smiths interconnect

Noordwijk, The Netherlands
October 11 – 14, 2022

SPCD
SPACE PASSIVE COMPONENT DAYS

RESISTIVE AND WILKINSON POWER SPLITTERS AT MILIMETER WAVES FOR SPACE APPLICATIONS

By Dr. Mo Hasanovic, Principal RF Design Engineer, Fiber Optics and RF Components

BEYOND CONNECTIVITY

Smiths Group - Facts and Revenues by Division

SPCD
SPACE PASSIVE COMPONENT DAYS

- Founded in 1851
- FTSE100 Listed Global Technology Business
- A World Leader in the Practical Application of Advanced Technologies
- Over 15,000 Employees
- More than 50 Countries
- Revenues £ 2.4bn

John Crane

Mission-critical solutions for global energy and process industries

36%

Smiths Detection

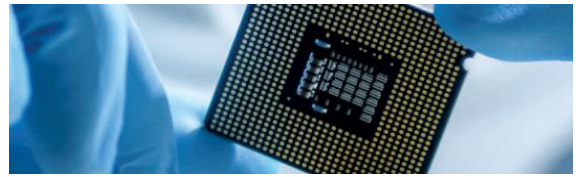
Detection and screening technologies for the identification of safety and security threats

30%

Flex-Tek

Innovative components to heat and move fluids and gases

21%



Smiths Interconnect

Solutions for high-speed, secure connectivity in demanding applications

13%

Board Level Components

SPACE PASSIVE COMPONENT DAYS

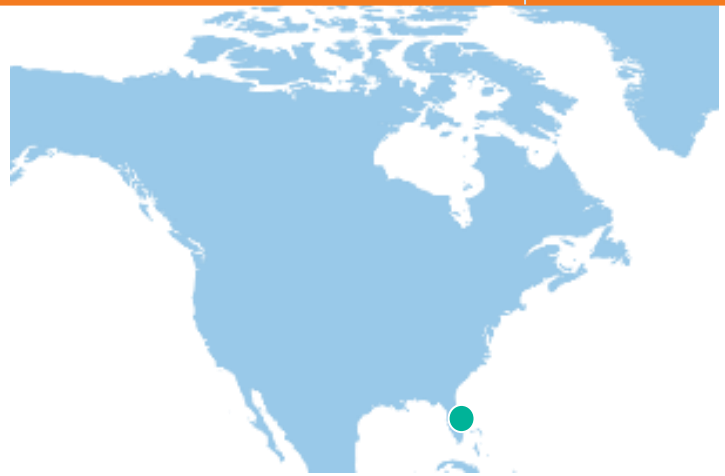
- RF components specifically designed for demanding high reliability applications
- Development of thin and thick film RF and Microwave components, signal distribution products
- Broad range of frequency spectrum applications
- High performance microwave cable assemblies and harnesses supporting critical operations
- Providing operational excellence tailored to volume manufacturing requirements
- Designed in Stuart, FL, manufactured in Alajuela, Costa Rica

Stuart, Florida, USA

Alajuela, Costa Rica

Research & Development, Design & Analysis in Stuart, FL

Manufacturing in Alajuela, Costa Rica



Radio Frequency Technology

Diamond RF Resistive

Signal Distributions

Resistors

Attenuators

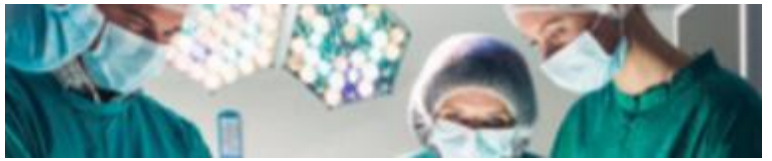
Terminations

Thermopad®

Cables

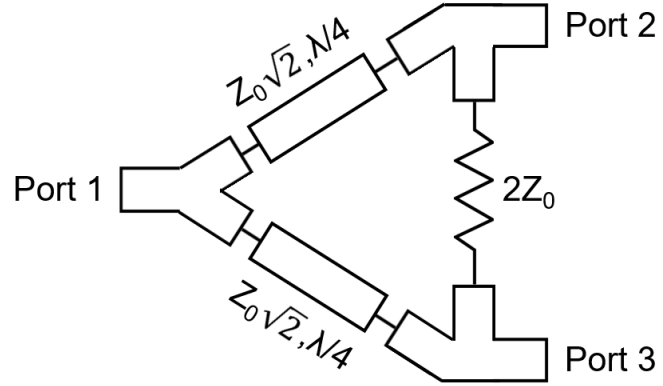
Current RF Market Trends

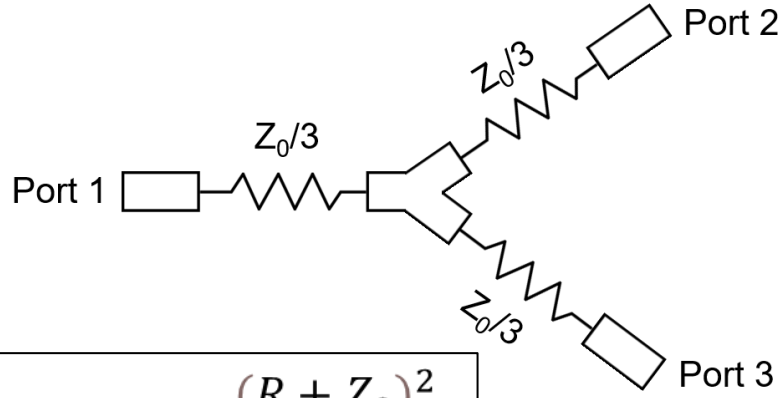
- Current developments in 5G, IoT, and Industry 4.0 technology require an efficient, affordable, and economically viable beamforming technology.
- Power splitters continue to play a prominent role in RF systems for many years and in many applications where distribution of RF power is required.
- For example, in hybrid beamforming, we use both analog and digital option that offers a trade-off between digital beamforming complexity and improves the thermal management while maintaining a reasonable level of performance provided by the limited digital processing.
- They enable electronic beam scanning as well as focusing the antenna beam on different directions as a function of the phase difference at individual antenna elements.
- The structure of power splitters has been continuously changing to respond to new challenges in modern communication systems.



