Agenda

• Intro to RF Components & Applications
• PCB Layout Design Case Studies for RF Components
• Chip Antenna Design Guideline & Technical Support
• TDK RF Product Center Website Walkthrough
• TDK RF Product Line Summary
• TDK RF Design Support & Technical Tools
RF Components & Applications Introduction
TDK offers complete front-end solution for wireless system design

- Chip Antennas
- Baluns / Couplers
- HP/LP/BP RF Filters
- Diplexers / Triplexers
- Magnetic Sheets
- Circulators/Isolators
TDK RF Material Technology

LTCC TECHNOLOGY
For over 25 years, TDK has been instrumental in the development of RF technologies. TDK’s industry leading RF components are based on the same Low Temperature Co-fired Ceramic (LTCC) technology used in our multilayer ceramic capacitors and multilayer inductors. More than ten layers (up to 35 layers) are stacked to integrate passive circuit elements using LTCC process.

Design Advantages
- High dielectric constant ceramic materials enables down-sizing of component
- Allows co-firing of two or more different dielectric materials for improved performance
- High-Q, low cost and shorter lead-time

THIN FILM
Originally, TDK developed the Thin-film process technology for HDD R/W heads. TDK now brings this leading-edge technology to RF components. This enables us to develop compact, low-profile components with outstanding performance ideally suited for applications such as smart phones. Thin film process provides fine pattern, high precision, and miniaturization for RF components.

Design Advantages
- Ferrite materials enables high quality factor
- Non-magnetic ferrite carrier with thin-film process enable world’s smallest RF components
- Small variation in performance and smaller/thinner component with same performance (space saving)
TDK RF Component Lineup

<table>
<thead>
<tr>
<th>Filters (BPF / LPF / HPF)</th>
</tr>
</thead>
</table>
TDK’s DEA and TFS series filters are designed using Low Temperature Co-fired Ceramic (LTCC) or Thin Film technology and create a resonance frequency allowing certain frequency ranges to pass while blocking, or attenuating, other unwanted frequency ranges. TDK offers both high and low pass filters, as well as band pass filters with frequencies ranging from 5MHz to 8GHz with variation in shape and size, terminal structure, specification values, etc.

TDK filters are used in products with a wide variety of wireless communications such as WLAN, BT, cellular, GPS, ZigBee, WiMAX and in both licensed and unlicensed frequencies.

<table>
<thead>
<tr>
<th>Diplexers</th>
</tr>
</thead>
</table>
TDK’s DPX series diplexers are 3-port filters that divide/route two frequencies from a common port. These diplexers offer low insertion loss and high attenuation versions and are available in various combinations of LPF/BPF/HPF designs. With dimensions ranging from 1.0 × 0.5mm to 2.5 × 2.0mm, their compact size and high performance offers stable characteristics for applications including 2.4GHz & 5GHz Wi-Fi, Bluetooth, ZigBee, LTE and GPS.

TDK diplexers using Low Temperature Co-fired Ceramic (LTCC) are available in a wide product range with variations in frequency, size, terminal structure, specification values, etc.

<table>
<thead>
<tr>
<th>Triplexers</th>
</tr>
</thead>
</table>
The newest of the filtering family, TPX series triplexers are designed to support high functionality with low insertion loss and high attenuation all in a compact 8 terminal SMD package measuring 2.0 × 1.25 × 0.9mm.

TDK triplexers are used in the I/O part of the antenna and have functions to separate or combine three different frequency signals during transmission and reception. They are also used in CA (carrier aggregation) circuits. The TPX series is designed for applications using a combination of GPS/Dual-band Wi-Fi/Bluetooth/ZigBee for connectivity. Look for new TPX products to support additional band combinations.
**TDK RF Component Lineup**

- **Baluns**
  A balun (balanced/unbalanced) is a two-port device used to connect a differential, balanced RF signal to a single-ended, unbalanced signal or vice versa. This device is essential in the RF signal chain because RFIC designs often use differential configurations for their internal topology since this provides improved noise immunity and better overall RF performance as well as lower cost. They are ideal for use in WLAN, Bluetooth, LTE, and GSM applications.

  TDK’s HHM1 and TFS Series baluns are available in a wide range of configurations with frequencies ranging from 673MHz to 5.95GHz and dimensions ranging from 0.65 × 0.5mm to 2.0 × 1.25mm.

- **Couplers**
  Directional couplers are used for signal monitoring and signal reporting, e.g., frequency, power level, etc., without interrupting the main system power path. TDK’s couplers utilize a Low Temperature Co-fired Ceramic (LTCC) process enabling low insertion loss and high isolation in small and compact package.

  They are ideal for use in MIMO and CA designs for signal monitoring and controlling. Applications include WLAN, LTE, GSM and other applications where signal monitoring is required, e.g., to minimize battery consumption. 3dB Wilkinson power divider and power combiner as well as 2-in-1 coupler + LPF also available.

- **Chip Antennas**
  Antenna has the function to send and receive signals in the desired frequencies. TDK’s ANT series ceramic chip antennas feature compact and low profile designs, with case sizes available as small as 1.6 × 0.8mm at a thickness of just 0.4mm. Even with their small size and thin profile, TDK antennas maintain high performance and reliability, all with the industry’s smallest “keep-out” area on the PCB.

  TDK antennas are capable of supporting multi-band applications including connectivity to mobile devices such as smartphones, tablets, wearables, IoT devices, smart meters, smart grids, HEMS, STBs, streaming devices, and game controllers.
Connectivity Applications

INDUSTRIAL / M2M
Industry 4.0, factory automation, etc.

HOME APPLIANCE
Smart Appliances, Smart TV, etc.

