KNUST
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Engineering

TE 364

LECTURE 1:

Microwave Integrated Circuits

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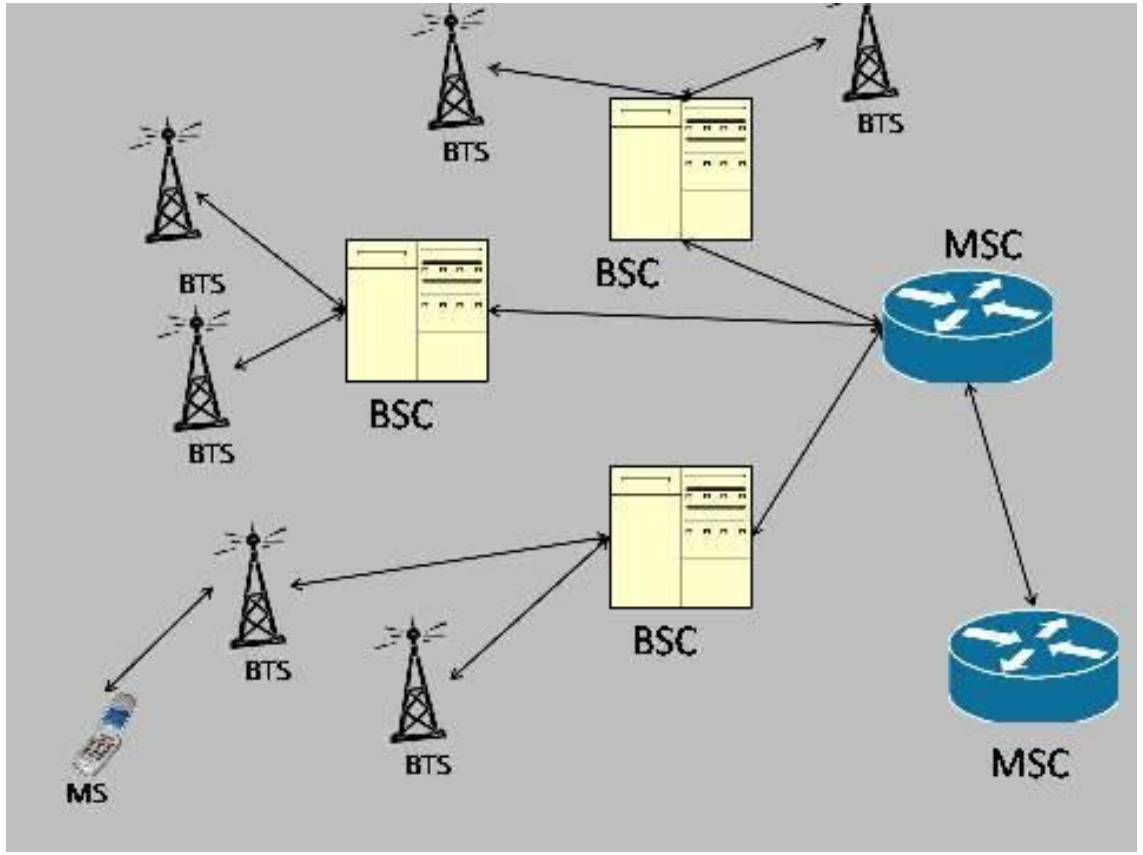
Telecommunication Today

