

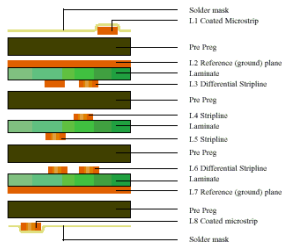
September 2002

# Polar Instruments

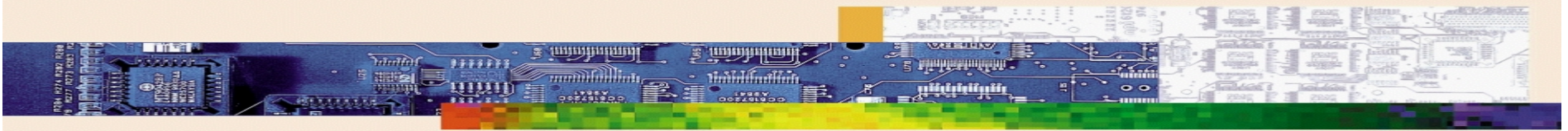
Why Effective Er is not the same as

Bulk Er

Ken Taylor

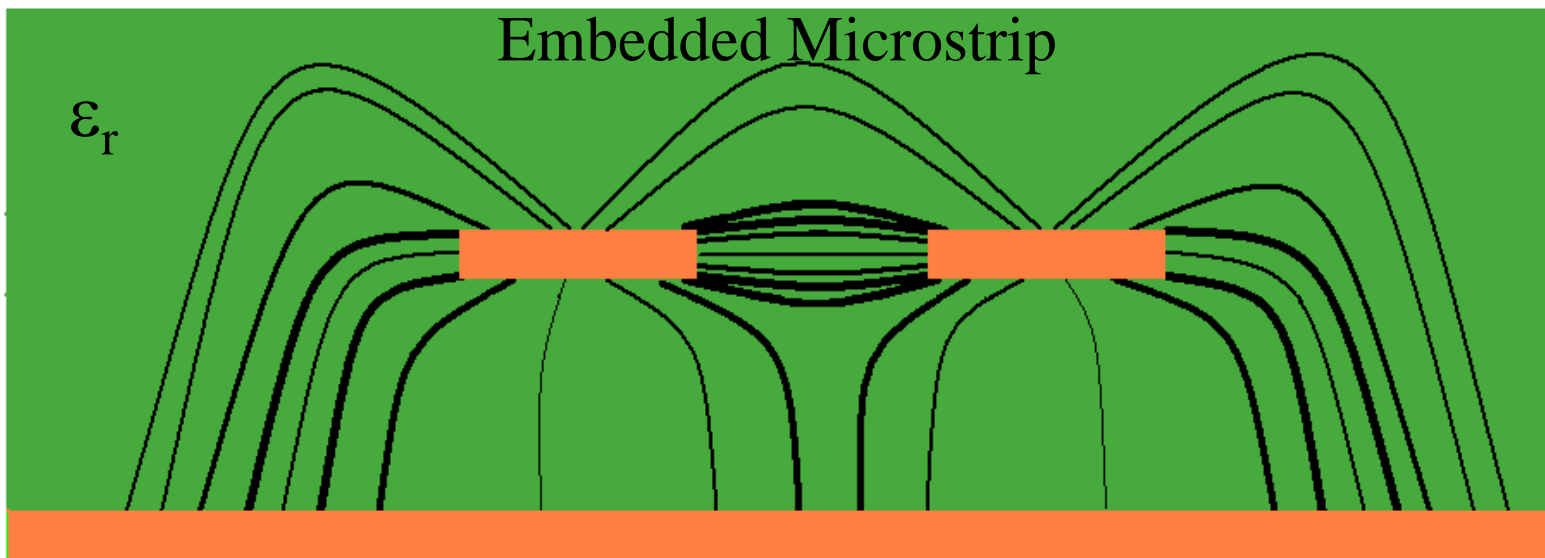
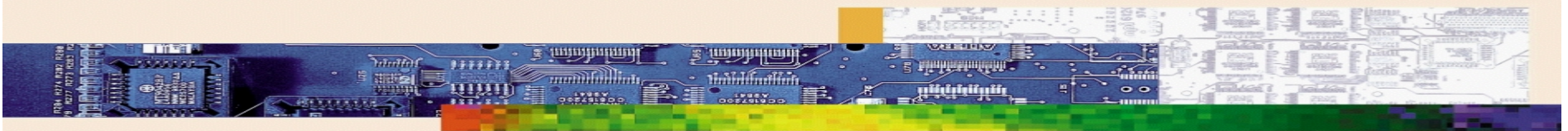