Game systems, Streaming Stick, STB, Wireless Speakers, Routers, Drones, Wearable, Hearable, etc.

COMSUMER ELECTRONIC / INTERNET OF THINGS
Cellular Applications

SMART PHONE / TABLET

3G, LTE, Mobile Network Connected Devices, etc.

MOBILE HOTSPOT / CELLULAR MODULES / OTHERS

Hotspot, Cell coverage booster, etc.

INFRASTRUCTURE

Microcells, BTS, Small Cell, Repeaters, Security Cameras, etc.
Cellular Applications

BLOCK DIAGRAM EXAMPLE
LTE w/ UHB and LTE-U/LAA

- **Low Band** (617-960MHz)
- **Mid Band** (1710-2170MHz)
- **RFIC**
- **High Band** (2300-2690MHz)
- **Ultra High Band** (3300-4200MHz)
- **LTE-U / LAA** (5150-5850MHz)
Cellular Applications

BLOCK DIAGRAM EXAMPLE
BASE TRANSCEIVER STATION (BTS)
## Cellular Technology Roadmap

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>ITU</strong></td>
<td>WRC 15</td>
<td>Sub-6GHz</td>
<td></td>
<td></td>
<td></td>
<td>WRC 19</td>
<td>mmWave</td>
<td></td>
<td></td>
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<tr>
<td><strong>3GPP</strong></td>
<td>Rel13</td>
<td>Rel14</td>
<td>Rel15</td>
<td>Rel16</td>
<td>Rel17</td>
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<td><strong>Service in</strong></td>
<td>LTE-A</td>
<td>LTE-A / LAA</td>
<td>4.5G / Pre 5G</td>
<td>5G</td>
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<td><strong>Frequency</strong></td>
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<tr>
<td><strong>Technology</strong></td>
<td>2CA</td>
<td>3CA</td>
<td>4CA</td>
<td>5CA</td>
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<tr>
<td><strong>Sub-6GHz NR</strong></td>
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<tr>
<td><strong>mmWave</strong></td>
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</tr>
</tbody>
</table>

**FW:** Fixed Wireless

**Korea 3GPP**

**Japan 3GPP**

**USA 3GPP**

**Europe 3GPP**

**China 3GPP**

**FW 5GTF**

**FW 3GPP**
### Cellular 5G Spectrum

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>USA 600MHz (2 × 35MHz)</th>
<th>Canada 600GHz (2 × 35MHz)</th>
<th>Japan 600MHz (2 × 35MHz)</th>
<th>Korea 600MHz (2 × 35MHz)</th>
<th>China 700MHz (2 × 30MHz)</th>
<th>EU 700MHz (2 × 30MHz)</th>
<th>Germany 700MHz (2 × 30MHz)</th>
<th>France 700MHz (2 × 30MHz)</th>
<th>Australia 700MHz (2 × 30MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1GHz</td>
<td>2.5GHz</td>
<td>n78(3.3~3.8GHz)</td>
<td>n78(3.3~4.2GHz)</td>
<td>n77(3.3~4.2GHz)</td>
<td>n77(3.3~4.2GHz)</td>
<td>n78(3.3~4.2GHz)</td>
<td>n78(3.3~4.2GHz)</td>
<td>n78(3.3~4.2GHz)</td>
<td>n77(3.3~4.2GHz)</td>
</tr>
<tr>
<td>3GHz</td>
<td>3.55~3.7GHz</td>
<td>3.55~4.2GHz</td>
<td>3.55~4.2GHz</td>
<td>3.55~3.6GHz</td>
<td>3.4~3.7GHz</td>
<td>3.4~3.8GHz</td>
<td>3.4~3.8GHz</td>
<td>3.48~3.8GHz</td>
<td>3.4~3.7GHz</td>
</tr>
<tr>
<td>4GHz</td>
<td>5.9~7.1GHz</td>
<td>n79(4.4~5GHz)</td>
<td>n79(4.4~5GHz)</td>
<td>n79(4.4~5GHz)</td>
<td>n79(4.4~5GHz)</td>
<td>n79(4.4~5GHz)</td>
<td>n79(4.4~5GHz)</td>
<td>n79(4.4~5GHz)</td>
<td>n79(4.4~5GHz)</td>
</tr>
<tr>
<td>5GHz</td>
<td>n257(26.5~29.5GHz)</td>
<td>24.5~27.5GHz</td>
<td>24.5~27.5GHz</td>
<td>24.5~27.5GHz</td>
<td>24.5~27.5GHz</td>
<td>24.5~27.5GHz</td>
<td>24.5~27.5GHz</td>
<td>24.7~25.25GHz</td>
<td>24.25~28.35GHz</td>
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<tr>
<td>24~28GHz</td>
<td>37~37.6GHz</td>
<td>37~37.6GHz</td>
<td>37~37.6GHz</td>
<td>37~37.6GHz</td>
<td>37~37.6GHz</td>
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<td>37~37.6GHz</td>
<td>37~37.6GHz</td>
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<tr>
<td>37~40GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
<td>47.2~48.2GHz</td>
</tr>
<tr>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
<td>64~71GHz</td>
</tr>
</tbody>
</table>

- **Licensed**: Represented by a solid blue box.
- **Unlicensed / Shared**: Represented by a striped pattern.
- **Existing band**: Represented by a light red pattern.
### TDK RF COMPONENTS