- Typical Example: Mobile Communication

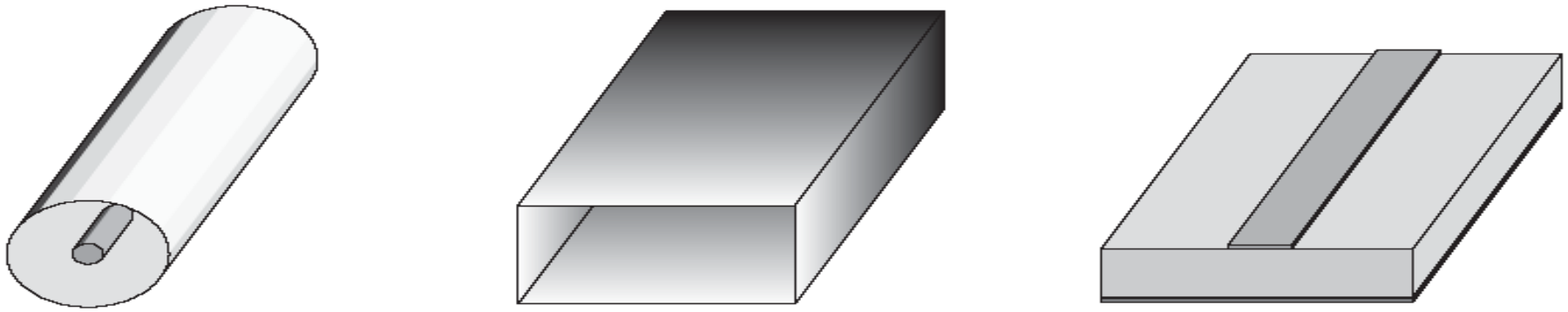


Classification of Microwave Integrated Circuits

- Active microwave circuit:
  - a circuit in which active and passive microwave devices such as resistors, capacitors, and inductors are interconnected by transmission lines.
- At low frequencies,
  - the transmission lines between these devices is a simple connection;
- At microwave frequencies,
  - their operation becomes a complicated distributed circuit element.
- Microwave integrated circuit is classified based on the fabrication method of the transmission lines used for interconnection

Common Transmission Lines Used in Microwave Circuits

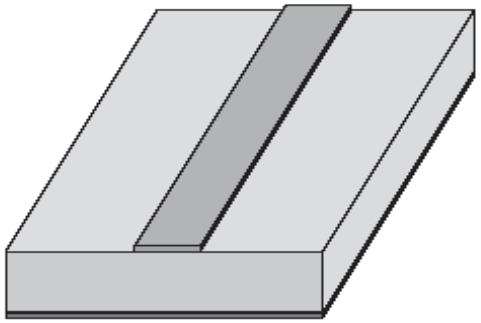
- Common examples of transmission lines:
  - are waveguides, coaxial, and microstrip lines.



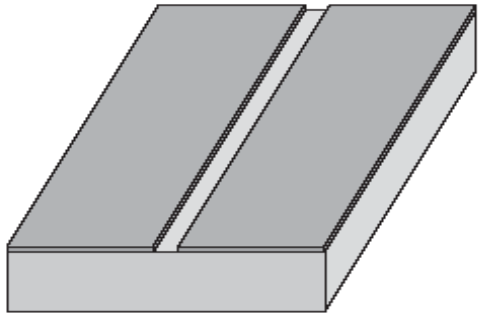
(a) coaxial line (b) rectangular waveguide and (c) microstrip line

Planar Transmission Lines Used in Microwave Circuits

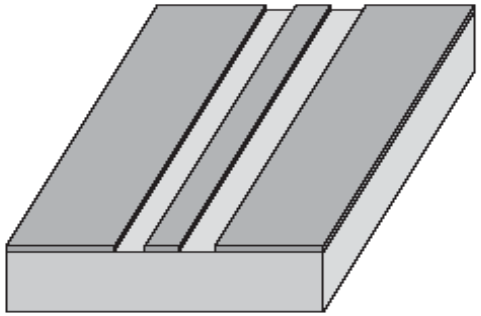
- Microwave circuit in most cases is integrated using planar transmission lines.



(a) Microstrip



(b) slot lines and



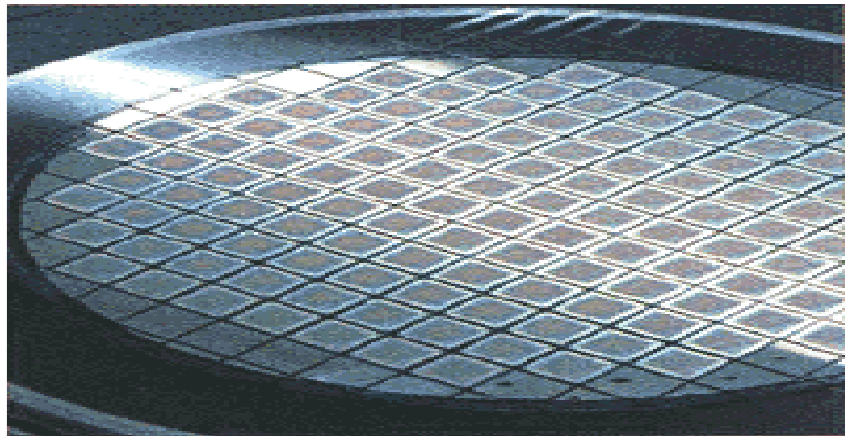
(c) CPW (CoPlanar Waveguide)