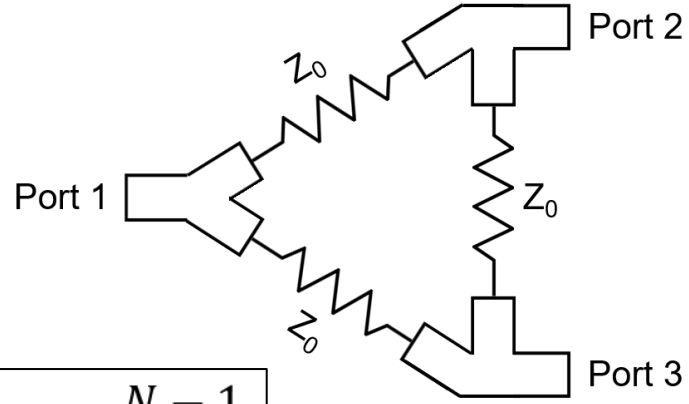
Resistive and Wilkinson Splitter – Basic Theory

- RF device that divides input RF power into multiple outputs
- May also be used to combine the power if the flow of the power is in the opposite direction
- Ideal requirement: perfectly-matched, reciprocal, and lossless RF device
- An ideal (matched+reciprocal+lossless) power divider is not physically realizable
- There are power dividers that satisfy two of the three of the above properties





$$Z_{in} = R + \frac{(R + Z_0)^2}{2R + 2Z_0}$$



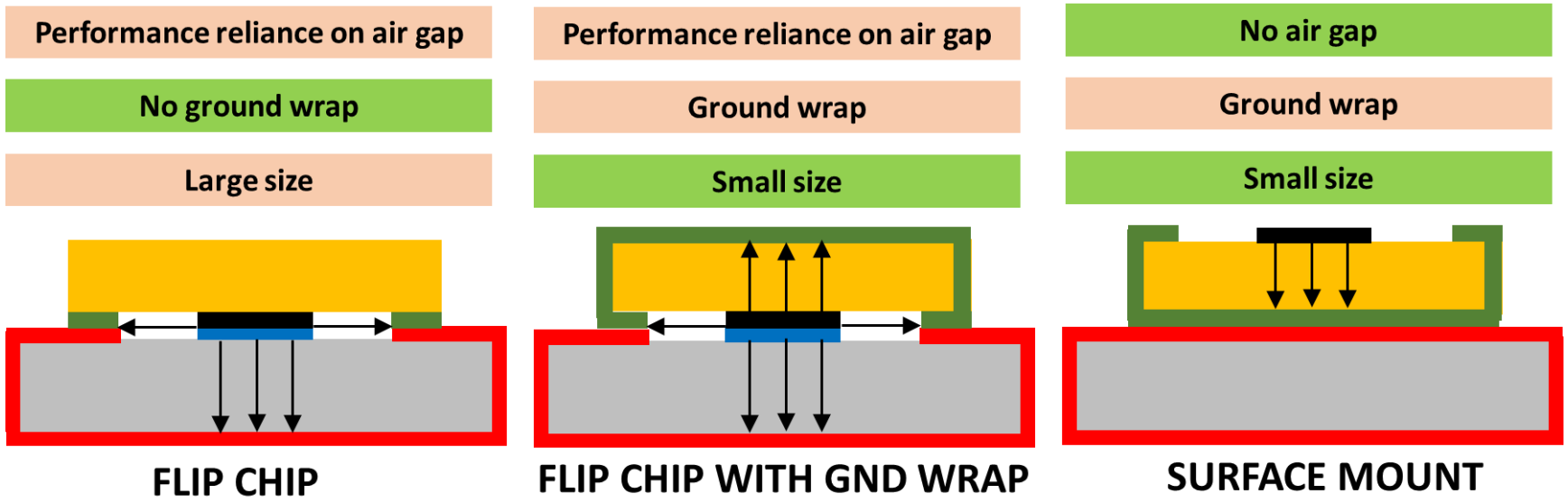
$$R = Z_0 \frac{N-1}{N+1}$$

- Three most popular types of power dividers :
  - resistive type
  - T-junctions
  - Wilkinson

https://www.microwaves101.com/encyclopedias/resistive-power-splitters

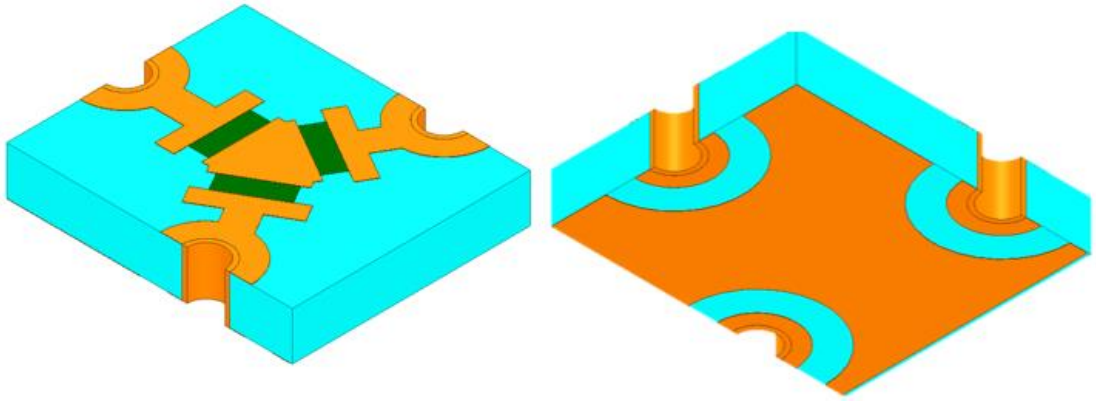
Mounting Options for Surface Mount Components

- Planar power dividers may be realized on different planar SMT platforms—microstrip, stripline, CPW
- Microstrip platform: simplest design, affordable manufacturing as no bonding of multiple RF layers is required
- Microstrip configurations: flip chip, chip with the ground wrap, true surface mounting
- Major disadvantage flip chip/flip chip with the ground wrap configurations is reliance on the electrical properties of the application board
- True SMT: the RF splitter placed on the top surface of MS chip; the RF structure is electrically separated from the application board through the presence of the GND plane on the bottom



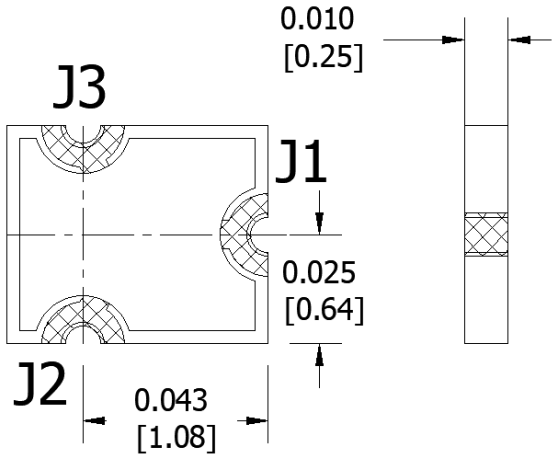
Resistive Power Splitter - Design

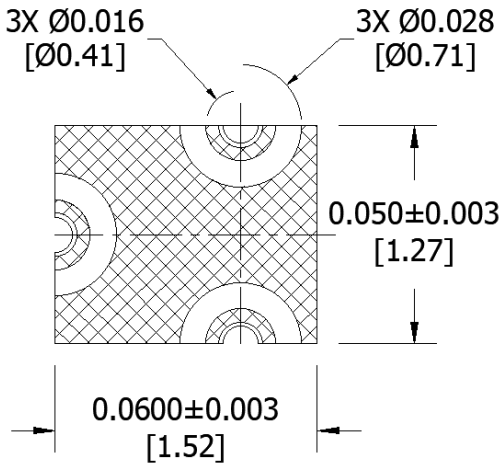
- Designing a resistive or a Wilkinson power divider for millimeter waves has its own unique challenges
- The physical length of the quarter-wave transformers is very short and often at the same order of scale as the corresponding line width at these incredibly high frequencies
- The size of the resistive elements is electrically significant and introduces reflections that need to be properly tuned
- Radiation effects become notable and must be properly addressed during the design of the power divider.
- A small misalignment during the mounting of the divider onto the application board may result in a significant amplitude and phase imbalance.
- Nevertheless, surface-mount resistive power dividers, if designed and mounted properly, provide for an excellent electrical performance and offer all the flexibility of a discrete component.



