection to thick film circuits by microwave engineers is line loss.

If one considers typical thin film microstrip line loss, it is composed of radiation and resistive elements. Although radiation loss at wavelengths below millimeter lengths are not severe, they are appreciable especially in open circuit resonant structures. But, these losses are independent of conductor type. Hence, only conductor losses need be considered. In Figure 1, the differential line loss for a 2.54 cm length of 50 ohm transmission line, which was fabricated on 0.375 mm thick 99.6% alumina substrate, and a comparable dimensioned transmission line fabricated on a 96% alumina substrate, is shown. The transmission line conductor in the thin film case is 5µm thick electrodeposited gold while the thick film conductor is 10µm thick fired gold paste. As can be seen the excess loss for a 2.54 cm length is only 0.4dB at 18 GHz. Thus, all but the most critical active circuits, such as low noise amplifiers, should be able to sustain an additional several tenths of a dB loss. However, this reduction in circuit Q probably could not be tolerated in narrow band filter structures.

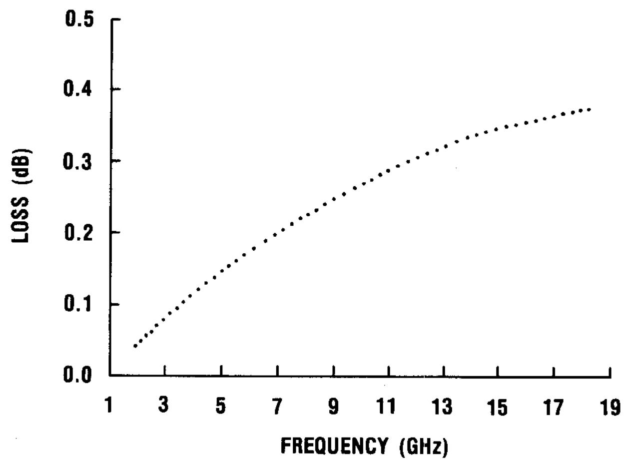


Figure 1. Differential Line Loss as a Function of Frequency

Line width definition is another key issue since typical thick film processes prefer line widths greater than 125µm and are most comfortable with line widths of greater than 250µm. However, structures with 75µm line widths and 75µm spacings have been fabricated. Based on the above observation, the design selected for thick film must be carefully considered. The use of minimum line widths of 125µm preclude the use of interdigitated structures, the most common of which is the Lange coupler. But by selecting substrates of 0.375 mm to 0.6 mm thickness, the impedance range available to the design engineer is no more restrictive than designing monolithic microwave integrated circuits which are commonly fabricated on 0.1 mm thick GaAs wafers. The usable microstrip impedance range for thin film and thick film microstrip on alumina (0.6 mm substrate) and microstrip on GaAs (0.1 mm substrate) is shown in Figure 2. Higher

0149-645X/86/0000-0431$01.00

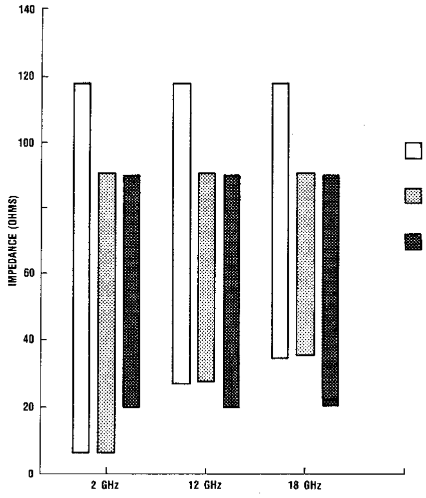


Figure 2. Useful Microstrip Impedance Range for Alumina and GaAs

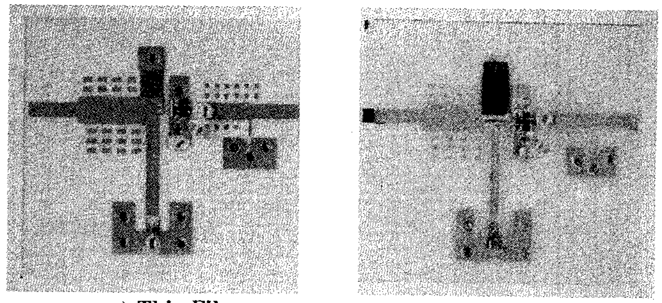
impedances, which are commonly required in FET circuit realizations can also be synthesized by short lengths of bond wires between the circuit and FET or between conductive pads placed on the substrate. This technique is especially useful at upper microwave frequencies where the necessary circuit inductances can be achieved with short bond wire lengths.

Although there are some circuit constraints, there exists a large family of microwave components that can be inexpensively produced. These include components such as branchline couplers, stub filters, power dividers, and a variety of amplifier topologies. One of the components selected for thick film realizations was a 6 to 18 GHz GaAs FET amplifier. This type of amplifier is very common in all types of communication, radar, and EW systems. In order to demonstrate the performance of this technique, two identical amplifier designs, one in thick film and the other in thin film were fabricated.

Both amplifiers were constructed on .375 mm thick substrates. The active devices were surface mounted with plated through holes used for FET source and circuit grounding. Conductive epoxy was used to mount the FETs and capacitors to the substrate. Bias resistors were either thin or thick film types. Each amplifier is shown in Figure 3. The amplitude response and input return loss for both circuits are shown in Figure 4. As can be seen, the two circuits exhibit excellent and identical gain performance throughout the entire 2 to 18 GHz frequency range. Their output return loss characteristics are also very similar. Other microwave thick film components were also fabricated and exhibited repeatable microwave performance.

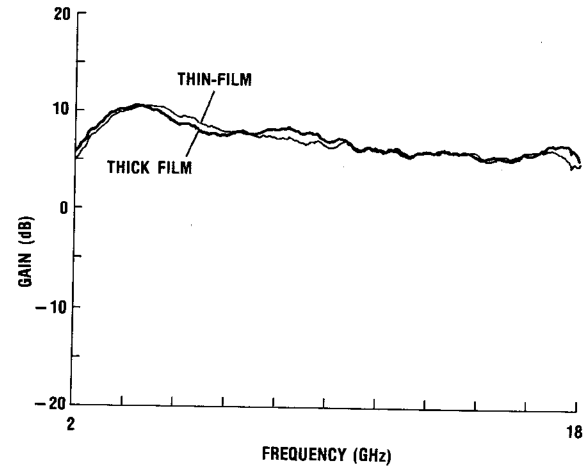
CONCLUSION

Because of the excellent results obtained with the above designs, a family of low cost microwave components can easily be developed. These components can fulfill numerous system requirements for commercial and military applications.



a) Thin Film b) Thick Film

Figure 3. 6-18 GHz Amplifier



a) Amplitude

b) Input Return Loss

Figure 4. 6-18 GHz Amplifier Responses