Classification of Microwave Integrated Circuits of with Planar Transmission Lines

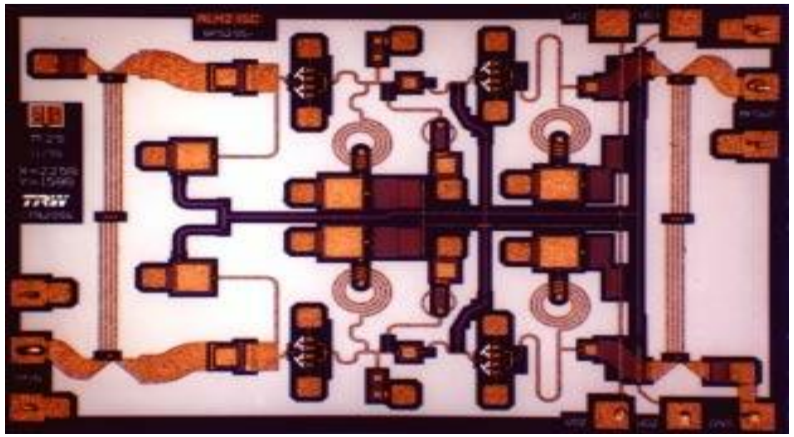
- This course is restricted to microwave circuits integrated using planar transmission lines.
  - frequently employed in the large-scale production of microwave circuits.
- The implementation of planar transmission lines on substrates can be largely classified into the two groups of
  - *monolithic and*
  - *hybrid integrated circuits.*

Monolithic Integrated Circuits

- Active and passive devices as well as planar transmission lines are grown *in situ* on one planar substrate, usually made from semiconductor material and is called *wafer*.



(a) wafer



(b) the single circuit on wafer

Monolithic Integration

- An advantage of the monolithic integration
  - It is well suited for large-scale production, which leads to lower cost.
- The disadvantage is that
  - it takes a long time to develop and fabricate,
  - and a small-scale production results in highly prohibitive cost.

