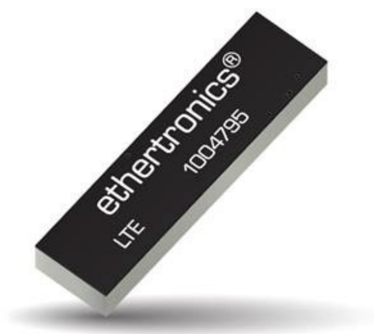
APPLICATION NOTES

AN-PT-LTE-MP-20210317

KYOCERA AVX

Universal Broadband FR4 Embedded LTE / LPWA Antenna

1004795/1004796



Applications:

Cellular Handsets
Wireless Headsets
M2M
Medical Applications

Automatic Meter Reading
Healthcare
Point of Sale
Tracking

Smart Applications
Tablets and
Notebooks Other
Wireless Devices

LTE CAT-M
Industrial Devices
Media Player
Narrow Band IoT

Octa-Band Worldwide LTE Cellular Embedded SMT Antennas

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Prestta™ Octa-Band LTE/Cellular SMT Antennas

Purpose

This document provides information for application KYOCERA AVX's Narrow Band 1004795 /1004796 standard embedded LTE Cellular antenna into wireless products. Specifications, design recommendations, board layout, packaging and manufacturing recommendations are included.
This document provides information for incorporating KYOCERA AVX's Prestta standard embedded LTE Cellular antenna into wireless products. Specifications, design recommendations, board layout, packaging and manufacturing recommendations are included.

This document is divided into two parts: a main section and appendices. The main section addresses points and issues common to all products. The appendices provide product-specific information

Overview

The Prestta LTE Product Line

The Prestta Standard Octa-Band LTE Cellular antenna, listed below, represents a new category of internal IMD antennas. KYOCERA AVX antennas utilize proprietary and patented Isolated Magnetic Dipole (IMD) technology to meet the needs of device designers for higher performance; providing greater than 55% average efficiency across a very wide band covers all LTE and Cellular bands (700MHz, 850MHz, 900MHz, 1800MHz, 1900MHz, 2100MHz, and 2700MHz). Standard, off-the-shelf, antennas lower total costs, enable quicker time to market and work with a variety of designs.

*Appendix 1 gives details instructions on (600-960 MHz) matching.

Difference between 1004795 and 1004796

The two LTE antennas 1004795 and 1004796 are using the same design and same dimensions. 1004796 is the mirrored antenna of 1004795, which should have same performance as 1004795.

Using the mirrored version 1004796 or the original 1004795 will be defined depending on the preferred location for the antenna feed on your board.

Product Selection Guide

Antenna PN	Application	Antenna PN Application Type Typical Deliverable	Typical Deliverable Size
1004795/1004796	• 600 MHz • 700 MHz • 850, 900 MHz • 1800, 1900 MHz • 2100 MHz • 2600 MHz	• Partial Ground • Flexible antenna placement	• SMT mountable antenna assembly • 36.0 x 9.0 x 3.2 mm
1004795-01/1004796-01	• 700 MHz • 850, 900 MHz • 1800, 1900 MHz • 2100 MHz • 2600 MHz	• Demo Board	• Antenna Assembly on PCB board • 45 x 125 mm

Additional antennas are under development, please see KYOCERA AVX'ss Website, or ask Ethertronic's sales person about additional products to meet your needs.

Figure 1

IMD Technology Advantages

Real-World Performance and Implementation

Other antennas may contain simple PIFA or monopole designs that interact with their surroundings, complicating layout or changing performance with user position. KYOCERA AVX's antennas utilize patented IMD technology to deliver a unique size and performance combination.

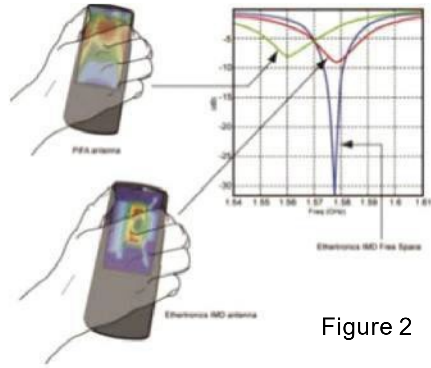


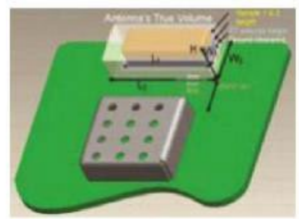
Figure 2

Stays in Tune

IMD technology provides superior RF field containment, so antennas resist de-tuning to provide a robust radio link regardless of the usage position. Other antennas may experience substantial frequency shifts and lowered performance, when held by users or placed next tot he head.

Smallest Effective Size

Unlike antennas using other technologies, IMD antennas require minimal ground clearance and keep-out areas for surrounding components. This can lead to a smaller "effective" size when all factors are taken into account. In addition to a ultra-thin, end-user device designs



IMD Technology: How it works

IMD technology uses confinement of the electrical field to create the antenna's mode. The strongly confined antenna mode reduces its coupling to the surrounding environment. The diagram to the right shows the electrical field created on the PCB ground plane for an KYOCERA AVX IMD antenna and a PIFA (Planar Inverted F Antenna). Red areas indicate the highest current while blue areas signify the lowest. As demonstrated, currents from the IMD design are highly localized, while high currents are observed all the way over to the ground plane edge on the PIFA.

KYOCERA AVX's IMD antennas are ideally suited for wireless data devices, where performance, size and system costs are critical. The surface mount design and compact size are suited for high volume applications. Standard antenna profiles are available or can be configured to suit individual OEM requirements.