<table>
<thead>
<tr>
<th>NO.</th>
<th>USAGE</th>
<th>CASE SIZE</th>
<th>TDK PART NUMBER</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coupler for LB-HB (617-2700MHz)</td>
<td>1.0x0.5 t:0.32</td>
<td>TFSC10051700-2306A5X</td>
<td>Sample</td>
</tr>
<tr>
<td></td>
<td>Coupler for LB-n78 (617-3800MHz)</td>
<td>1.0x0.5 t:0.35</td>
<td>TFSC102250-2325A4</td>
<td>Sample</td>
</tr>
<tr>
<td>2</td>
<td>Coupler for n77-LAA (3.3-5.95GHz)</td>
<td>1.0x0.5 t:0.35</td>
<td>TFSC10054625-2317A2</td>
<td>MP</td>
</tr>
<tr>
<td></td>
<td>Coupler for JMB-LAA (1.42-5.95GHz)</td>
<td>1.0x0.5 t:0.45</td>
<td>HHM2952A2</td>
<td>Sample</td>
</tr>
<tr>
<td>3</td>
<td>Triplexer (LB-HB/n77-78/LAA)</td>
<td>2.5x2.0 t:0.65</td>
<td>TPX255925MT-7062B1</td>
<td>Sample</td>
</tr>
<tr>
<td>4</td>
<td>Hybrid Triplexer (LB / JMB / HB)</td>
<td>3.5x3.5 t:1.0</td>
<td>TPX352690MT-7033C1-X</td>
<td>Sample</td>
</tr>
<tr>
<td>5</td>
<td>BPF for n78 (3.3-3.8GHz)</td>
<td>2.0x1.25 t:0.65</td>
<td>DEA203550BT-2224A4-H</td>
<td>Sample</td>
</tr>
<tr>
<td></td>
<td>LPF for n78 (3.3-3.8GHz)</td>
<td>1.0x0.5 t:0.25</td>
<td>TFSB1A3550-1409A1</td>
<td>Sample</td>
</tr>
<tr>
<td></td>
<td>LPF for n78 (3.3-3.8GHz)</td>
<td>1.6x0.8 t:0.7</td>
<td>DEA163800LT-5017C1</td>
<td>MP</td>
</tr>
</tbody>
</table>

---

**BLOCK DIAGRAM EXAMPLE**

- **Low Band (617-960MHz)**
- **Mid Band (1427-2200MHz)**
- **High Band (2300-2690MHz)**
- **Sub6 n76 (3300-3800MHz)**
- **Sub6 n77 (3300-4200MHz)**
- **5GHz / LAA (5150-5925MHz)**
- **Sub6 n79 (4400-5000MHz)**

- **LTCC Products**

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# 5G NR (Sub-6GHz) Block Diagram

## TDK RF COMPONENTS

<table>
<thead>
<tr>
<th>NO.</th>
<th>USAGE</th>
<th>CASE SIZE</th>
<th>TDK PART NUMBER</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>BPF for n77 (3.3-4.2GHz)</td>
<td>2.5x2.0 t:0.65</td>
<td>DEA253750BT-2258A1</td>
<td>Sample</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0x1.25 t:0.65</td>
<td>DEA203750BT-2292A1</td>
<td>Sim</td>
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<tr>
<td></td>
<td></td>
<td>1.0x0.5 t:0.25</td>
<td>TFSB1A3750-1407A1</td>
<td>Sample</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0x0.5 t:0.25</td>
<td>TFSB1A3600-1408A1</td>
<td>Sim</td>
</tr>
<tr>
<td>7</td>
<td>BPF for n79 (4.4-5.0GHz)</td>
<td>2.0x1.25 t:0.65</td>
<td>DEA204700BT-2307A1</td>
<td>Sample</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0x0.5 t:0.25</td>
<td>TFSB1A4700-1404B1</td>
<td>Sample</td>
</tr>
<tr>
<td>8</td>
<td>BPF for LAA (6150-5925MHz)</td>
<td>1.6x0.8 t:0.65</td>
<td>DEA166538BT-2263A1-H</td>
<td>Sample</td>
</tr>
<tr>
<td>9</td>
<td>LPF (617-960MHz)</td>
<td>0.65x0.5 t:0.3</td>
<td>TFSL060960-4409B2</td>
<td>Sample</td>
</tr>
<tr>
<td>10</td>
<td>LPF (1880-2025MHz)</td>
<td>1.0x0.5 t:0.4</td>
<td>DEA102025LT-6326B1</td>
<td>MP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.65x0.5 t:0.3</td>
<td>TFSL062025-4406C1</td>
<td>Sample</td>
</tr>
<tr>
<td>11</td>
<td>LPF (617-2690MHz)</td>
<td>1.6x0.8 t:0.7</td>
<td>DEA162690LT-5064A1</td>
<td>MP</td>
</tr>
<tr>
<td>12</td>
<td>Splitter for B42/43 (3.4-3.8GHz)</td>
<td>0.65x0.5 t:0.3</td>
<td>TFSC063600-6116A1</td>
<td>Sample</td>
</tr>
<tr>
<td>13</td>
<td>Splitter (4900-5950MHz)</td>
<td>0.65x0.5 t:0.3</td>
<td>TFSC065425-6102A1</td>
<td>MP</td>
</tr>
</tbody>
</table>

## BLOCK DIAGRAM EXAMPLE

- **Low Band (617-960MHz)**
- **Mid Band (1427-2200MHz)**
- **High Band (2300-2690MHz)**
- **Sub6 n78 (3300-3800MHz)**
- **Sub6 n77 (3300-4200MHz)**
- **5GHz / LAA (5150-5925MHz)**
- **3300-4200MHz**
- **617-5925MHz**
- **to WiFi 5GHz**

**LTCC Products**

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PCB Layout Design Case Studies for RF Components
Do you know the following fact?