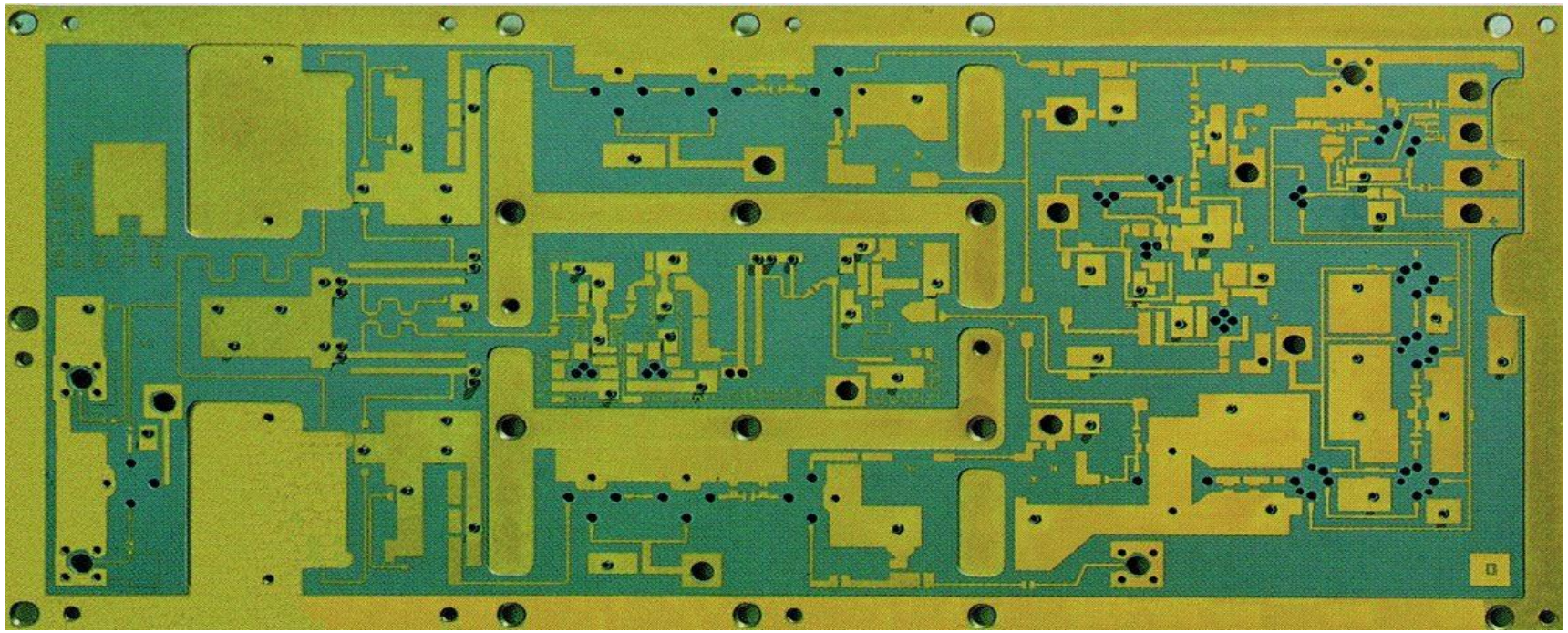
Hybrid Integrated Circuits

- Hybrid integration
  - a fabrication method in which, the transmission lines are implement -ed by conductor patterns on a selected substrate with either
    - *printing* or
    - *etching*;
  - and active and passive devices are assembled on the patterned substrate by either soldering or wire-bonding.

Classification of Hybrid Integrated Circuits

- Hybrid integration is classified into three kinds based on the method by which the lines are formed on the substrate;
  - *printed circuit board* (PCB),
  - *thick-film* substrate, and
  - *thin-film* substrate.
- Choice of integration method depends on
  - the application and situation, taking into account factors such as,
    - the operating frequency of integrated circuit,
    - the forms of semiconductor components (chip or packaged),
    - large-scale fabrication costs, and method of assembly

Printed Circuit Boards



- Both sides of the dielectric material are attached with a copper clad which is then etched to obtain the desired patterns.

PCB Substrate Materials

- *Epoxy-fiber-glass* (FR4), *teflon*, and *duroid* are widely used.
- FR4 substrate
  - a kind of epoxy-fiber-glass
  - can be used from lower frequencies to approximately 4 GHz,
- Teflon or duroid can be used up to the millimeter wave region
- Generally,
  - all these materials lend themselves to soldering while
  - wire-bonding as an integrated circuit assembly is typically, not widely used.

Advantages of PCBs

- PCB can provide a lower cost;
- its fabrication is easy and
- takes a shorter time to produce.
- In addition, production on a small-scale is possible
  - without the use of expensive assembly machines;
  - it is easy to fix and
  - could also be used on a large-scale production; and is thus widely used.