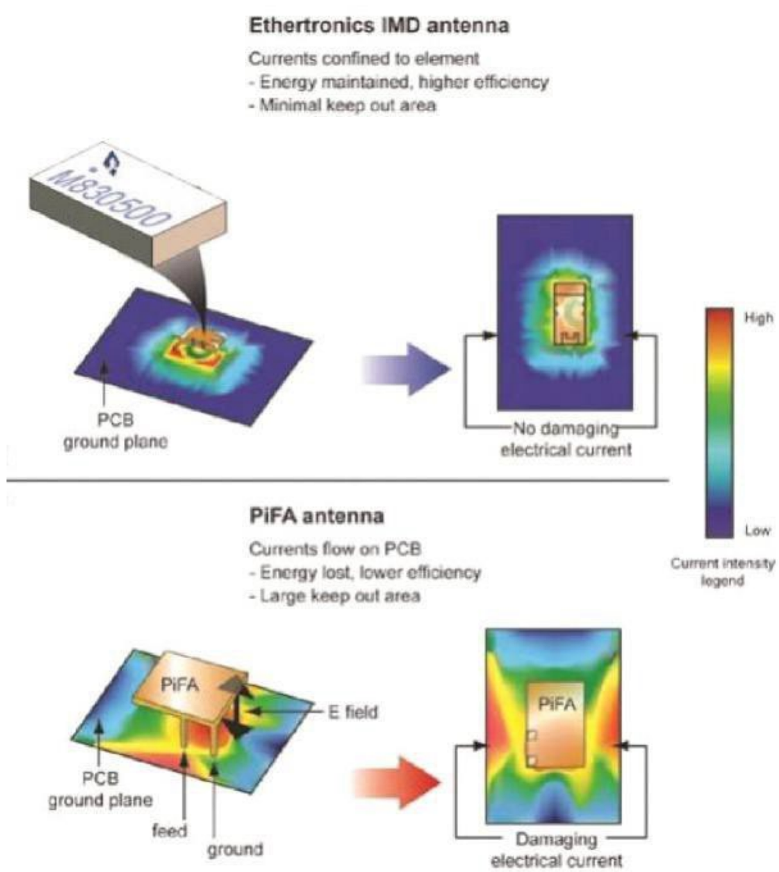


Figure 5

Prestta Standard 1004795/1004796 LTE Cellular Antenna Features and Benefits Summary

Feature	Advantage
LTE Cellular	• Eliminates external antennas
High Performance Embedded Solution	• Greater than 55% average efficiency across all brands
Extensive design collateral and apps support	• Speed's development time
Standard "Off-the-Shelf" Product	• Speed's development time and reduces costs since reduces NRE and custom development time
Smaller Form Factor & Ground Clearance Requirements	• Can be used in a variety of custom form factors and applications

Design Guidelines

Introduction

The Universal Broadband FR4 Embedded LTE antenna can be designed into many wireless product types. The following sections explain KYOCERA AVX's recommended layouts to help the designer integrate the antennas into a product with optimum performance.

Electrical Specifications

Typical Characteristics Measurement taken with a matching circuit on a 45 x 125 mm ground plane.

LTE Cellular Antenna (MHz)	600-698	700-746	746-787	824-894	880-960	1710-1880	1850-1990	1920-2170	2500-2700
Peak Gain	Appendix 1 600MHz Tuning	0.5dBi	1.1dBi	1.6dBi	1.6dBi	2.6dBi	2.1dBi	2.8dBi	1.8dBi
Average Efficiency		57.6%	63.6%	67.7%	63.3%	55.0%	51.6%	55.5%	52.8%
VSWR Match		<2.5:1							<3.0:1
Feed Point Impedance		50 ohms unbalanced							
Power Handling		2-Watt cw							
Polarization		Linear							

Mechanical Specifications

Maximum Dimensions	36.0 x 9.0 x 3.2
Mechanical Mounting	Antenna Assembly is SMT attached to main PCB.
RF Mounting	RF and Ground feed pads are SMT attached to main PCB.

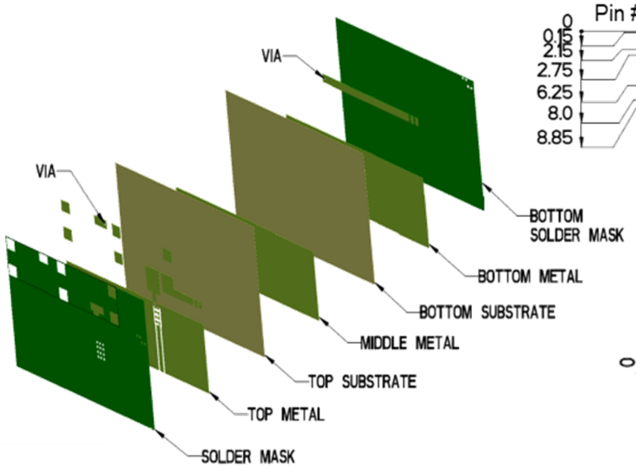
Antenna Layout

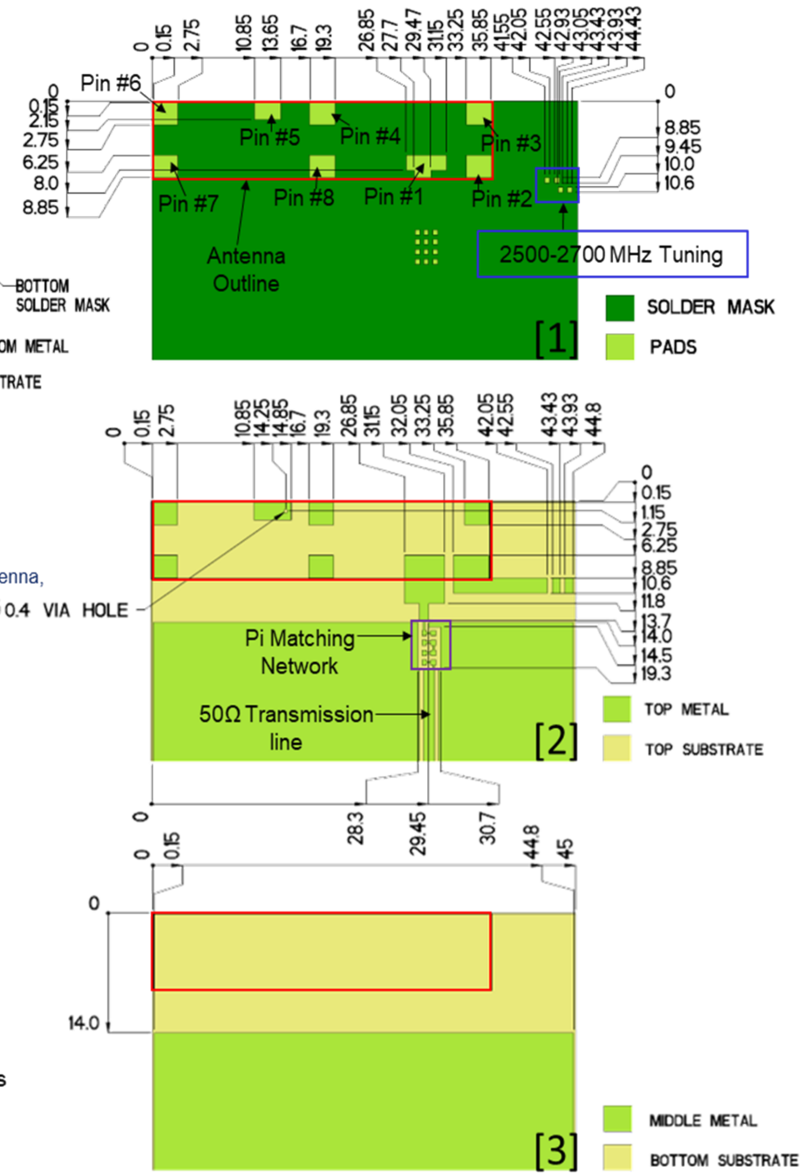
Figure 1 below shows the Broadband FR4 Embedded LTE antenna layout for 1004795