**PCB GND design significantly impact RF component performance…**

➢ *In this section, we will introduce example case studies and their countermeasures.*
PCB Ground Design Impact

1608 size BPF for 2.4GHz

SHAPES AND DIMENSIONS

EVALUATION BOARD

Line width be designed to match 50Ω characteristic impedance, depending on PCB material and thickness.

Dimensions in mm
Example of Via Holes Layout Impact

Simulation Models

<table>
<thead>
<tr>
<th>Center Ground Via hole</th>
<th>No Via Hole</th>
<th>TDK recommendation</th>
<th>Φ0.16mm</th>
<th>Φ0.3mm</th>
<th>Φ0.3mm x 3pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing</td>
<td>Nothing</td>
<td>Φ0.16mm</td>
<td>Φ0.3mm</td>
<td>Φ0.3mm</td>
<td></td>
</tr>
</tbody>
</table>

Simulation Results

- Existence, diameter and number of via holes affect RF component performance

Attenuation Pole
Example of Soldering Pads Layout Impact

Simulation Models

Center GND PAD layout

0.5mm  
TDK’s recommendation

0.6mm

0.7mm

0.5mm

0.6mm

0.7mm

Simulation Results

- 0.5mm
- 0.6mm
- 0.7mm

Changing distance between two pads affect RF component performance
**Countermeasure #1**

**During PCB Design Stage:**
- Follow pad layout and via holes pattern recommended in TDK datasheet as close as possible for optimal performance

- The diagram illustrates:
  - Do not change the dimension of soldering pad.
  - Do not change the via hole closest to the component as much as possible.

Datasheet details include:
- **Land**
- **Solder resist**
- **No pattern and solder resist**
- **0.3 Through-hole**
Countermeasure #2

TDK has dedicated RF FAE Team

Therefore…

- We can estimate the performance by simulation when you provide TDK with PCB information (such as DXF) before the PCB design is fixed
- We can tune & measure with matching elements when you send TDK actual PCB/product/prototype after the PCB design is fixed

TDK FAE Team welcome your request anytime
Please do not hesitate to contact us!
How to Minimize Shielding Cans Impact

Simulation Models

- Shielding Can model
  - Perfect conductor
  - Shield thickness 0.1mm

Simulation model for shielding can influence by Z direction

- DPX252170DT-5051D1

- Height Z
  - No Shielding Can
  - 3mm
  - 2mm
  - 1mm
  - 0.7mm
  - 0.5mm
  - 0.4mm
  - 0.3mm
  - 0.2mm
  - 0.1mm
Simulation Results

Z direction impact

01_1 Low Band Insertion Loss and Att

02_1 High Band Insertion Loss and Att

01_2 Low Band Insertion Loss

02_2 High Band Insertion Loss
These results indicate that…

When designing shielding cans for your product, please take into considerations the electrical characteristics of RF components
Countermeasure #1

Filter/Diplexer

Shielded Filter/Diplexer

Merit:
Unaffected by surrounding components and shielding cans

Demerit:
Performance decrease compared to similar case size (about same performance as 1 case size smaller)

Influence of Shielding Can

No shielding can
Z=3mm
Z=1mm
Z=0.7mm
Z=0.5mm
Z=0.3mm
Z=0.2mm
Z=0.1mm

Standard Component

Shielded Component

Stable
Countermeasure #2

TDK has dedicated RF FAE Team

Therefore…

- We can estimate the shielding can impact by simulation during design stage
- We can tune, measure and propose matching elements when provided with PCB/product

**TDK FAE Team welcome your request anytime**

**Please do not hesitate to contact us!**
GND impact for RF filters was introduced in the last section.

For antenna performance, GND design is much more important.

- In this section, we will introduce factors that affect chip antenna performance and design support from TDK.
Example of PCB Size Impact for Antenna

**EVALUATION BOARD**

Antenna Location: Center
Board size: L x 20 x 1 mm²
Antenna keep out area: 5 x 3 mm²

**MAX EFFICIENCY & BANDWIDTH (SIMULATION RESULTS)**

- For maximum efficiency with center mount antenna: length L = 50
Factors Affecting Antenna Performance

<table>
<thead>
<tr>
<th>PCB GND Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB GND size is one of the factors that determine the performance of antenna</td>
</tr>
<tr>
<td>There is an optimal size at each frequency</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Antenna Location of PCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Location is one of the factors that determine the performance of antenna</td>
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<tr>
<td>There is an optimal location for each PCB size</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Antenna Keep-Out Area Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna area is one of the factors that determine the performance of antenna</td>
</tr>
<tr>
<td>Bigger is better for antenna performance</td>
</tr>
</tbody>
</table>
Antenna performance will depend on each product and it is important to find the best layout in the early design stage.

Therefore,

TDK FAE team can provide antenna technical design support for your product.
Chip Antenna Simulation Support

Purpose: Recommend optimal antenna PCB layout

- Customer Action: Send PCB information to TDK
  - Customer’s PCB information
    - antenna area
    - PCB size
    - Customer’s PCB
  - Customer sends PCB information to TDK

- TDK Action: Propose optimal PCB layout by simulation
  - TDK proposes optimal PCB layout
  - Comparison of models:
    - Model-1
    - Model-2
    - Model-3
  - Graphs showing VSWR and Efficiency for each model
  - TDK returns proposal to Customer
Chip Antenna Measurement Support

Purpose 1: Recommend optimal tuning elements
Purpose 2: Provide actual antenna performance by measurements