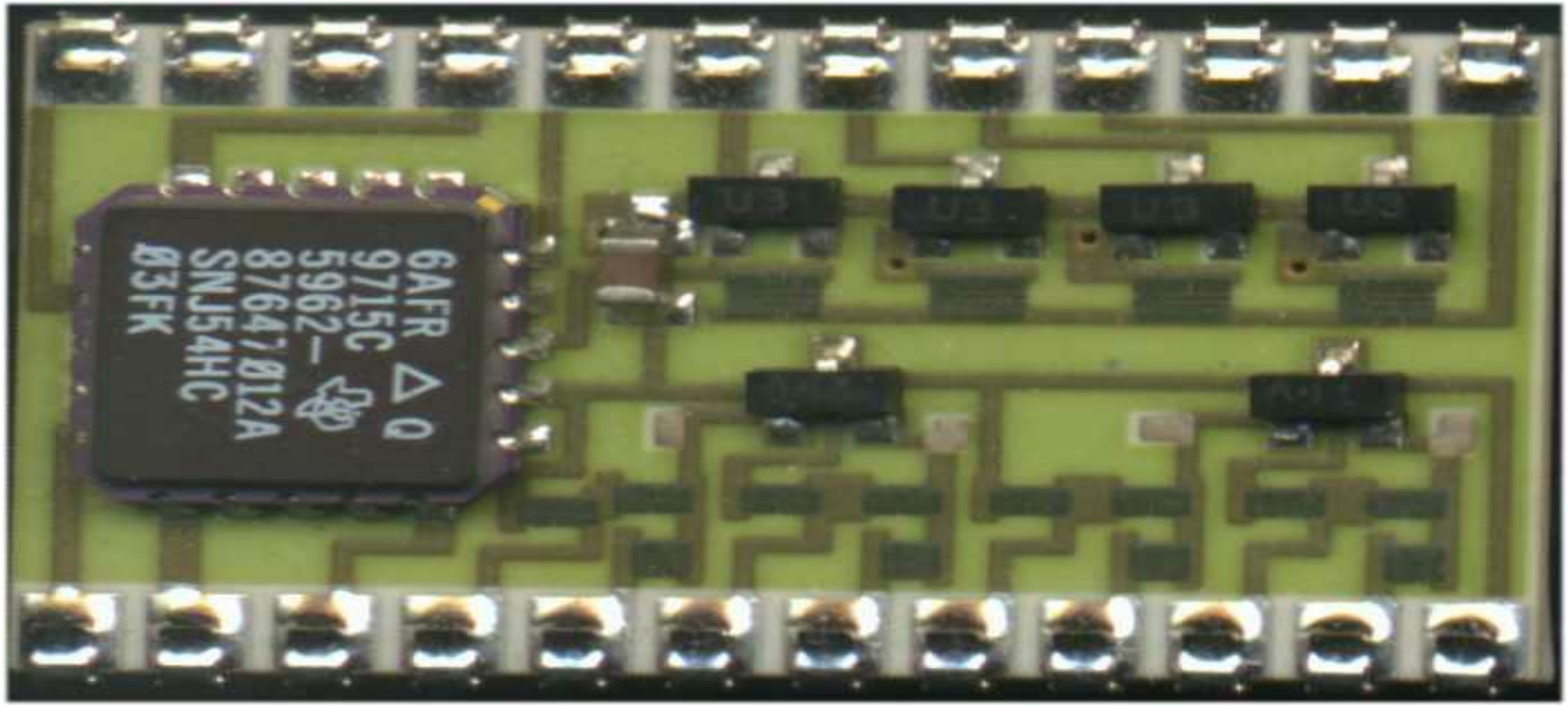
Thick Film

- Thick films substrate are produced by screen printing techniques;
  - in which conductor and dielectric patterns are printed using screen on ceramic substrates.
- The patterns formed by this technique is generally far thicker than that formed using thin film techniques, hence the name.
- As a benefit of using printing techniques,
  - multiple printing is possible and
  - it is also possible to form capacitors.

Thick Film…

- Due to the use of ceramic substrate which is more tolerant to heat, it is easy to assemble active devices in the form of chips.
- On the other hand, the pattern accuracy of thick film is far less superior compared to thin film.
- The cost and development time, on case by case basis,
  - could be seen to lie between those of PCB and thin film process.

Sample Fabricated Thick Film



- A photograph of an IC fabricated by thick film process

Thin Film

- Thin film technique is very widely used in the fabrication of microwave circuits
  - for military and
  - microwave communication systems.
- In the case of the thin film process, a similar ceramic substrate material used as in thick film is employed, but
  - compared to thick film substrate; a fine surface-finish substrate is used.
  - The most widely used substrate is 99% alumina (Al_2O_3).

Fabrication of Thin Film

- The pattern formation on the substrate is by photolithographic process,
  - which can produce fine tracks of conductor patterns close to those in semiconductor process.
- As in the case of thick film,
  - it is possible to assemble semiconductor chips directly
  - and wire-bonding is primarily used in the assembly.