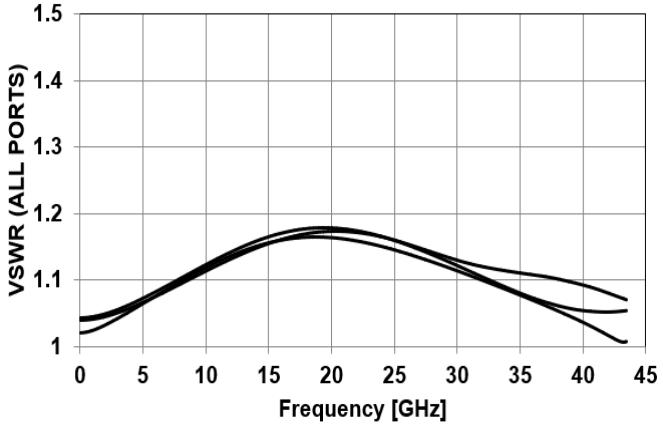
TOP

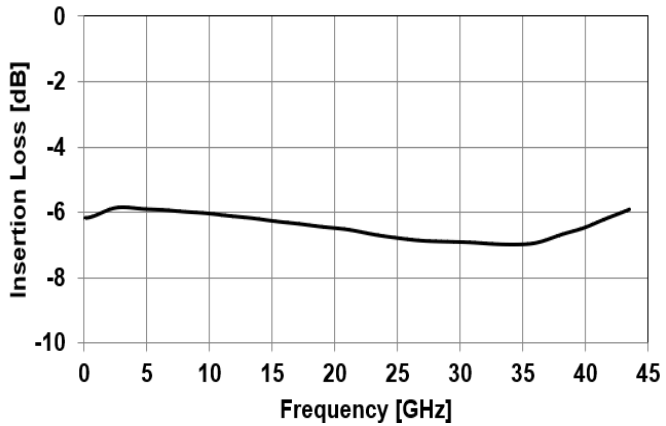
BOTTOM

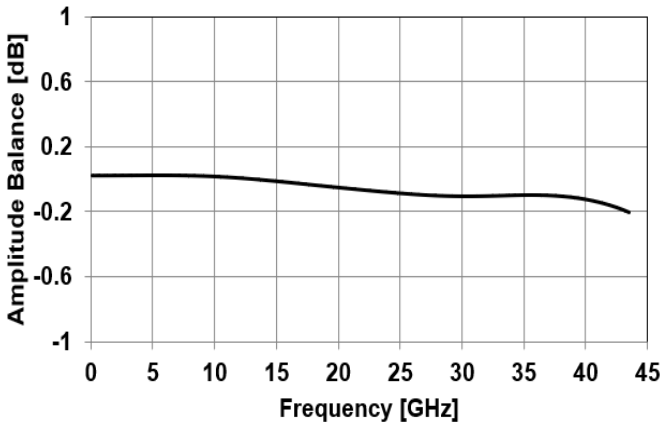


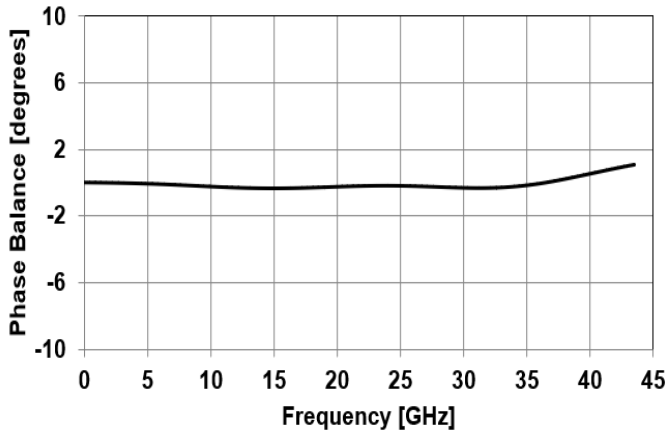


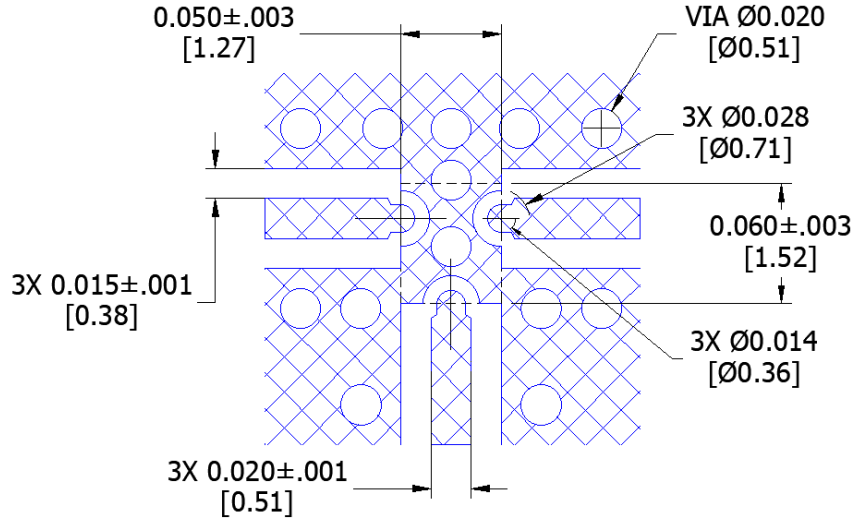
Resistive Power Splitter – Sample Test Data