# FR4 Dielectric

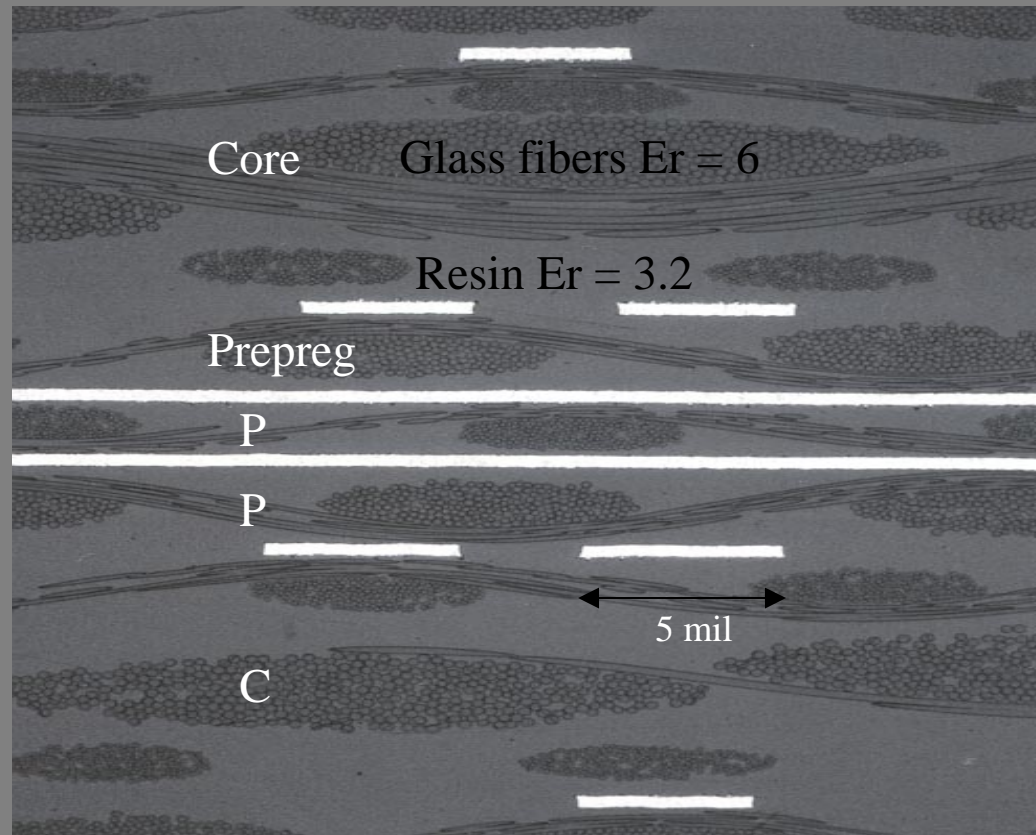
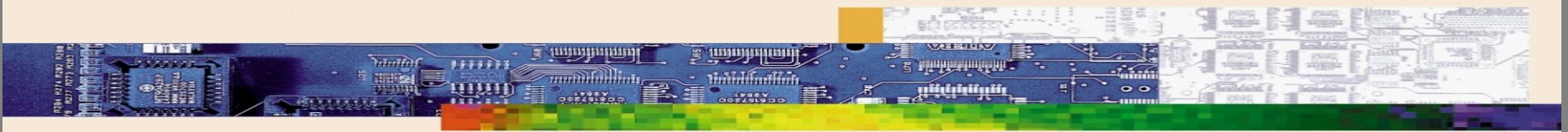