Fabrication of Thin Film

- Thin film compared to PCB and thick film,
  - is more expensive,
  - and due to the requirement of fine tracks, a mask fabrication is accompanied
  - and the process generally takes a longer time.

Features of Thin Film

- Passive components such as resistors and air-bridge capacitors can be formed with this process.
- Integrated circuits produced by thin film require special wire bonders and micro-welding equipment for assembly.
- Compared to monolithic integration process, it tends to be cheaper in terms of the cost.
- The thin film process
  - tends to have large unknown and
  - not precisely described parasitic circuit elements accompanied

Fabricated Thin Film Substrate

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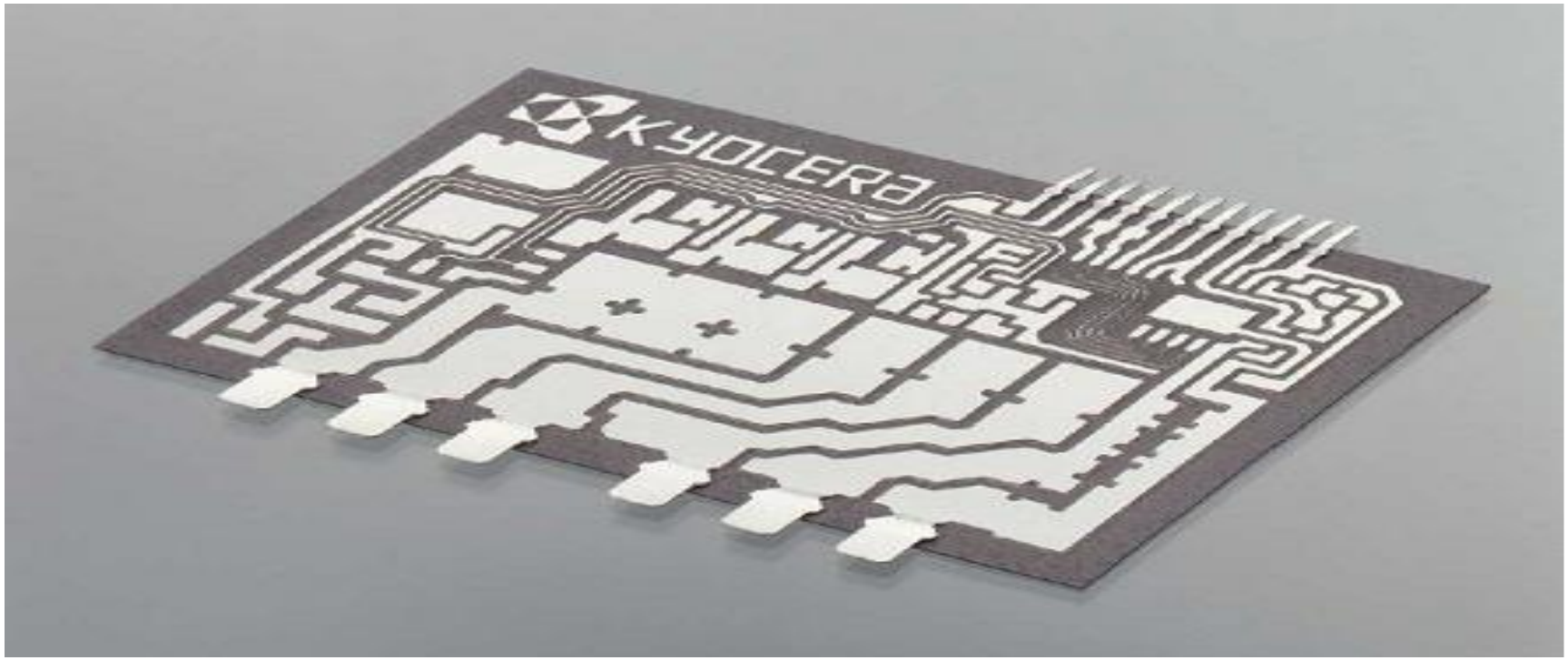


A photograph of a substrate produced by thin film process (Kyocera)

Microwave Circuits in Communication System

- Examples of microwave integrated circuits are
  - low noise amplifier (LNA),
  - power amplifier (PA),
  - oscillator,
  - mixer,
  - directional coupler,
  - switch,
  - attenuator,
  - filter and a host of other microwave integrated circuits.