Customer Action: Send prototype PCB/product to TDK

TDK Action: Provide performance & suitable tuning element value

Customer

Send customer's product

TDK

Customer
## Comparison of Corner-Mounting Antennas

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CERAMIC CHIP</th>
<th>PCB TRACE</th>
<th>MECHANICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Chip Antenna" /></td>
<td><img src="image2" alt="Trace Elements" /></td>
<td><img src="image3" alt="Mechanical Structure" /></td>
<td></td>
</tr>
</tbody>
</table>

### Keep-out Area
- CERAMIC CHIP: 6 × 2.5 mm²
- PCB TRACE: 10 × 2.5 mm²
- MECHANICAL: 10 × 3.5 × 2 mm³

### Example Efficiency
- CERAMIC CHIP: -2.4 dB
- PCB TRACE: -3 dB
- MECHANICAL: -2.5 dB

### Feeding Structure / Cost
- CERAMIC CHIP: Strip line / $0
- PCB TRACE: Strip line / $0
- MECHANICAL: Spring contact, C-Clip / $0.1

### Tooling Cost
- CERAMIC CHIP: N/A
- PCB TRACE: N/A
- MECHANICAL: ~ $3000+

### Design / Simulation
- CERAMIC CHIP: TDK support (EM simulator: HFSS)
- PCB TRACE: By customer
- MECHANICAL: By customer

### Tuning Method
- CERAMIC CHIP: • By changing tuning elements (caps and inductors) • No need to revise PCB
- PCB TRACE: • By changing length of trace elements • Need to revise PCB afterward
- MECHANICAL: • By changing length of trace elements • Need to revise mechanical structure afterward

### Evaluation
- CERAMIC CHIP: TDK support (in-house Starlab System)
- PCB TRACE: By customer (specialized equipment require)
- MECHANICAL: By customer (specialized equipment require)
Comparison of Center-Mounting Antennas

Customer request: Convert single band antenna to dual band antenna

- TDK Chip antenna can achieve dual band radiation without extending antenna area
Chip Antenna Cost Advantage

TDK antenna is SMD type so …

- Connector & cable: NOT necessary
- Spring connector and manual assembly cost: NOT necessary
- Antenna initial design cost: NOT necessary

TDK antenna is SMD type so it can be mounted by reflow with other components simultaneously.
Chip Antenna Design Support

**FEATURES**
- Ultra small & low profile design (1608)
- High performance / high reliability
- Capable of supporting multi-bands
- Smallest keep-out area in industry
- Linear polarization & omnidirectional

**APPLICATIONS**
- WLAN: 2.4GHz and 5GHz Wi-Fi
- PAN: Bluetooth / Bluetooth Smart / BLE / Zigbee
- GNSS: GPS / GLONASS / Galileo / Beidou
- Cellular high band LTE [B40/B41]
- Automotive: DSRC

**Product Selection**
- With expertise in platform antenna design and more than 20 years in manufacturing LTCC RF products, TDK can help you select the right component based on application, frequency, and PCB layout needs

**Design Simulation**
- With state-of-the-art software (Agilent ADS, Ansys HFSS, Solidworks) and a full engineering team, TDK can provide you with free-of-charge simulation support along with recommended PCB layout for optimal in-application performance

**Design Evaluation**
- With our fully-equipped in-house lab (Starlab by Satimo), TDK can support measurements with your product for impedance matching and radiation pattern to provide tuning work and propose matching components
Simulation & Evaluation Technology

Specification of StarLab

- Frequency Range: 0.8 – 18.0GHz
- Maximum DUT Size:
  - 40cm @ 0.9GHz - @ 2.4GHz
  - 35cm @ 5.8GHz
- Measurement Uncertainties of peak gain:
  - <±1.1dB @ 0.8GHz – 1.0GHz
  - <±0.8dB @ 1.0GHz – 6.0GHz
- Measurement Repeatability:
  - ±0.3dB (Peak Antenna Gain)
- Dynamic Range:
  - 50dB (VNA dependent)
TDK RF Product Center Website Walkthrough
RF Components and Modules

Product Lineup

- Filters
- Diplexers
- Triplexers
- Baluns
- Directional Couplers
- Chip Antennas
- Isolators / Circulators
- Modules

Tech Notes

- General Technical Information (DEA, DPX, TPX, HMM, ANT, DLF Series) [New]
- Chip Antennas Selection Guide [New]
# Chip Antenna Selection Guide

**Easy to select chip antenna for your application and antenna location**

## Commercial Grade

<table>
<thead>
<tr>
<th>Chip Antenna Mounting Position</th>
<th>Application</th>
<th>Frequency Band</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Single Band</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sub GHz Band</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5x0.8x0.4mm</td>
</tr>
</tbody>
</table>

**PCB Corner Edge Mounting Position**

- **Single Band**
  - Mount at center edge of PCB Board: (Surrounded by GND in 3 directions)
  - ANT016081CD1575MA1
  - ANT016081CS2442MA1
  - ANT165550ST-1003A1

- **Dual Band**
  - ANT016081CD1575MA1
  - ANT162442DT-200A1

- **Triple Band**
  - ANT16157ST-300A1
  - ANT16920ST-120A1

**PCB Center Edge Mounting Position**

- **Single Band**
  - ANT016515ST-1202A1
  - ANT016081CS2442MA2
  - ANT165550ST-1003A1

- **Dual Band**
  - ANT162442DT-220A1

- **Triple Band**
  - ANT025020CT1575MA1

*Please mount near the corner of PC Board for these items.*


Click part number in the diagram for more details.
Chip Antenna Design Notes & Simulation Models


Easy to design by antenna design guide and HFSS model

HFSS Black Box Model

ANSYS® HFSS™ Simulation Model
**Chip Antenna Simplified Simulation Tool**

<table>
<thead>
<tr>
<th>Product</th>
<th>ANT016008LC32442MA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (L)</td>
<td>1.80mm ±0.10mm</td>
</tr>
<tr>
<td>Width (W)</td>
<td>0.80mm</td>
</tr>
</tbody>
</table>

**Evaluation Board**

A characteristics simulation can be performed by moving the slider.