- Core and Prepreg have different  $\epsilon_r$
- Both are Mixtures of Resin and Glass Fibers
  - Materials are non-homogenous
    - $\epsilon_r$  specified for laminate is the bulk value
    - $\epsilon_r$  for glass  $\sim 6.1$   $\epsilon_r$  for epoxy  $\sim 3.2$
  - So significant local variations occur for  $\epsilon_r$

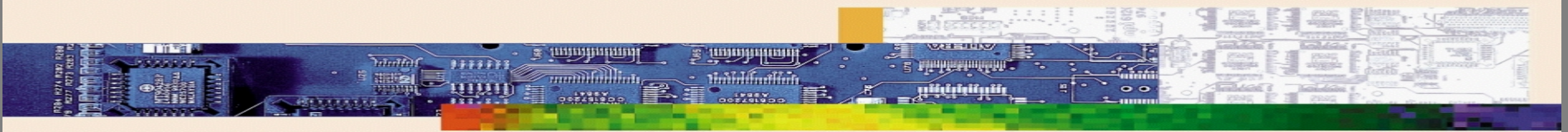
# Typical E-field distribution



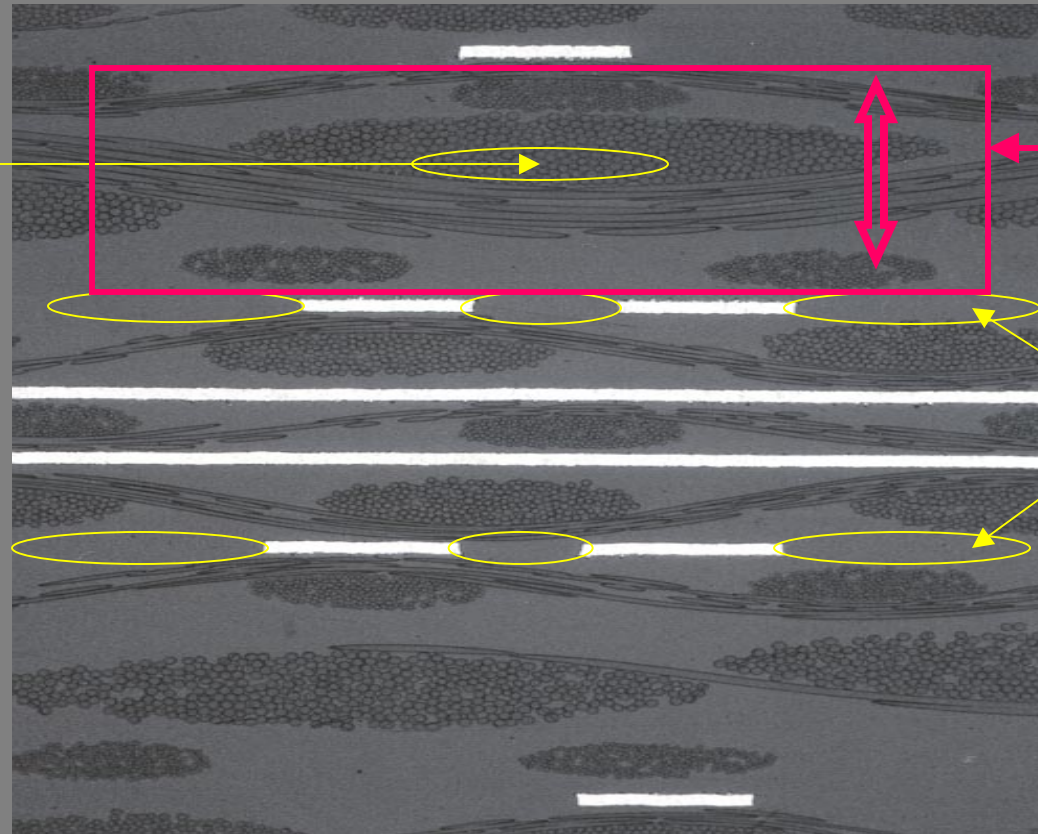
# Microphotograph of FR4 structure



# FR4 structure



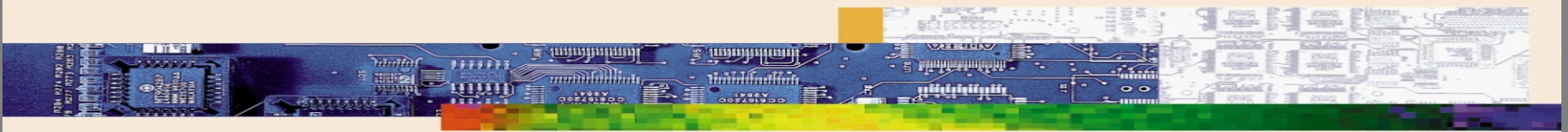
$Er = 6.0$



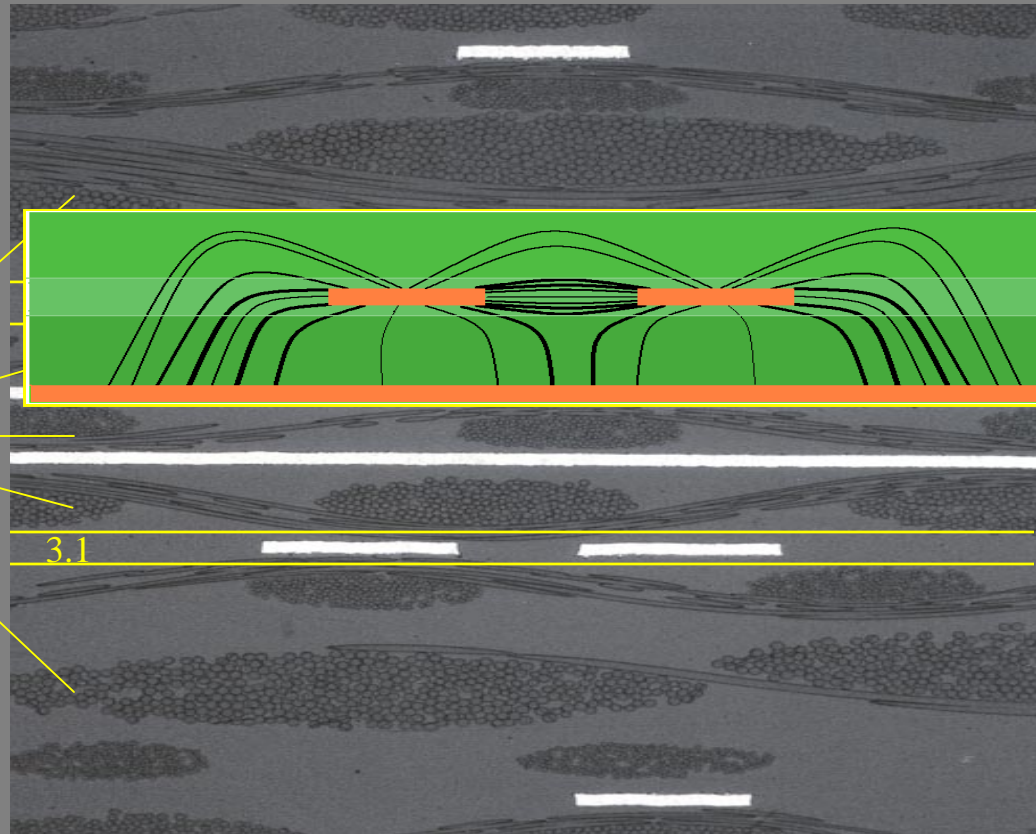
Bulk  $Er$  value  
in this  
direction is 4.2  
approx