Figure 2 below shows the Broadband FR4 Embedded LTE antenna layout for 1004796

- **Maximum Dimensions:** 36.0 x 9.0 x 3.2 mm
- **RF Mounting:** RF Feed and Ground pads are SMT attached to the main PCB
- **Mechanical Mounting:** Antenna Assembly is SMT attached to the main PCB

Antenna Layout for 1004795



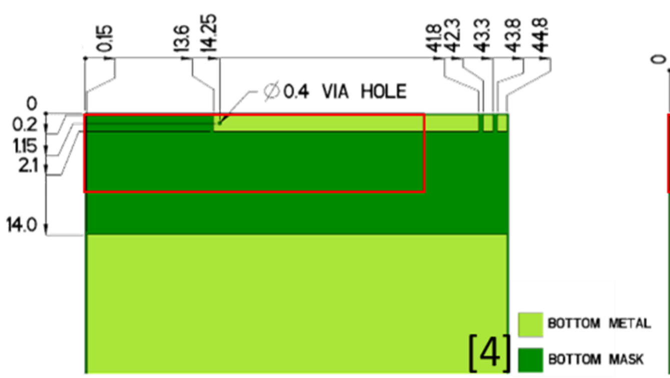


- Additional VIAS: Diam. 0.4mm to be placed around antenna, (no vias on transmission lines).
- Via holes must be covered by solder mask

Pin Descriptions

Pin#	Description
1	Feed
2	Antenna Tuning
3	Dummy Pad
4	Dummy Pad
5	Antenna Tuning
6	Dummy Pad
7	Dummy Pad
8	Dummy Pad

Default Pi Matching Network values with instructions can be found under Antenna Matching Network.



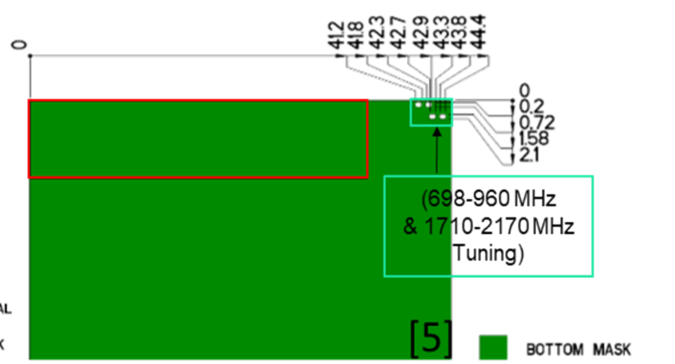
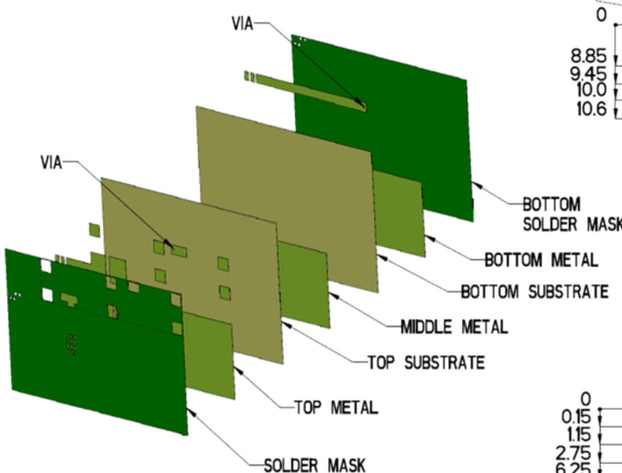
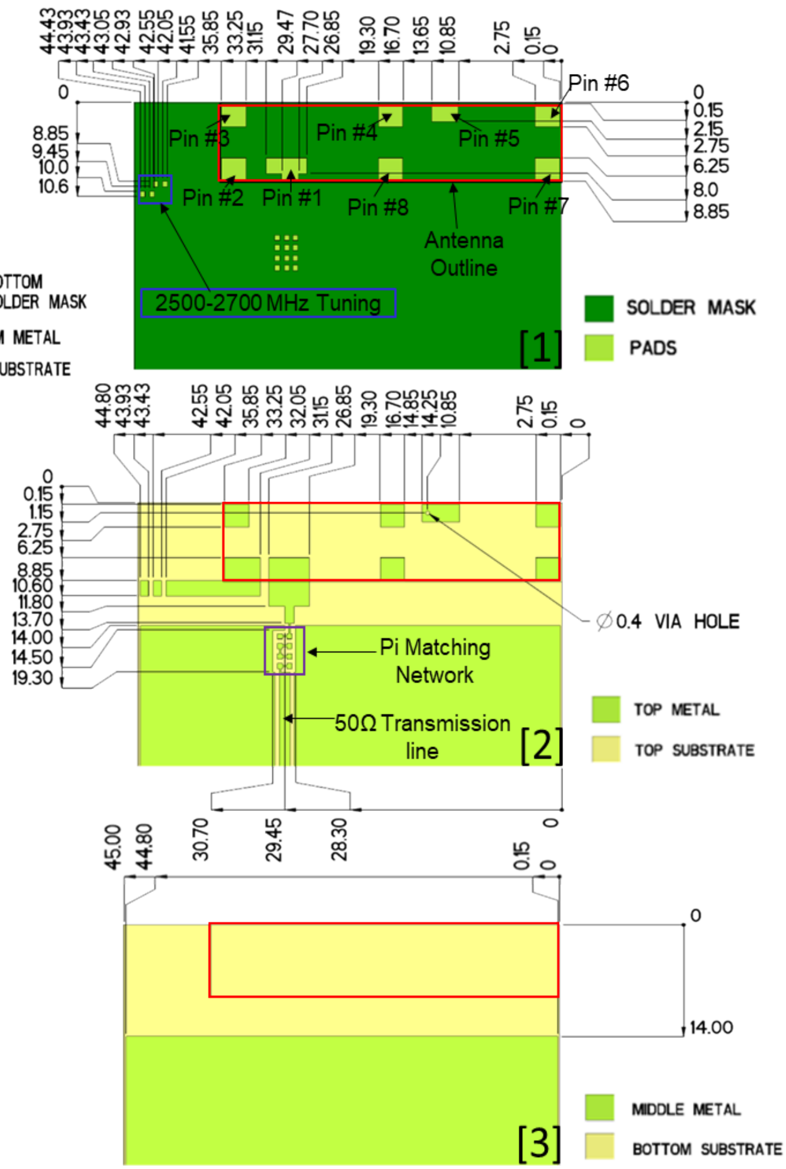


Figure 1: Antenna Layout for 1004795

Antenna Layout for 1004796



- Additional VIAS: Diam. 0.4mm to be placed around antenna, (no vias on transmission lines).
- Via holes must be covered by solder mask



Pin Descriptions

Pin#	Description
1	Feed
2	Antenna Tuning
3	Dummy Pad
4	Dummy Pad
5	Antenna Tuning
6	Dummy Pad
7	Dummy Pad
8	Dummy Pad

*1004795 uses the same layout but mirrored.