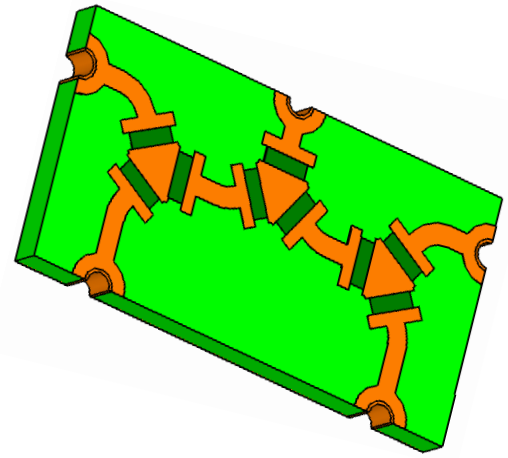








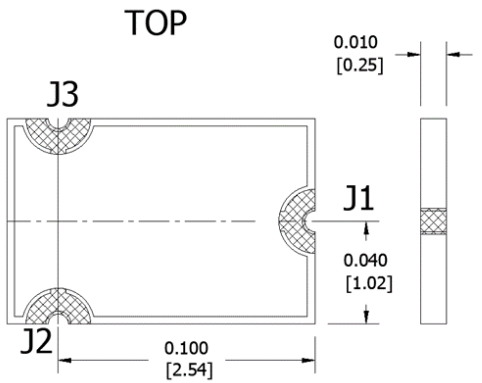


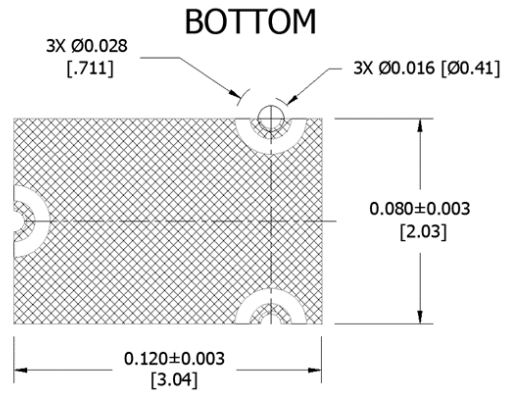


- 2-way resistive divider can be expanded into more complex structures such as 4-way, 8-way
- Possible to customize the design for a specific size and position of input and the outputs.

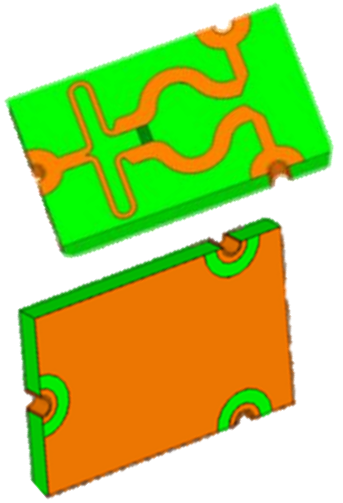
Equal Split Wilkinson Power Splitters - Design

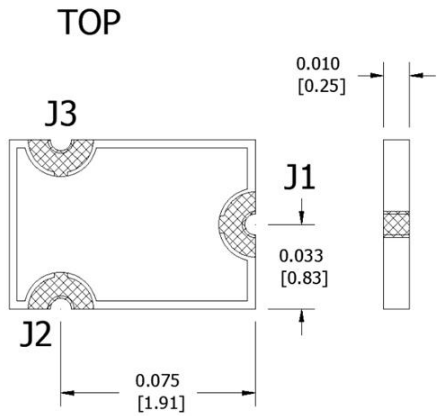
- Better insertion loss performance than resistive power dividers.
- Relies on the quarter-wave impedance transformation, and thus it is inherently a narrowband structure
- The shape of the power splitters may be properly adjusted accordingly by bending the quarter-wave sections.
- The design of Wilkinson 2-way splitters with equal split ratio is based on: (1) even-mode and odd-mode analysis and (2) heavy reliance on the RF structure symmetries
- The entire simulation may be performed on a half of the splitter which significantly reduces the complexity of the simulated model and the required simulation time

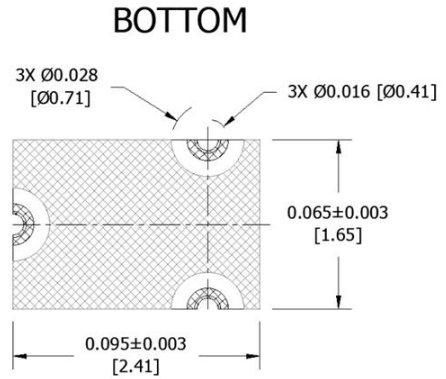




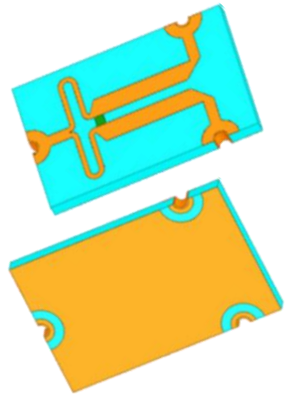
15 – 25 GHz



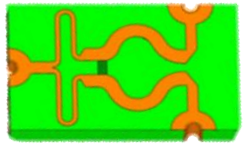




25 – 35 GHz



Equal Split Wilkinson Power Splitters – Sample Test Data



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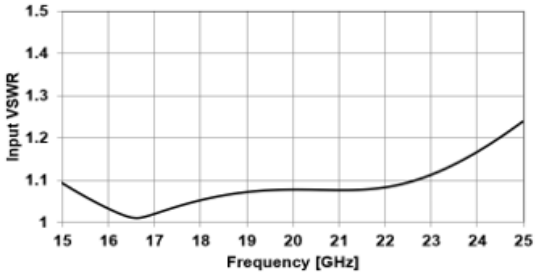
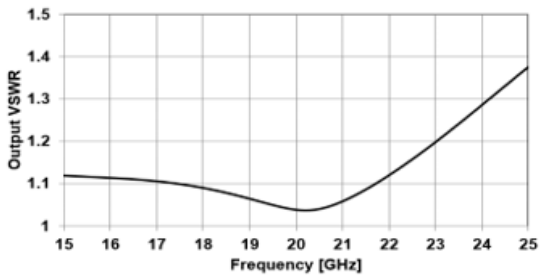
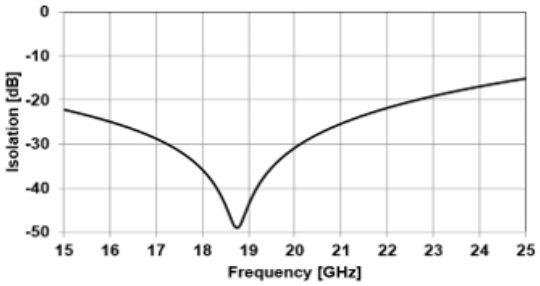
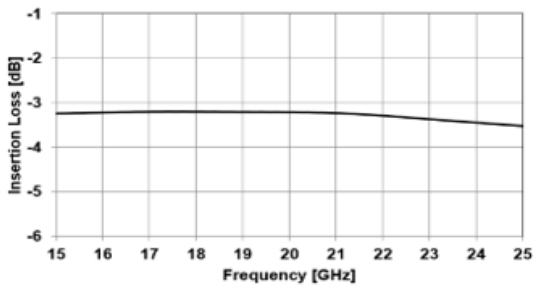
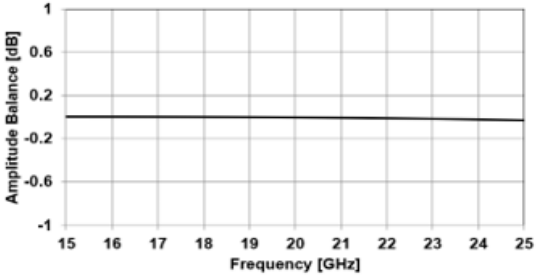
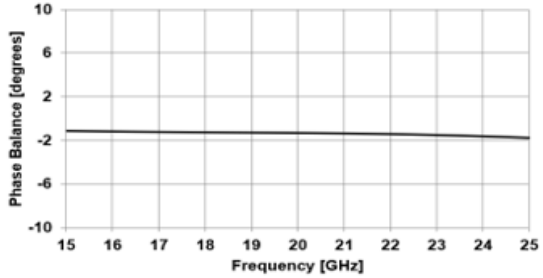