$Er = 3.2$

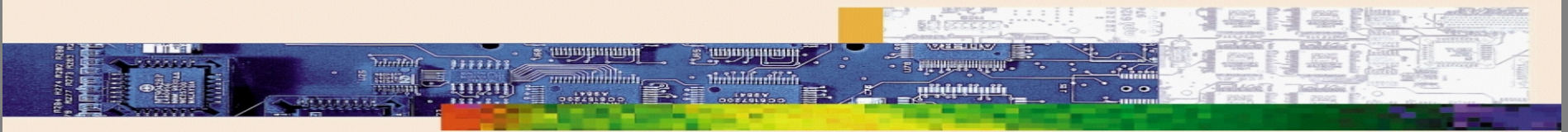
# Field in FR4 structure



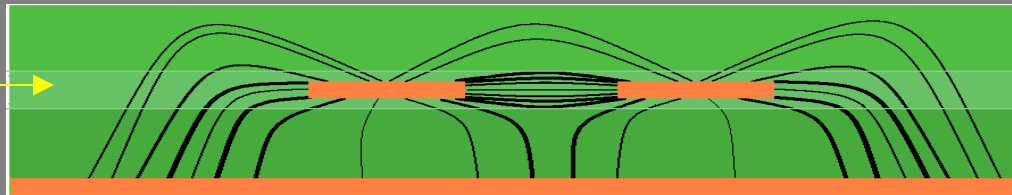
4.2



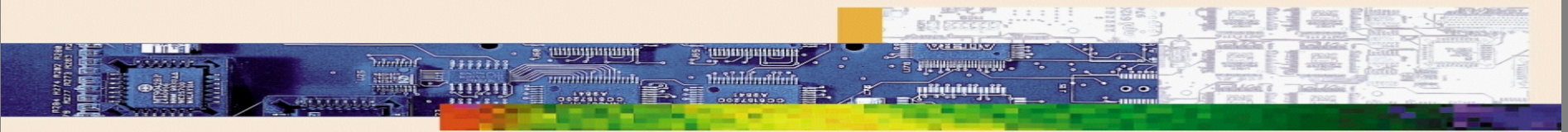
# Field distribution in Differential Pair



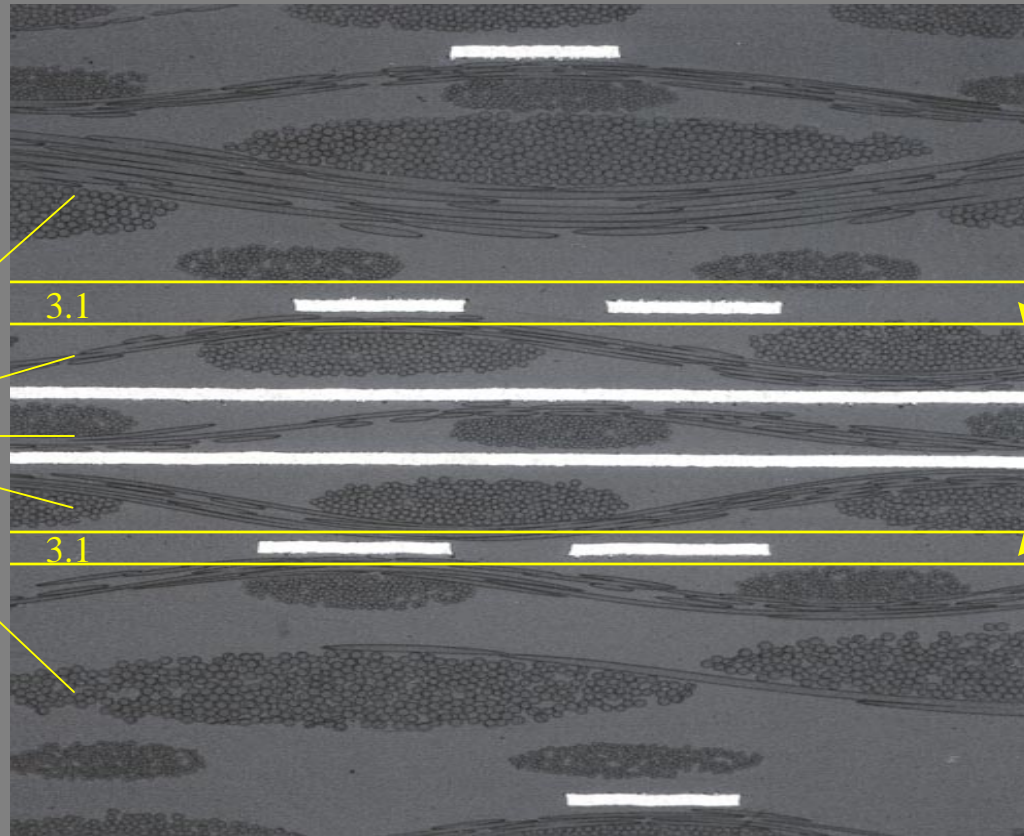
Impedance value  
Increases as  
 $\epsilon_r$  and C decrease