Default Pi Matching Network values with instructions can be found under Antenna Matching Network.

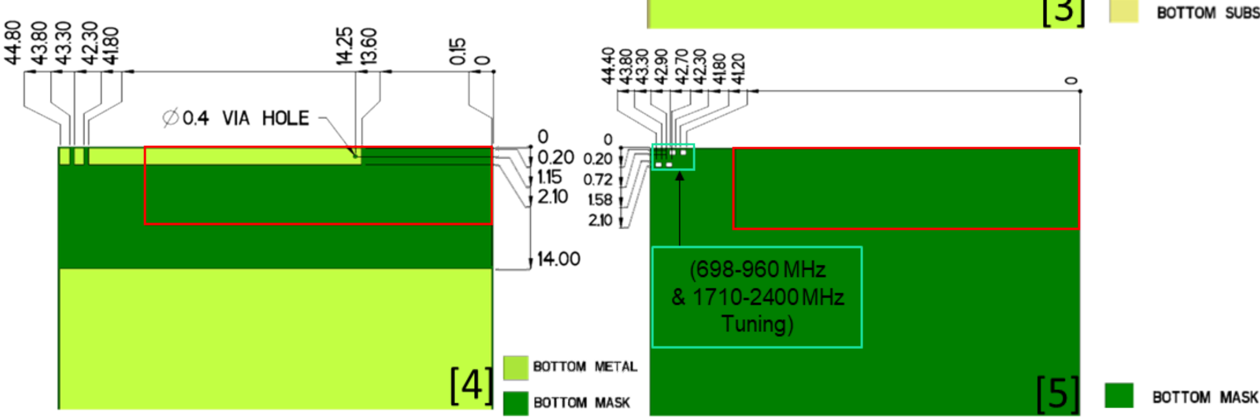


Figure 2: Antenna Layout for 1004796

Antenna Footprint

The Universal Broadband FR4 Embedded LTE Antenna can be designed into many wireless product types. The following sections explain KYOCERA AVX's recommended layouts to help the designer integrate the antennas into a product with optimum performance.

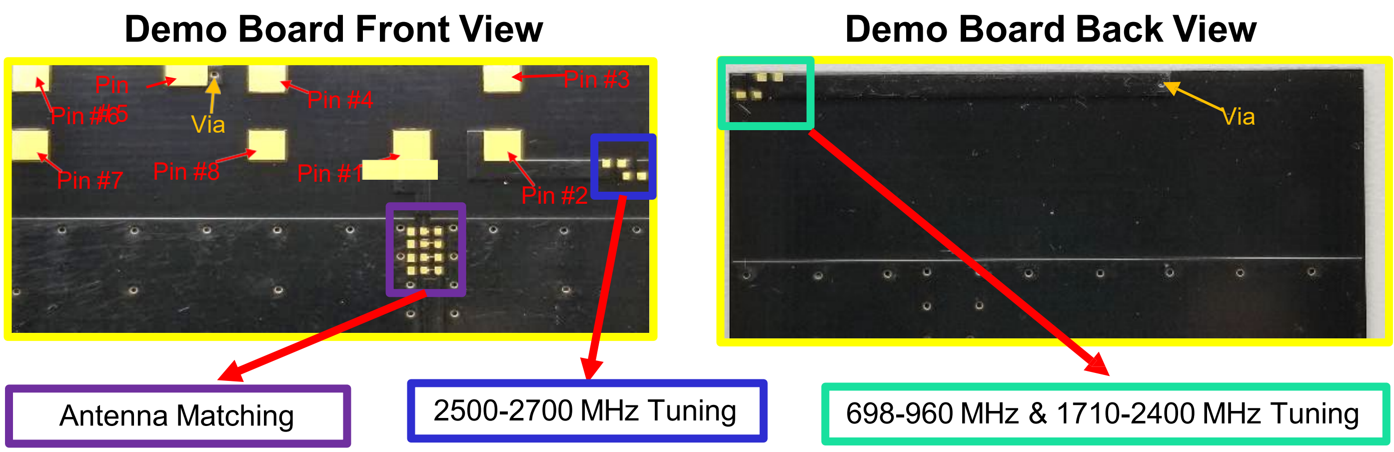
Antenna Location

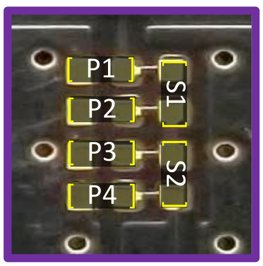
Figure 3 shows 1004795 landing location on Demo Board: Front/Back view.

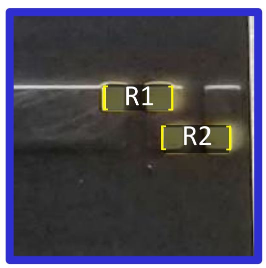
Figure 3: Demo Board 1004795 (Front & back view)

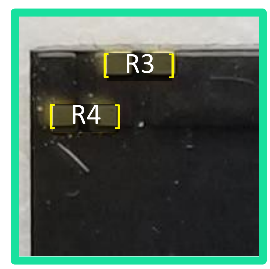
Matching Networks

Figure 4 below shows the Matching Circuit. The default Components used on ET demo board are listed below:

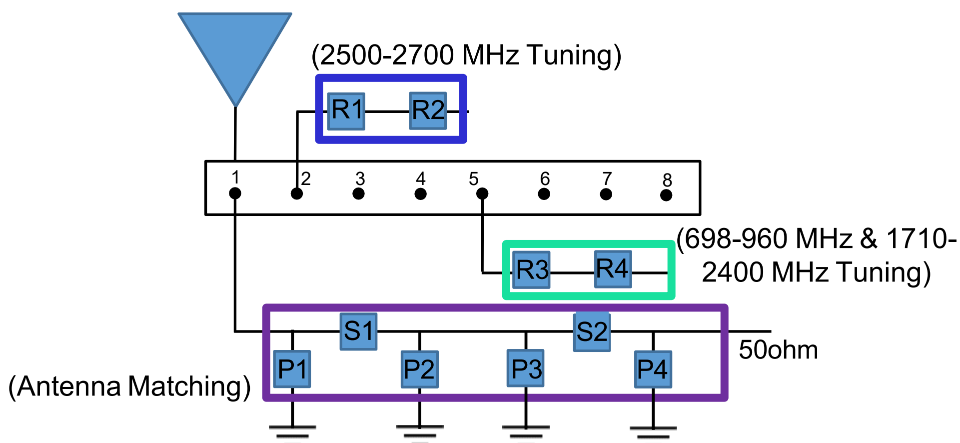








(Antenna Matching):
pads are directly inline with
the antenna feed trace.