<table>
<thead>
<tr>
<th>whole PCB</th>
<th>L 50</th>
<th>A 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>off GND area</td>
<td>W 10</td>
<td>B 6</td>
</tr>
</tbody>
</table>

You can roughly check chip antenna performance and matching components value with simplified simulation tool

https://product.tdk.com/en/search/rf/rf/antenna/simulation
S-Parameter for all RF Components

Search by Characteristics

Product research results table

Product micro page

You can get S-parameter from here.

RF Components & Modules Product Center

Visit the TDK Product Center online to find the latest datasheets and production status information, as well as selection and application guides, general technical information, environmental and material datasheets, and many other technical articles and support tools.


Features / Functions:
- Datasheets & S-Parameters
- Search by Part Number
- Search by Characteristics
- Catalog
- Technical Notes
- Application Guide
- Selection Guide
- Frequently Asked Questions (FAQs)
- Sample Kits
- TDK Newsletter
- and more…
Search, compare, and review TDK RF components performance with a variety of technical support materials on TDK new enhanced web site.

But due to the sheer number of components, please contact us: wirelessinfo@us.tdk.com
RF Filters Product Line Summary

**CHIP ANTENNAS**
- LTCC-based platform antennas
- Case Size: EIA 0603 ~ EIA 1008
- Frequencies: 900MHz ~ 5.95GHz
- Termination Type: STD or LGA
- Operating Temperature: -40 ~ +85°C
- Efficiency: Up to 80%
- Omni-directional & Linear Polarization

**DIPLEXERS**
- LTCC-based LC Diplexers
- Case Size: EIA 0402 ~ EIA 1008
- Frequencies: 570MHz ~ 5.95GHz
- Termination Type: STD or LGA
- Operating Temperature: -40 ~ +85°C
- Low Insertion Loss
- Temperature-stable performance

**TRIPLEXERS**
- LTCC-based LC Triplexers
- Case Size: EIA 0805 ~ EIA 1008
- Frequencies: 450MHz ~ 5.95GHz
- Termination Type: STD or LGA
- Operating Temperature: -40 ~ +85°C
- Low Insertion Loss
- Temperature-stable performance

**BALUNS**
- LTCC and Thinfilm-based Baluns
- Case Size: EIA 0202 ~ EIA 0805
- Frequencies: 673MHz ~ 5.95GHz
- Termination Type: STD or LGA
- Operating Temperature: -40 ~ +85°C
- Available in 50:50, 75:50, 100:50, and 200:50 as well as chipset specific

**COUPLERS**
- LTCC and Thinfilm-based Couplers
- Case Size: EIA 0202 ~ EIA 0805
- Frequencies: 869MHz ~ 5.95GHz
- Termination Type: STD or LGA
- Operating Temperature: -40 ~ +85°C
- Available in 50:50, 75:50, 100:50, and 200:50 as well as chipset specific

**LOW PASS FILTERS**
- LTCC and Thinfilm-based LC Filters
- Case Size: EIA 0202 ~ EIA 1008
- Frequencies: ~ 5.95GHz
- Termination Type: STD or LGA
- Operating Temperature: -40 ~ +85°C
- Low loss and high reliability performance

**HIGH PASS FILTERS**
- LTCC-based LC Filters
- Case Size: EIA 0302 ~ EIA 0805
- Frequencies: 1710MHz ~
- Termination Type: STD or LGA
- Operating Temperature: -40 ~ +85°C
- Low loss and high reliability performance
# Chip Antenna Selection Guide

<table>
<thead>
<tr>
<th>CHIP ANTENNA MOUNTING GUIDELINE</th>
<th>APPLICATION</th>
<th>FREQUENCY BAND</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sub-GHz Band</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANT016008LCD1575MA1</td>
</tr>
<tr>
<td></td>
<td>Single Band</td>
<td>1574-1576MHz / 2400-2484MHz</td>
</tr>
<tr>
<td></td>
<td>Dual Band</td>
<td>ANT016008LCD1575MA1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1574-1576MHz / 2400-2484MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.6×0.8×0.4mm</td>
</tr>
<tr>
<td></td>
<td>Triple Band</td>
<td>ANT161575TT-3000A1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1574-1577MHz / 2400-2484MHz / 5150-5850MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.6×0.8×0.4mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANT160920ST-1204A1</td>
</tr>
<tr>
<td></td>
<td>Single Band</td>
<td>902-930MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.6×0.8×0.4mm</td>
</tr>
<tr>
<td></td>
<td>Dual Band</td>
<td>ANT162442DT-2200A1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2400-2484MHz / 5150-5850MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.6×0.8×0.4mm</td>
</tr>
<tr>
<td></td>
<td>Triple Band</td>
<td>ANT025020LCT1575MA1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1574-1577MHz / 2400-2484MHz / 5150-5850MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5×2.0×0.6mm</td>
</tr>
</tbody>
</table>

*¹: Recommended for mounting near the corner of PC Board

---

Mount at center edge of PC Board (Surround by GND in 3 directions)