# FR4 structure

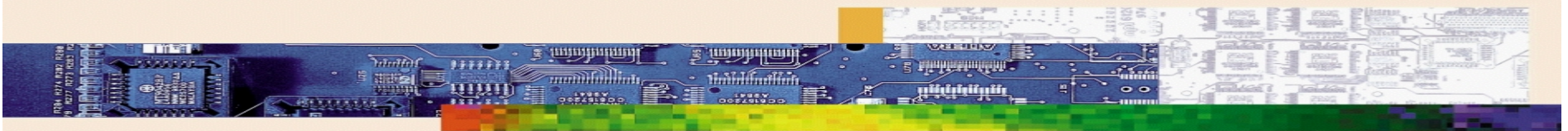


4.2

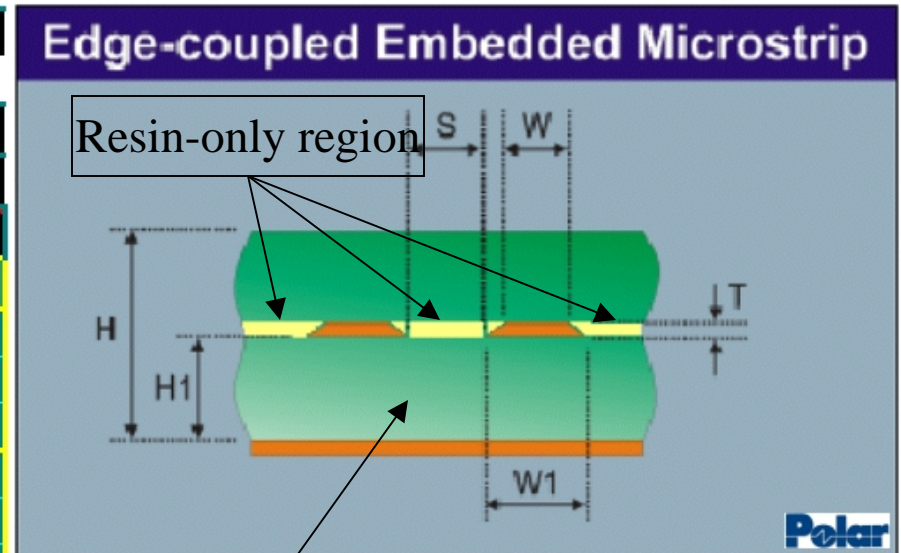


Impedance Value  
Increases

# Resin Layer in Differential Microstrip

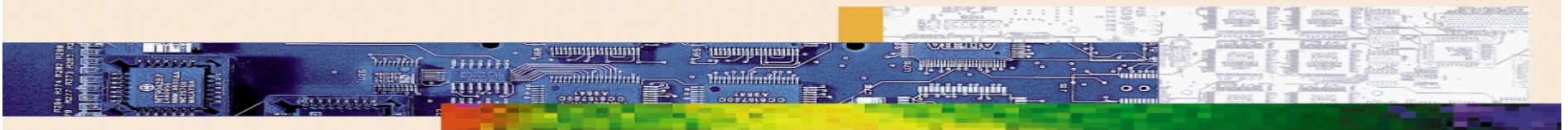


$W1=75$		$W=65$		$H1=500$		$H=600$	
				$S=100$		$S=75$	
				$T=35$		$T=17$	
$Er(\text{Core})$	$Er(\text{Prepreg})$	$Er(\text{Resin})$	$Z_{\text{diff}}$	$Z_{\text{diff}}$	$Z_{\text{diff}}$	$Z_{\text{diff}}$	$Z_{\text{diff}}$
4.2	4.2	--	102.29	103.23			
	3.8	--	104.87	105.79			
4.2	3.8	3.8	104.86	105.78			
	3.8	3.2	106.53	106.88			