Pin Descriptions

Pin#	Description
1	Feed
2	Antenna Tuning
3	Dummy Pad
4	Dummy Pad
5	Antenna Tuning
6	Dummy Pad
7	Dummy Pad
8	Dummy Pad

	P1	S1	P2	P3	S2	P4	R1	R2	R3-R4
Default Matching	8.2nH	4.7pF	0.3pF	DNI	0 Ohm	0.5pF	0 Ohm	DNI	0 Ohm
Tolerance	± 0.1nH	± 0.05pF	± 0.05pF	N/A		± 0.05pF		N/A	

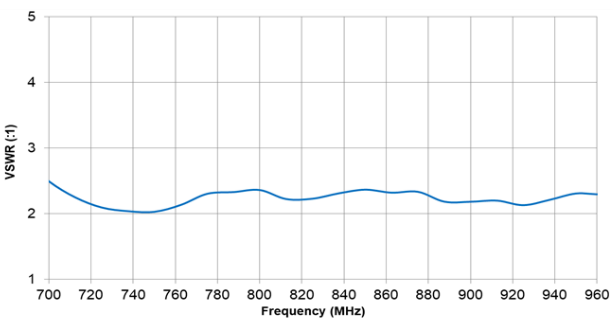
Figure 4: Antenna Matching Circuit

Measured Data

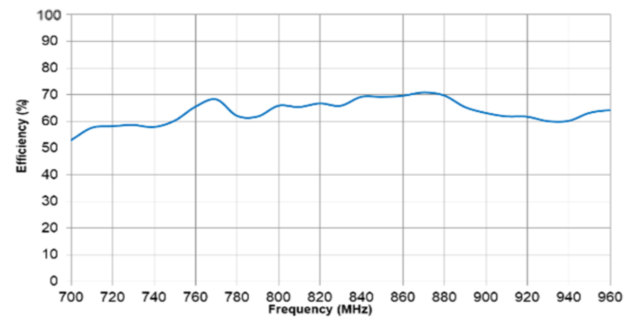
VSWR and Efficiency

Below are the typical performances using KYOCERA AVX standard demo-board 1004795-01.
Performances will be similar to the 1004796-01

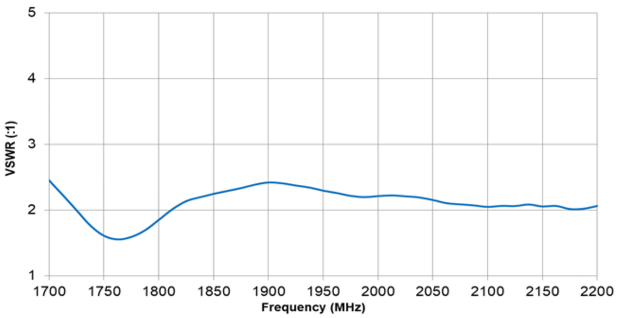
Low Band VSWR



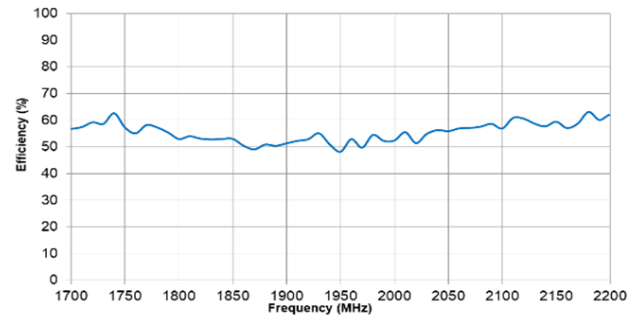
Low Band Efficiency



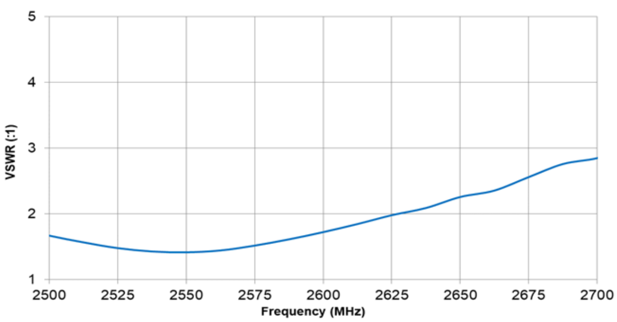
High Band VSWR



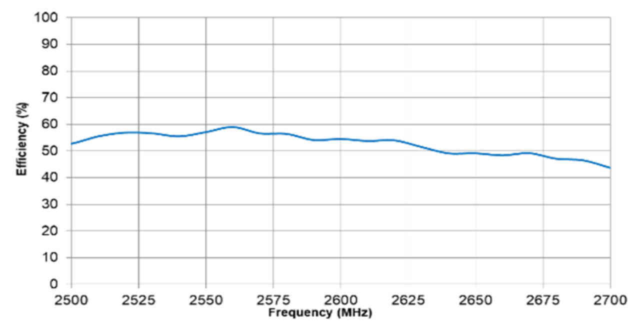
High Band Efficiency



High High Band VSWR



High High Band Efficiency



Radiation Patterns

Figure 5 represents the test setup using KYOCERA AVX standard demo-board 1004795-01.
Performances will be similar to the 1004796-01