Mount at corner of PC Board (Surround by GND in 1 or 2 directions)
# Circulators/Isolators Product Line Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Available Frequency Range</th>
<th>Power Handling Capability (W)</th>
<th>Isolation (dB) Min</th>
<th>Insertion Loss (dB) Max</th>
<th>Case Size (mm) L x W x Tmax</th>
<th>Product Series</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Square Type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISOLATORS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylindrical Type</td>
<td>700MHz – 2,700MHz</td>
<td>11</td>
<td>0.60 – 1.20</td>
<td>5 x 5 x 2.2</td>
<td>CU4S0506*C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2,000MHz – 2,700MHz</td>
<td>20</td>
<td>0.30 – 0.35</td>
<td>10 x 7.0</td>
<td>CU1S1055*C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,800MHz – 3,800MHz</td>
<td>18</td>
<td>0.25 – 0.50</td>
<td>11 x 7.0</td>
<td>CU1S1281*C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,500MHz – 2,700MHz</td>
<td>20</td>
<td>0.30</td>
<td>19 x 8.5</td>
<td>CU1S1941*C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700MHz – 2,200MHz</td>
<td>18</td>
<td>0.25 – 0.30</td>
<td>25 x 10.5</td>
<td>CU1S2403*C</td>
<td></td>
</tr>
<tr>
<td>CIRCULATORS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylindrical Type</td>
<td>700MHz – 2,700MHz</td>
<td>2.5</td>
<td>11 – 15</td>
<td>4 x 4 x 2.0</td>
<td>CU4S0401*T</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700MHz – 3,600MHz</td>
<td>5</td>
<td>10 – 15</td>
<td>5 x 5 x 2.2</td>
<td>CU4S0506*T</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700MHz – 2,700MHz</td>
<td>10</td>
<td>8.0 – 15</td>
<td>7 x 7 x 3.0</td>
<td>CU4S0701*T</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700MHz – 2,200MHz</td>
<td>20</td>
<td>10 – 15</td>
<td>10 x 10 x 4.2</td>
<td>CU4S1001*T</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700MHz – 2,700MHz</td>
<td>110</td>
<td>21</td>
<td>22 x 10.5</td>
<td>CU1S2252*T</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700MHz – 2,200MHz</td>
<td>150</td>
<td>21 – 25</td>
<td>25 x 9.5</td>
<td>CU1L2581*T</td>
<td></td>
</tr>
</tbody>
</table>

**TYPES**
- Cylindrical Type: 10m ~ 24m
- Square Type: 5x5mm
- Cylindrical Type: 10m ~ 24m
- Square Type: 4x4mm ~ 10x10mm
- Frequencies: 700MHz – 6GHz
- Handling Power: 5W ~ 110W
- Operating Temperature: -35 ~ +85°C
- Low Insertion Loss
- Customizable & available CW or CCW

**Power Handling Capacity**
- 2.5W ~ 150W
- 5W ~ 110W

**Insertion Loss**
- 0.25 – 0.50 dB
- 0.30 – 0.35 dB
- 0.60 – 1.10 dB
- 0.25 – 0.30 dB
- 0.60 – 0.95 dB
- 0.65 – 1.20 dB
- 0.70 – 1.20 dB
- 0.60 – 0.95 dB
- 0.25 – 0.30 dB
- 0.25 – 0.50 dB
- 0.25 – 0.50 dB
- 0.25 – 0.30 dB
- 0.25 – 0.30 dB

**Case Size**
- 5 x 5 x 2.2 mm
- 10 x 10 x 4.2 mm
- 7 x 7 x 3.0 mm
- 4 x 4 x 2.0 mm
- 5 x 5 x 2.2 mm
- 22 x 10.5 mm
- 25 x 9.5 mm

**Product Series**
- CU4S0506*C
- CU1S1055*C
- CU1S1281*C
- CU1S1941*C
- CU1S2403*C
- CU4S0401*T
- CU4S0506*T
- CU4S0701*T
- CU4S1001*T
- CU1S2252*T
- CU1L2581*T

*RF Components Seminar • TDK Developers Conference 2018*
### Flexield Product Line Summary

#### FEATURES
- Flexible & thin noise suppression sheets
- Thickness: 25µm ~ 200µm
- Permeability@1MHz: 100 ~ 220
- Frequencies: 0.5MHz to 6GHz
- Up to 1MΩ/sq min. Surface Resistivity

#### APPLICATIONS
- Suppression of noise emitted from ICs & flexible cables
- Protection of circuits from noise emission
- Improving performance in RFID reader/writers & NFC
- Integrate IC cards/tags with metal
- Reduce noise in Automotive HUD, Camera, Harness, etc.

#### IFL10M | THIN TYPE

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>THICKNESS</th>
<th>TDK PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ@1MHz &gt; 120</td>
<td>0.025 mm</td>
<td>IFL10M-025NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.050 mm</td>
<td>IFL10M-050NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.100 mm</td>
<td>IFL10M-100NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.200 mm</td>
<td>IFL10M-200ND300X200</td>
</tr>
</tbody>
</table>

#### IFL12 | HIGH PERMEABILITY

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>THICKNESS</th>
<th>TDK PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ@1MHz &gt; 180</td>
<td>0.050 mm</td>
<td>IFL12-050NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.100 mm</td>
<td>IFL12-100NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.200 mm</td>
<td>IFL12-200NB300X200</td>
</tr>
</tbody>
</table>

#### IFL16 | SUPER HIGH PERMEABILITY

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>THICKNESS</th>
<th>TDK PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ@1MHz &gt; 220</td>
<td>0.030 mm</td>
<td>IFL16-030NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.050 mm</td>
<td>IFL16-050NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.100 mm</td>
<td>IFL16-100NB300X200</td>
</tr>
</tbody>
</table>