	3.9	--	102.54	103.35			
4.5	3.9	3.9	102.52	103.34			
	3.9	3.2	104.36	104.55			

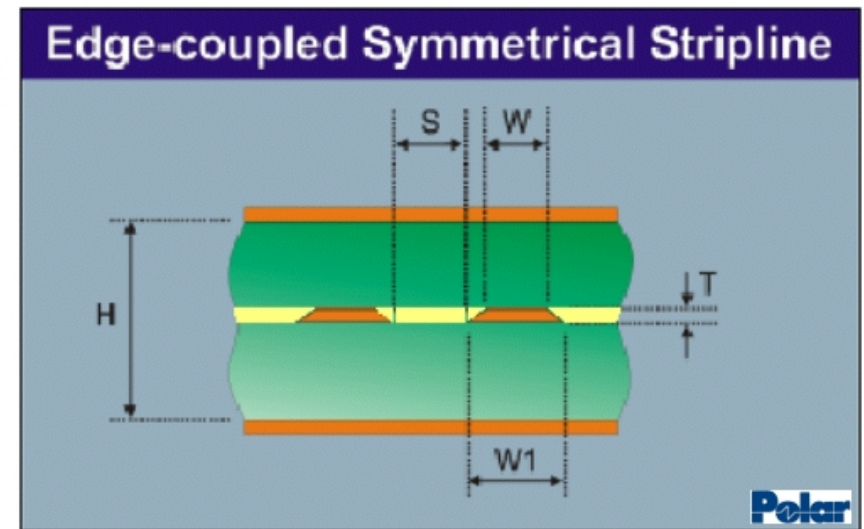


Glass/Epoxy mixture

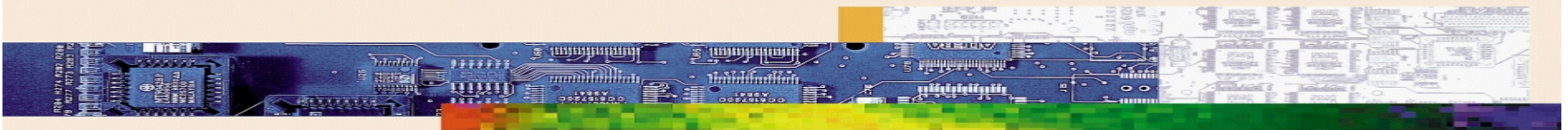
# Resin Layer in Differential Stripline



		$W1=75$	$W=65$	$S=100$	$T=35$		
					$H=200$	$H=1000$	
$Er(Core)$	$Er(Prepreg)$	$Er(Resin)$			$Z_{diff}$	$Z_{diff}$	
4.2	4.2	--			74.114	96.825	
	3.8	--			76.469	99.752	
4.2	3.8	3.8			76.467	99.732	
	3.8	3.2			77.343	101.188	
	3.9	--			74.849	97.576	
4.5	3.9	3.9			74.848	97.557	
	3.9	3.2			75.811	99.154	