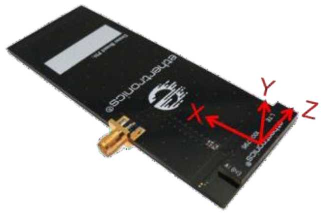
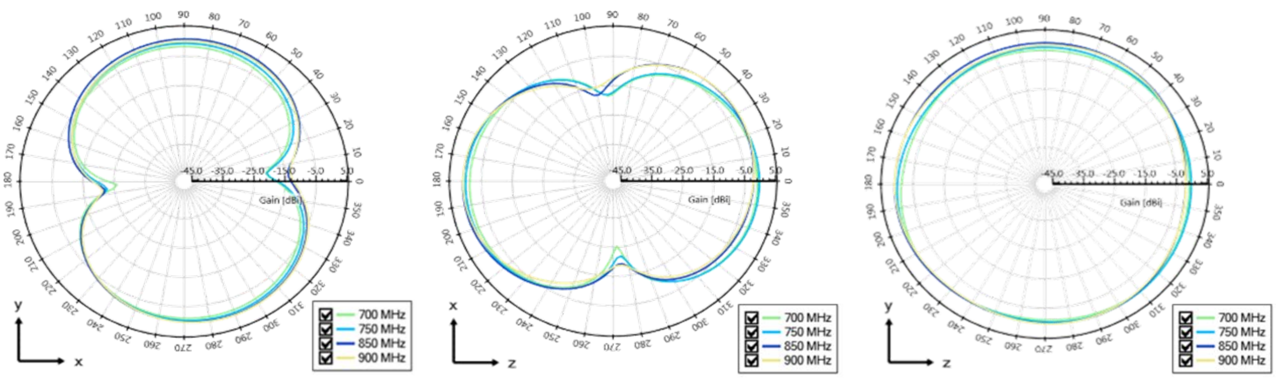
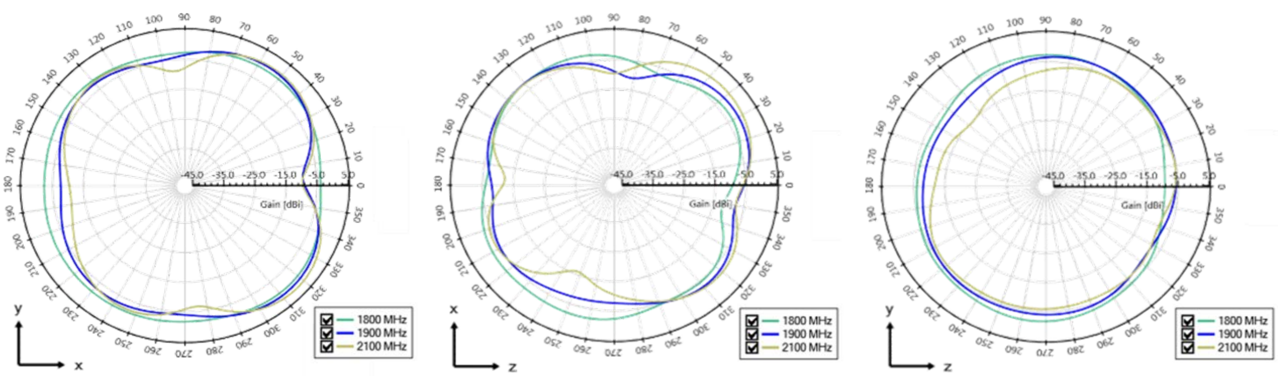


Figure 5: Test Setup (orientation)

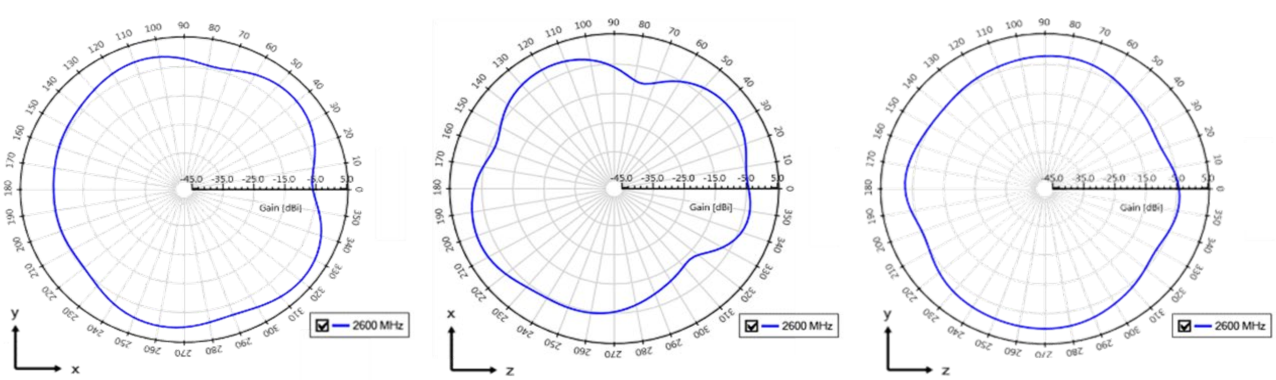
Low Band measured at 700, 700, 750, 850, 900 MHz



High Band measured at 1800, 1900, 2100 MHz



High High Band measured at 2600 MHz



Antenna Tuning Guidelines

All tuning is done through the PCB layout or matching circuit value. There are three ways to tune the antenna using the PCB layout:

- Major tuning through the tuning pad printed on the PCB
- Minor tuning through the matching network
- Change of the antenna location and varying board size

Major Tuning Through the Tuning Pad Printed on the PCB

A common effect of shield cans, housing and other close by components on the antenna performances is frequency shift. To offset the detuning effect, the PCB includes printed Tuning Pads. The low band tuning pads mainly control the 2nd frequency mode of low band and high band tuning pads impact the 2nd frequency mode of high band. The general control rule is that the larger number of tuning pads are connected, the lower the frequency is shifted.
Figure 6 represents the tuning pads on the back of the antenna footprints.
Table 1 defines the (698-960 MHz & 1710-2400MHz) tuning configurations
Table 2 defines the High band (2500-2700 MHz) tunings configurations
Figure 7 plots the return loss variations based on the different tuning configurations

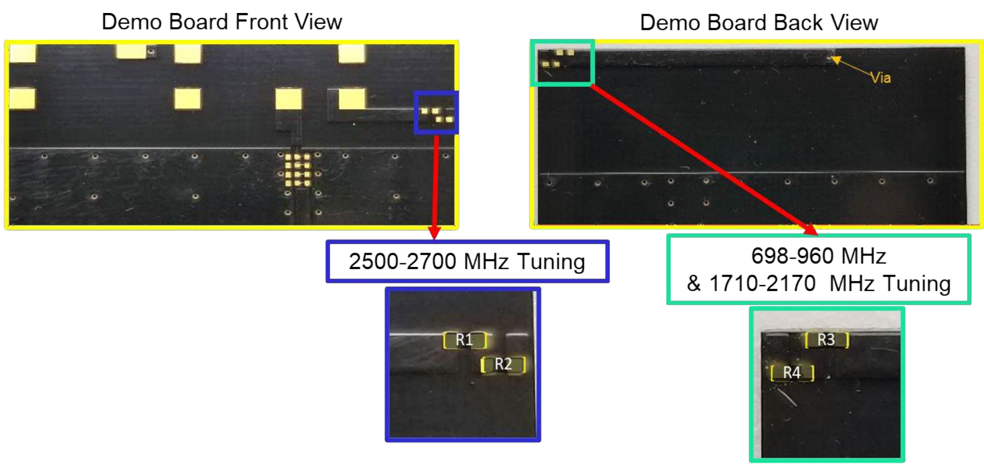


Figure 6: Tunings pads on the front and back of the antenna footprints

Mode	T1	T2		T3	
*R = 0 Ohm PADS	Connect: R3 & R4	Remove: R4		Remove: R3 & R4	
Outcome: (Ref: Baseline)	BASELINE	(698-960 MHz) ~20 MHz shift high	(1710-2400 MHz) ~20 MHz shift high	(698-960 MHz) ~30 MHz shift high	(1710-2400 MHz) ~35 MHz shift high