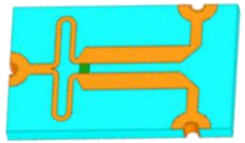




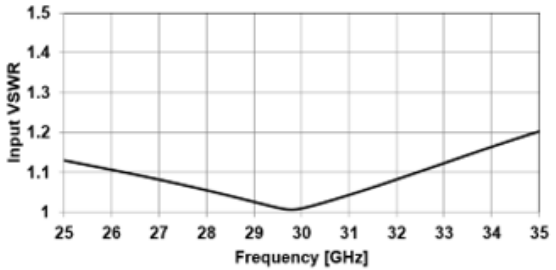


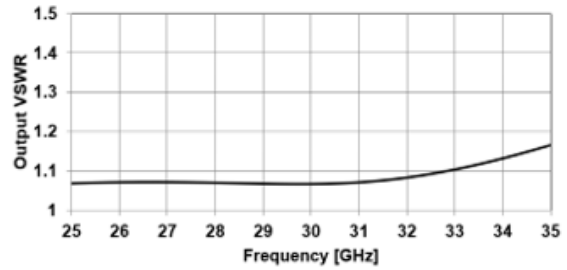


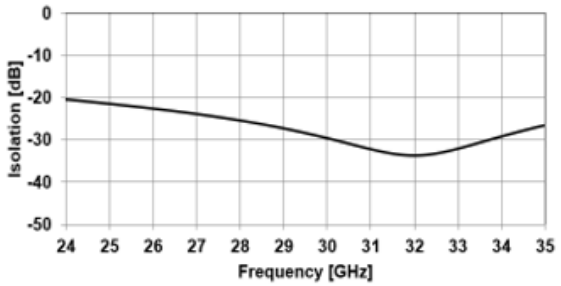


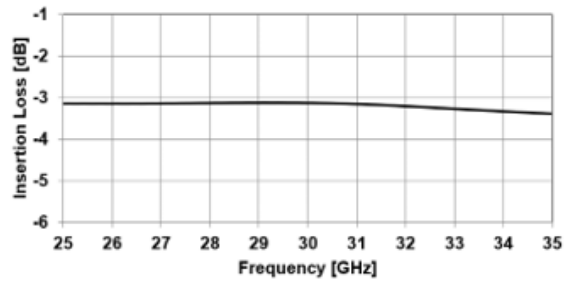


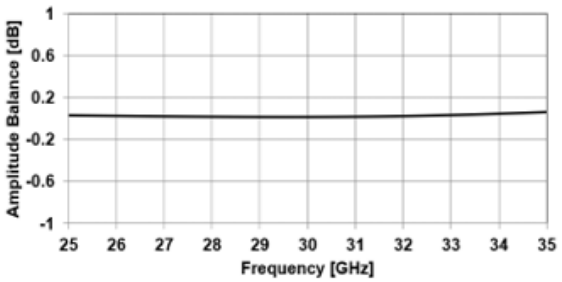
25 – 35 GHz

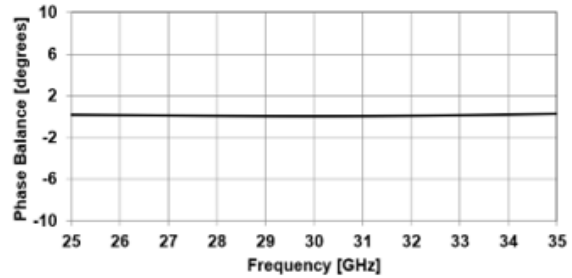








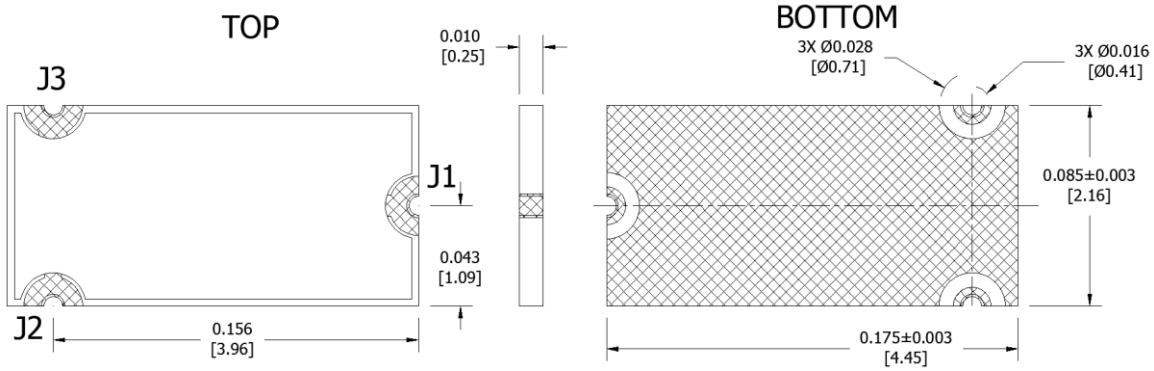




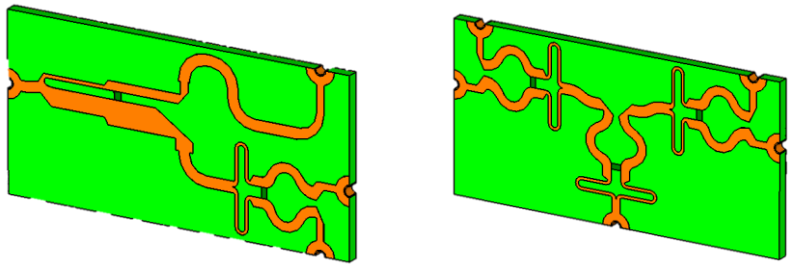
Unequal Split Wilkinson Power Splitters – Design and Test Data