#### IFL04 | For NFC & RFID

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>THICKNESS</th>
<th>TDK PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Loss μ'=45 &amp; μ''=1.3 @13.56MHz</td>
<td>0.050 mm</td>
<td>IFL4-050NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.100 mm</td>
<td>IFL4-100NB300X200</td>
</tr>
<tr>
<td></td>
<td>0.200 mm</td>
<td>IFL4-200ND300X200</td>
</tr>
</tbody>
</table>

#### IFL16 & IFM10M | HYBRID TYPE

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>THICKNESS</th>
<th>TDK PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ@1MHz &gt; 220</td>
<td>0.030 mm</td>
<td>IFL16-030EB300X200</td>
</tr>
<tr>
<td>w/ ALPET (30µm)</td>
<td></td>
<td>IFL16-030GB300X200</td>
</tr>
<tr>
<td>μ@1MHz &gt; 120</td>
<td>0.025 mm</td>
<td>IFM10M-025BB300X200</td>
</tr>
</tbody>
</table>

#### IFF08 | HEAT-RESISTANT TYPE

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>THICKNESS</th>
<th>TDK PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Operating Temperature 125ºC</td>
<td>0.050 mm</td>
<td>IFF08-050ND300X200</td>
</tr>
<tr>
<td></td>
<td>0.100 mm</td>
<td>IFF08-100ND300X200</td>
</tr>
</tbody>
</table>

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Product Marketing Department • 09/18 • 53
Flexield for EMC | ILF/IFM/IFF Series

Noise Suppression
- Noise suppression in the IC peripheral circuit of the main circuit board
- Noise suppression for flexible cables
- Reduce EMI level at connector
- Noise suppression for external cables

Reflected Noise Absorption
- IC, inductor capacitor, etc. generate EMI noise and is reflect by metal cover
  >> Increase noise level inside of metal cover

Flexield absorbed reflection noise

ESD Suppression
- No measures
- With Flexield

Measured waveform during the ESD application test
- In the absence of any measures
- Peak voltage 1630V

With the use of Flexield
- Peak voltage 1410V
  - Peak voltage drops by about 15%

Measurement conditions:
- IEC61000-4-2
- Level 2 (ESD voltage 8kV)
- Human body model
- Contact discharge
Flexield For NFC | IFL04 Series

**Without Magnetic Sheet**

- Metal objects interfere with magnetic flux

**With Magnetic Sheet**

- Flexield remove disturbance allow for better reception

**FEATURES**

- High permeability, low magnetic loss @13.56MHz
- Thin & Flexible: can be processed into various shape and size
- Available in sheets or rolls

**APPLICATIONS**

- For improving reception performance in NFC/RFID systems
- Integrate IC cards with metal (e.g. credit cards, gift cards, etc.)
- Integrate IC tags with metal (e.g. security access cards, etc.)
- Improve antenna reception sensitivity

**RELATIVE PERMEABILITY**

*Flexield can also be used in mobile handy readers/writers.*
Flexield Selection Guide

Pass Band Characteristics (dB)

**IFL16 | Hybrid Type**
- Magnetic + Conductive Layer

**IFM10M | Hybrid Type**
- Magnetic + Copper Layer

- **IFL12-200 | High Permeability**
- **IFL16-050 | Super High Permeability**
- **IFL12-050 | High Permeability**
- **IFL10M-050 | Thin Type**
- **IFL04-050 | For NFC & RFID**

**Power Supply System**
- **Low-Speed Transmission**
- **High-Speed Transmission**
- **RF**

<table>
<thead>
<tr>
<th>Frequency</th>
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<tbody>
<tr>
<td>KHz</td>
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<tr>
<td>10KHz</td>
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<tr>
<td>10MHz</td>
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<tr>
<td>500MHz</td>
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<td>1GHz</td>
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<td>3GHz</td>
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<td>10GHz</td>
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</table>
TDK RF Design Support & Technical Tools
RF Filters Product Line Summary

E-Books & Promotional Materials

- **General E-Books**
  - WLAN/BT
  - Cellular/LTE
  - Modules
- **Reference Design E-Books**
  - QCOM WTR 2K/3K/4K
  - QCOM WTR 5K/6K/8K/SDR855
  - MediaTek MT6K
  - Intel Smarti4/5/5S
- **Product Overview Presentations**
  - LTCC & TFS General Presentation
  - LTCC & TFS Standard Item List
  - Diplexer Selection Guide
  - Triplexer Selection Guide
  - Balun Selection Guide
  - Coupler Comparison Chart
  - Chip Antenna Overview & Services
  - Isolator/Circulator Overview
  - Connectivity (WLAN/BT)
  - Cellular (General)
  - 5G (Sub 6GHz) RF Components
  - RF Components for Automotive

Samples, Evaluation Boards, & Sample Book

Available:
- Thru Board
- Blank Test Board
- Test Board with Samples Mounted
- Bulk Samples
- Sample Book:
  - WLAN / BT
  - Cellular / LTE
  - Modules
  - Flexield
  - Chipset Specific

RF Components Product Guide

**Contents:**
- Product Line Summary / Part Number Decipher
- Series Overview for All RF Products
- Application Guide
  - Cellular / Connectivity / Automotive / Infrastructure
- Design Support Information

AVAILABLE FROM YOUR LOCAL SALES REPS!
Summary

- RF components are sensitive to GND conditions
  - Please follow our pad layout recommendation in the datasheet
  - By using shielded type products, you can disregard shielding can impact
  - You can also request technical support from our FAE team FOC

- Antenna performance is affected by GND size and antenna location
  - TDK FAE can provide technical support for antenna layout design FOC

- You can find technical support on our new enhanced web site
  - You can simulate our antenna & design the PCB layout
  - You can evaluate TDK RF component performance with s-parameter

◆ Wirelessinfo@us.tdk.com