Table 1: (698-960 MHz & 1710-2400MHz) Tuning Pad Configurations

Mode	T4	T5	T6
*R = 0 Ohm PADS	Connect: R1	Remove: R1 & R2	Remove: R1, R2
Outcome: (Ref: Baseline)	BASELINE	(2500-2700 MHz) ~60 MHz shift low	(2500-2700 MHz) ~70 MHz shift high

Table 2: (2500-2700 MHz) Tuning Pad Configurations

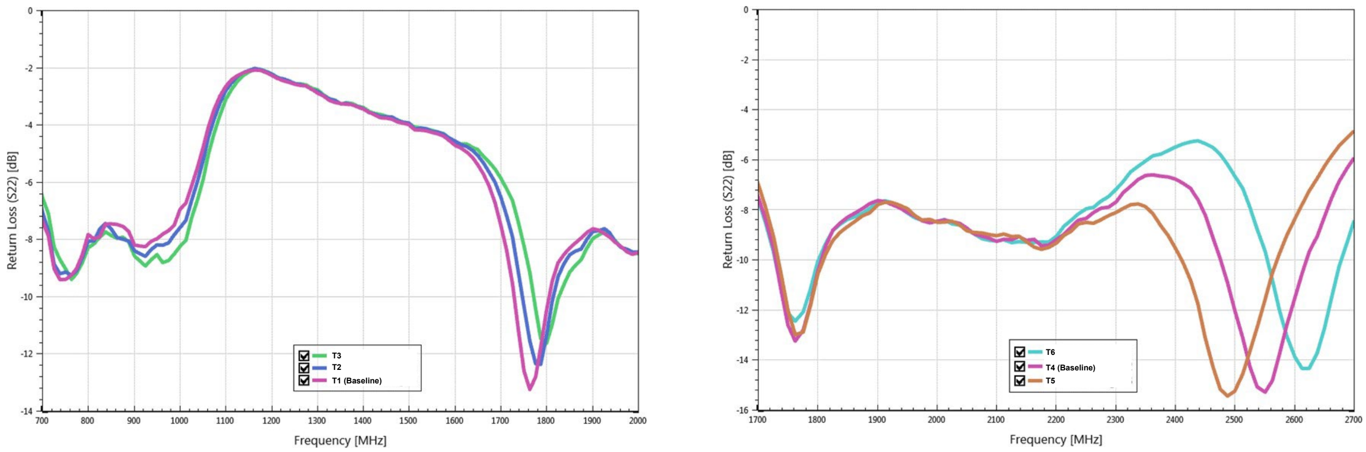


Figure 7: Return Loss plots of Major Tuning Configurations

Minor tuning through the matching network

Performance can be also improved by tuning the matching circuit. In general, low band resonance is mainly affected by P1 and S1, while high band resonance is affected by P2 and P4. By adjusting the value of matching components, it is possible to control slight resonance shifts and optimize coupling between neighboring resonances. Optimum matching values may vary with different board transmission line designs and antenna working environments. The following page shows the Return Loss variation with different matching values of each component using KYOCERA AVX 125mm x 45mm demo board 1004795-01 or 1004796-01. Each baseline matching value is adjusted one value higher and one value lower to show the impact on performance within the demo board.

Figure 8 represents the matching circuit on the front of the antenna footprints.
Figure 9 and 10 plots the return loss variations based on the different matching circuit values