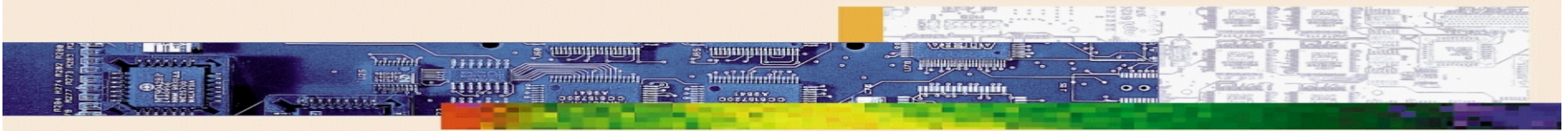


# Conclusions



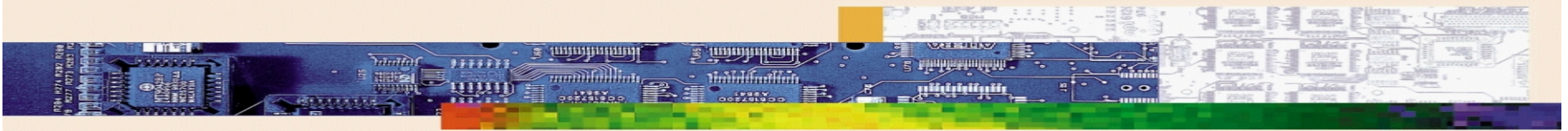
- Over simplified modeling of differential structures leads to impedance discrepancies of several ohms
- Resin flow into region coplanar with tracks increases the impedance of typical embedded microstrip or stripline by 4%

# Conclusions



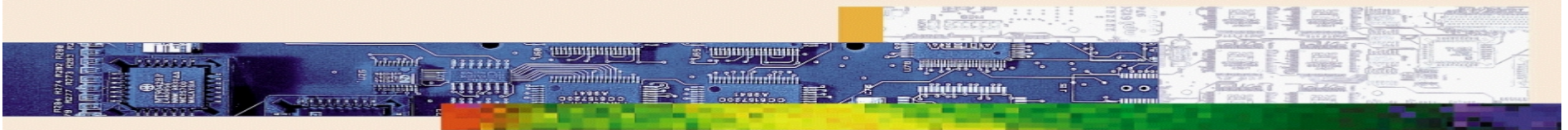
- Your predictions must consider
  - Structure
  - Track dimensions
    - Thickness
    - Widths
    - Spacing
    - Etch taper
    - Symmetry
  - Dielectric layer composition and Effective  $\epsilon_r$  values

# Conclusions



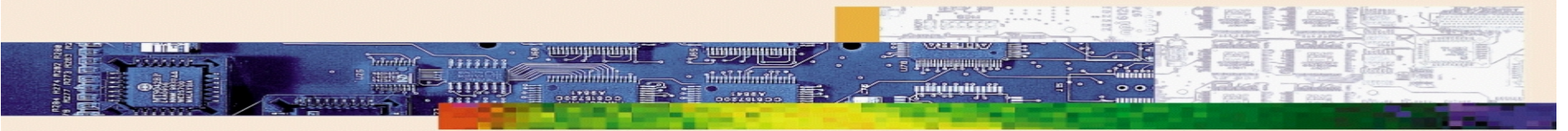
- Accurate implementation of predicted impedance requires
  - Accurate knowledge of dielectric composition
    - Dielectric layers
    - Resin region and local  $\epsilon_r$  value
  - Accurate build of predicted dimensions
    - Track width
    - Track spacing
    - Track etch taper
      - Increased etch taper leads to enlarged resin region
    - Track symmetry
      - Loss of symmetry also affects differential performance

# Recommendation



- Build samples of small differential structures
- Measure impedance using CITS500s
- Microsection and micro-dimension the sample
- “Back” calculate to obtain the Effective  $\epsilon_r$  using Si6000
- In future, use that value of  $\epsilon_r$  for
  - similar structures
  - same dimension range
  - same materials
- For small differential structures in FR4, expect  $\epsilon_r(\text{effective}) \sim 3.7$  (About 10% less than spec.)

# Thank You



- Questions?....

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