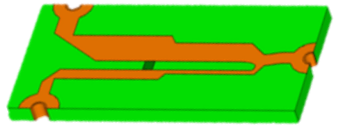
SPACE PASSIVE COMPONENT DAYS

- To design a Wilkinson power splitter with an unequal power ratio poses a significant challenge as a designer cannot rely on symmetries

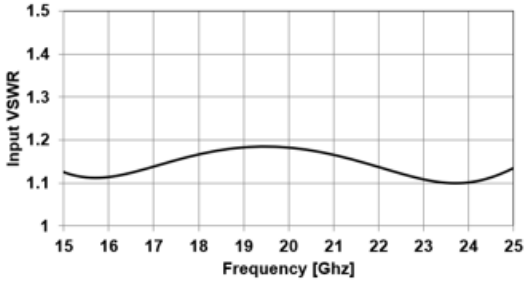


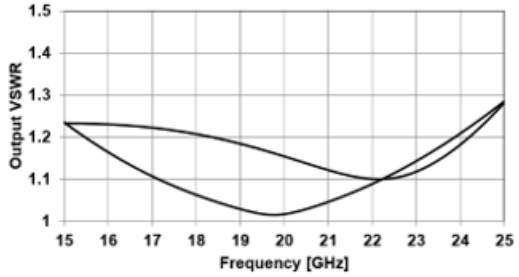
- Wilkinson power splitters with unequal power ratios play a critical role in many phased-array applications and more power splitters with more complex power ratios such as a 3-way, 6-way, and others.

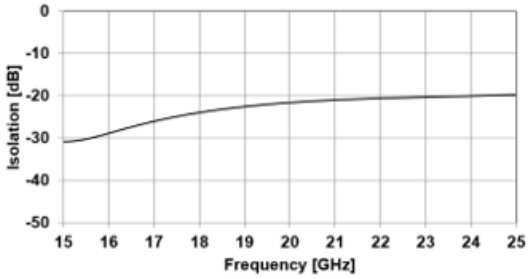


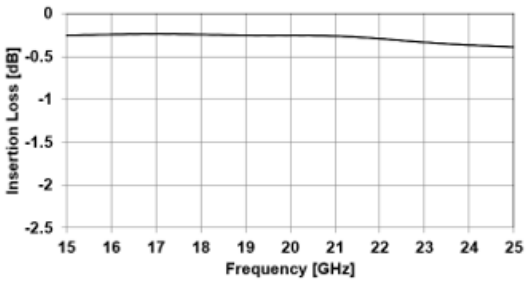


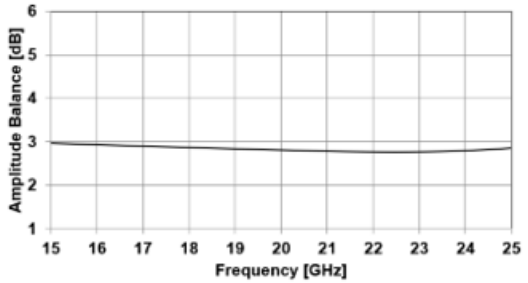
15 – 25 GHz

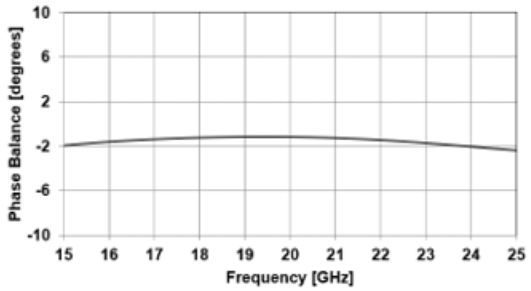






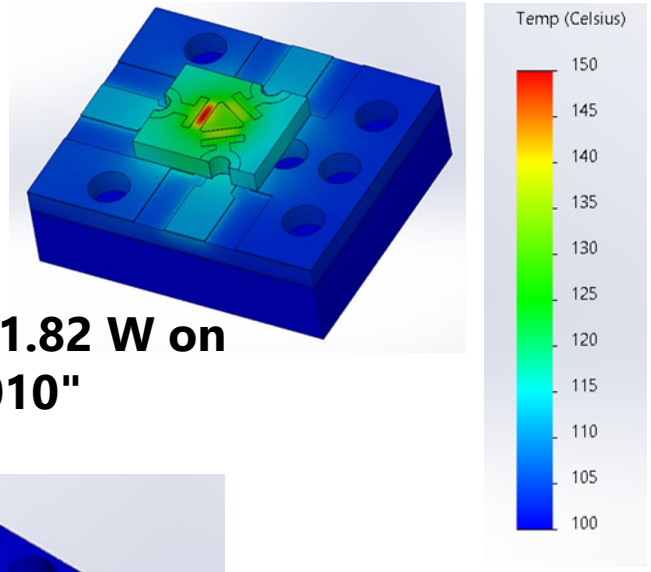




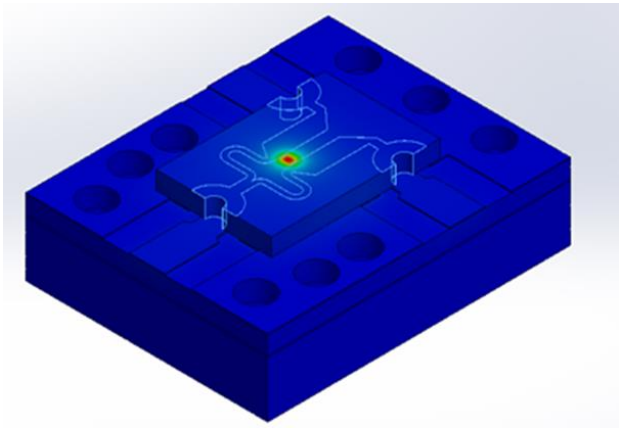


Power Splitters – Thermal Analysis

- All devices were simulated using 1/2 oz copper on both sides and Sn96 solder with 30% porosity at an approximate thickness of 0.001“
- The power handling of the resistive power Divider accounts for the power dissipated in the primary resistor and secondary resistors under normal operation.
- The power handling of the Wilkinson power divider is not expected to dissipate power into thermal energy in the resistor under normal operation.