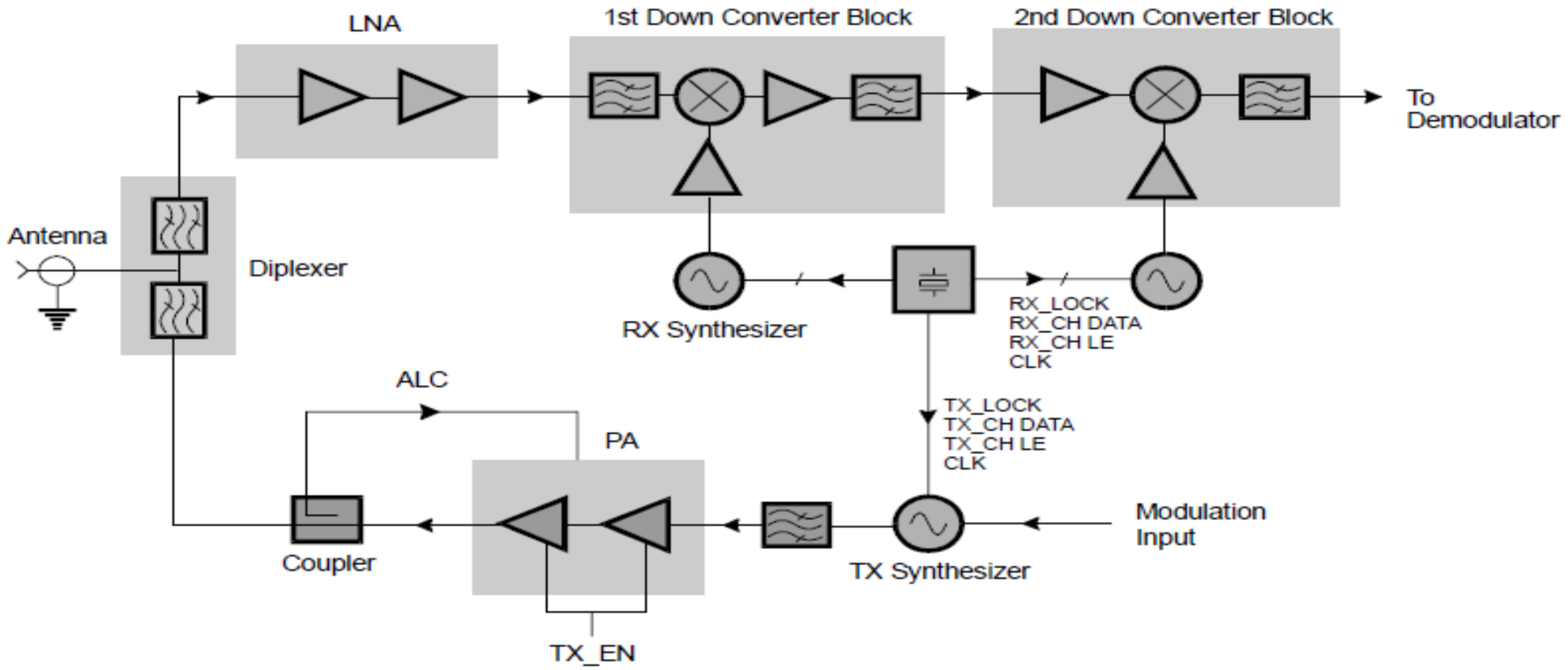
Microwave Circuits in Communication System

- Among these,
  - directional coupler,
  - switches,
  - attenuators,
  - filters, etc are basically passive microwave circuits

Microwave Circuits in Communication System…

- These passive devices are generally not regarded as the basic building blocks of a wireless system.
- This course will therefore cover the basic design theory as well as devices related to circuits such as
  - amplifiers, oscillators and mixers, which are the most commonly used circuits to build wireless communication systems.
- Filters, although passive is also an important communication circuit.

Analog Transceiver System



- A block diagram of an analog mobile phone handsets