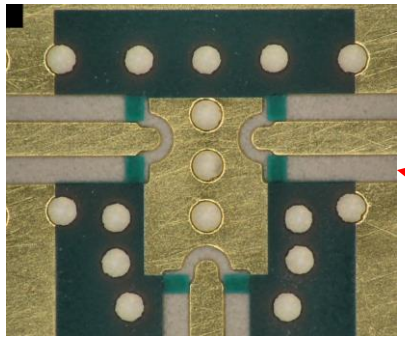
Input Power = 1.82 W on 6035HTC at 0.010"

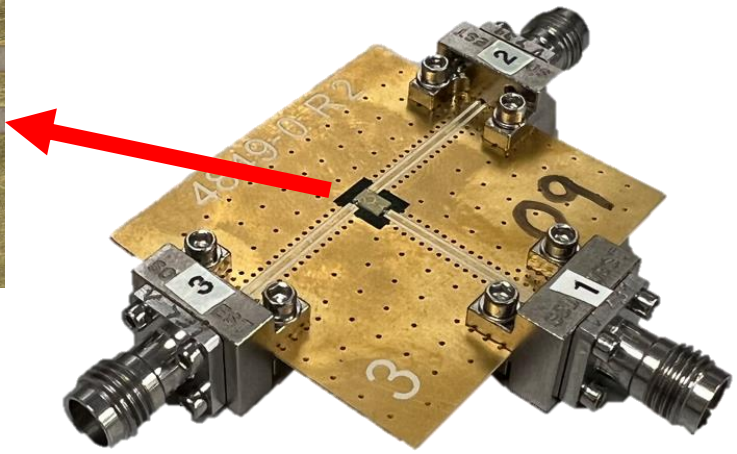


Input Power = 0.45 W on 6035HTC at 0.010"

Proper Installation Practices

- To avoid any potential electrical failures, the chip termination needs to be properly positioned (centered) and soldered in place
- Introduction of the solder mask around the footprint area where the SMT chip is to be soldered helps this positional alignment
- Surface mount installation (SMT) usually consists of chip (DUT) tinning, flux application to the test board, chip positioning (placement), and reflow





- Special care should be taken to ensure there is no solder run-out into the area where the chip is to be mounted
- This is usually achieved by printing the solder paste directly onto the test board; if not possible, tinning the chip is the easiest way to control the amount of solder
- If the chip is to be tinned, pay special attention to a uniform tinning on all pads of equal size and use mildly activated flux

Proper Installation Practices (continued)

STEP 1.

Apply flux directly to the board by using the minimum amount of flux

CAUTION: Extensive flux may cause performance failures and is hard to clean from under the chip

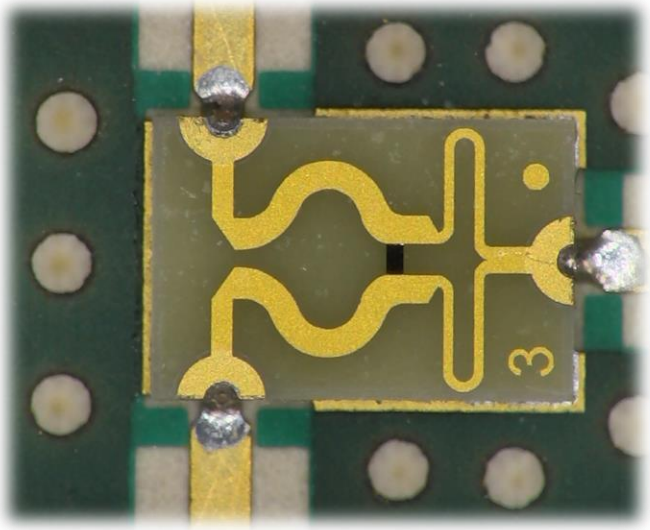
STEP 2.

Using the tweezers, place the chip on the board and align it correctly

CAUTION: If tinning and flux are done correctly, the chip rarely moves during the reflow

STEP 3.

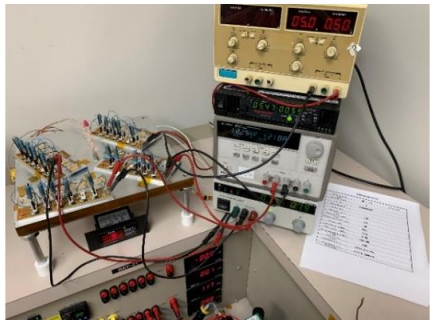
Use the hotplate for reflow (set proper temperature levels on the hotplate for the applied solder)

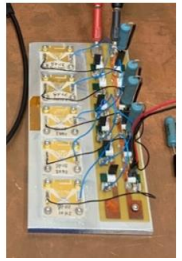


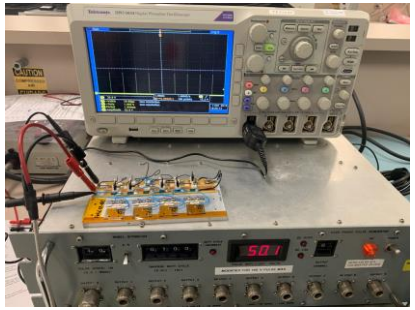
Product Qualification

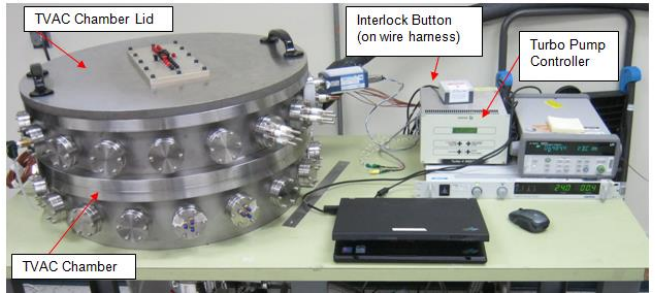
SPACE PASSIVE COMPONENT DAYS

Group A → Mechanical and Visual Inspection → Initial Electrical Test → Thermal Shock (10 cycles) → Post-TS Electrical Test → 168 hour Bake Test → Post-Burn Electrical Test → Solderability Test (5 DUTs) → Die Sheer Test → Final Electrical Test (5 DUTs)

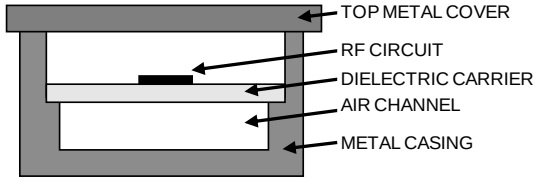




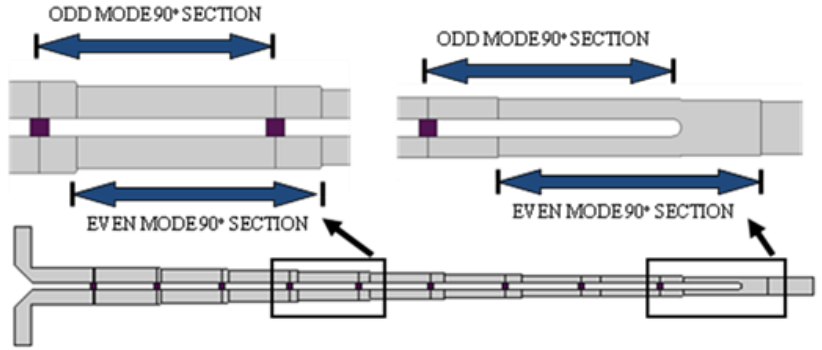


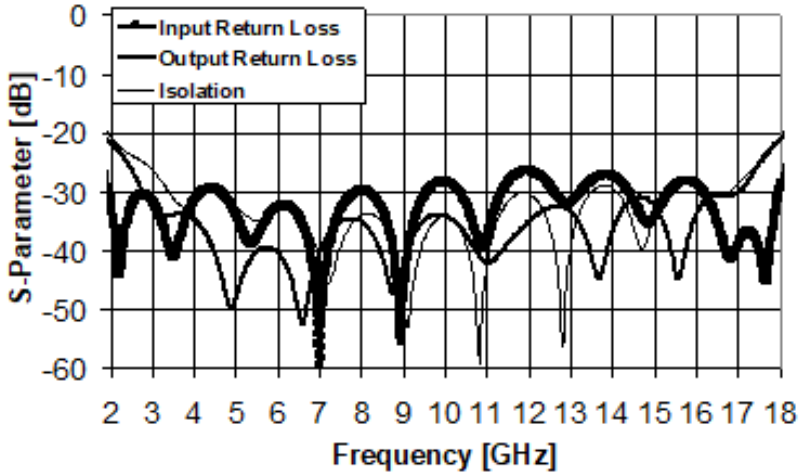


Power Splitters in Suspended Stripline Technology



- Addressing a low insertion-loss requirement in modern space applications to accommodate for a stringent loss budget and long communication paths.
- Quarter-wave impedance transforming sections are optimized to different electrical lengths in even and odd modes due to different phase velocities of the two modes. poor functionality of the corresponding splitter.
- Phase velocity compensation techniques – using lumped elements “wiggly” quarterwaves use of anisotropic substrates or dielectric overlays
- Here, we propose a simpler and more space friendly solution with even and odd mode sections physically ending at different locations.

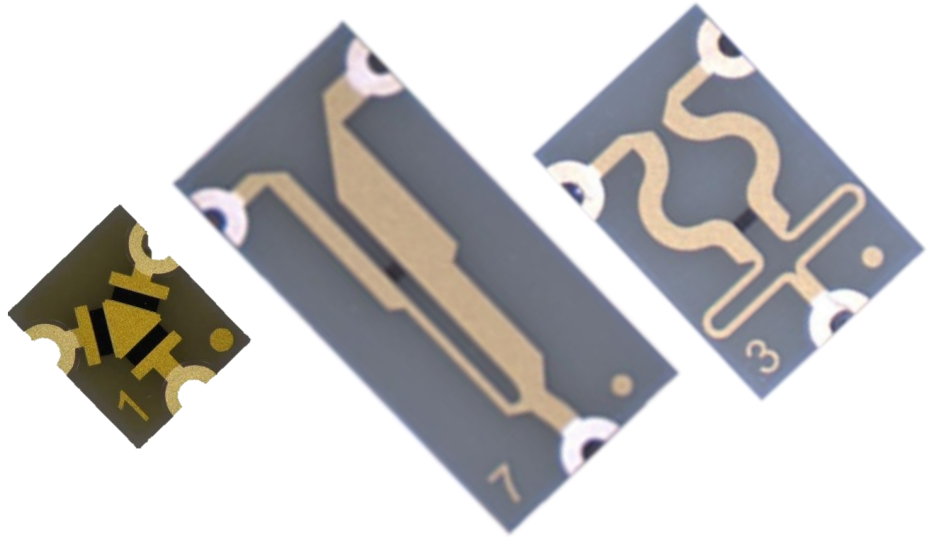




Proof of Concept: 10-section, 10-chip equal-split Wilkinson power splitter is on 0.125mm thick Taconic TLE-95 substrate and 0.625mm deep air channels on the top and bottom of the carrier

Conclusion

- Here, we presented a series of surface-mount resistive and Wilkinson power splitters at millimeter wave frequencies that could be easily deployed in various RF beamforming and other space applications.
- Advantages and disadvantages of various mounting platforms have also been discussed with the conclusion that the surface-mount option provides the superior performance compared to the alternatives.
- A design technique for Wilkinson power splitters in suspended airline technology is also proposed that provides a low insertion loss and thus is attractive for space applications.



Alumina Substrate
Total Thin Film Construction
Small Footprint
Up to 50 GHz Capability
Various Power Split Ratios
Low Insertion Loss

Larger High Frequency Product Portfolio

SPACE PASSIVE COMPONENT DAYS

THANK YOU VERY MUCH.

QUESTIONS?

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Board Level Components, Smiths
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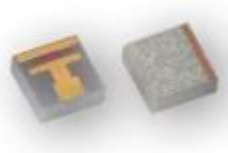
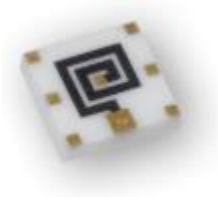
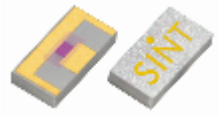


Wirebondable Terminations
(CT Series, DC-64 GHz, 0.040”x0.040”)

SMT Outrigger Resistors
(CHX Series, DC-27 GHz, as small as 0402)

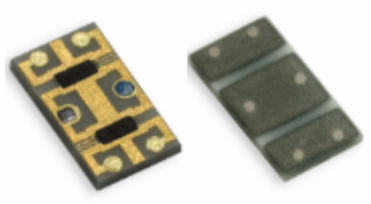


SMT Spiral Terminations
(DC-40 GHz, 0.055”x0.055”)

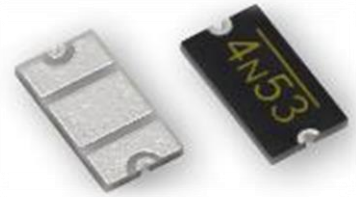


SMT RF Terminations
(CTH Series, DC-67 GHz, 0.060”x0.030”)

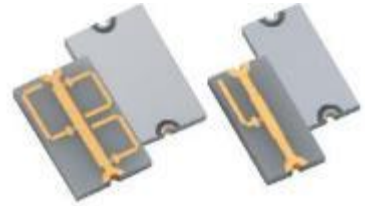
SMT Planar Filters
(DC-40 GHz, 0.200‘x0.100”)



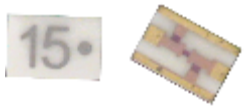
Wirebondable Temperature Variable Attenuators
(K2TVA Series, DC-32 GHz, 0.120”x0.065”)



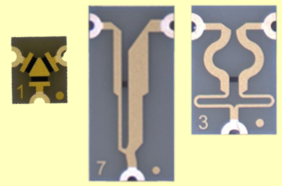
SMT Temperature Variable Attenuators
(K2TVA Series, DC-32 GHz, 0.120”x0.065”)



SMT Frequency Equalizers
(CEX Series, DC-40 GHz, 0.120”x0.065”)



SMT Fixed Attenuators
(TSX Series, DC-40 GHz, 0.060”x0.040”)



SMT Resistive and Wilkinson Dividers
(DC-40 GHz, as small as 0.060”x0.050”)

more > smithsinterconnect.com

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BEYOND CONNECTIVITY