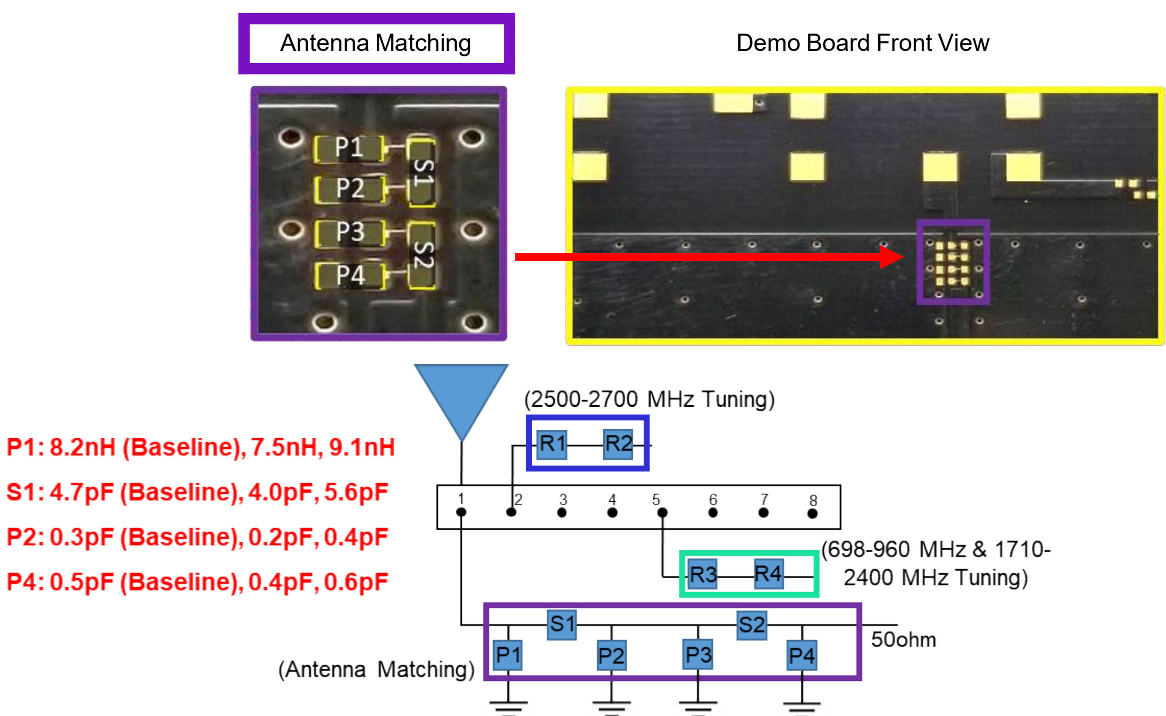


Figure 8: Matching circuit on the front of the antenna footprints

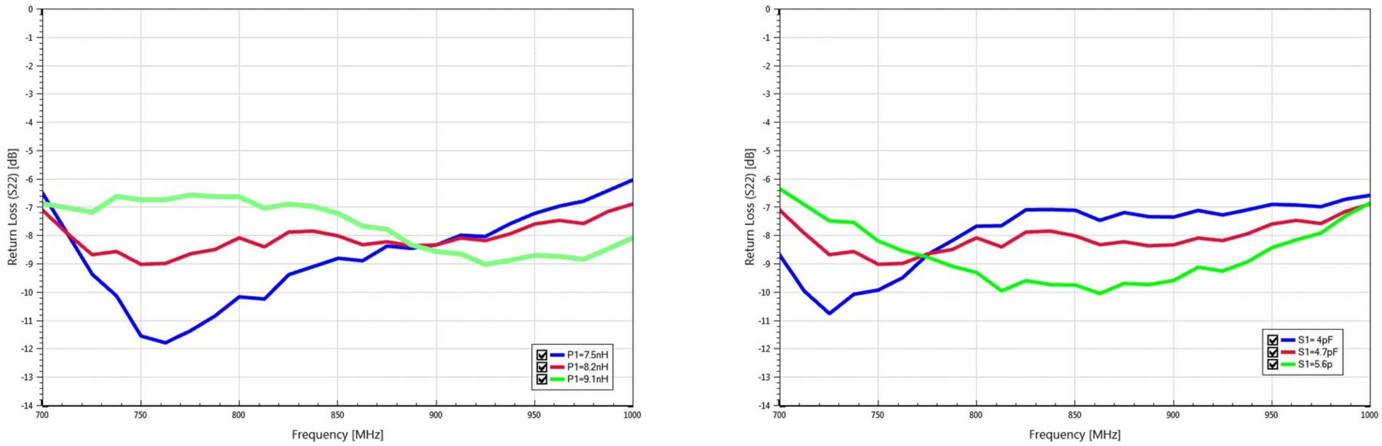


Figure 9: Return Loss plots Matching circuit antenna guidelines (P1 and S1)

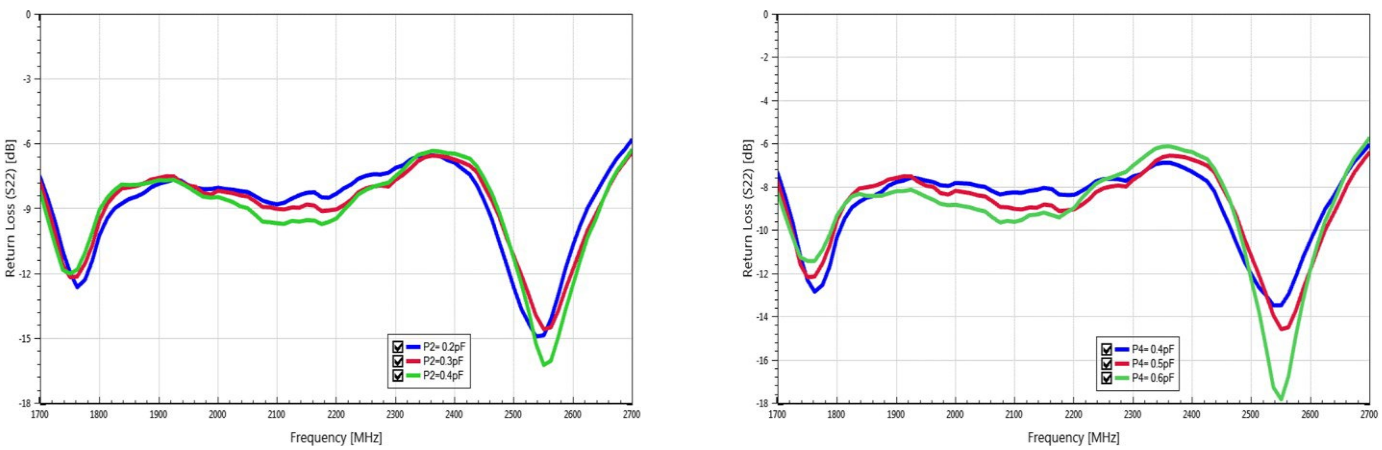


Figure 10: Return Loss plots Matching circuit antenna guidelines (P2 and P4)

Change of Antenna Location and Variation in Board Size

The board size and antenna location are the most important factor for antenna performance. The ideal PCB size is 125x45mm. In general, the smaller the board size, the lower the low band performance will be. Nevertheless, antenna performance can be improved by modifying the tuning pad and optimizing the matching components accordingly. Here are some studies to help identify the best antenna location in different board sizes and shapes configuration.

Study 1: Antenna performance variation using different PCB length.
The optimum PCB length is 140mm, this is especially true for the low band performances. Antenna performances may degrade if the PCB is shorter or longer. Using a shorter length PCB from recommended reduces low band bandwidth and high bandwidth will become narrow if the PCB length is too long. Recommended PCB length range is from 120mm to 160mm.

Study 2: Antenna performance variation with different PCB widths on different sides of the board. Antenna performance may degrade if additional ground is added on either side of the board. Adding ground on the left-side impacts the low band performance while extra ground on the right-side impacts the high band. Lengths tested range from baseline width of 45mm to 90mm total width on demo board. Board tested with extensions on both left and right side of the demo board.

Study 3: Antenna performance variation based on antenna location on large PCB. If both width and length of the PCB exceed 130mm, the preferred antenna location is changed to the right corner of the PCB.

Study 1: Antenna performance variation using different PCB lengths

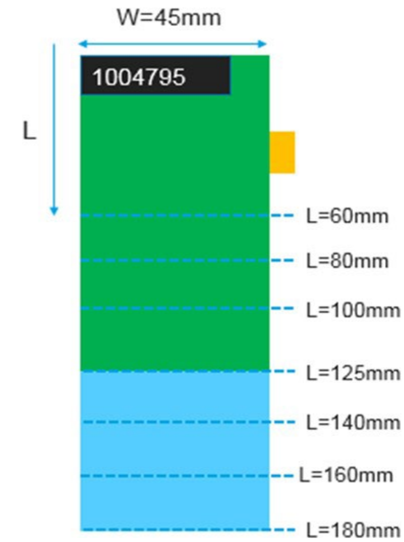


Figure 11: Study 1 Board length test setup

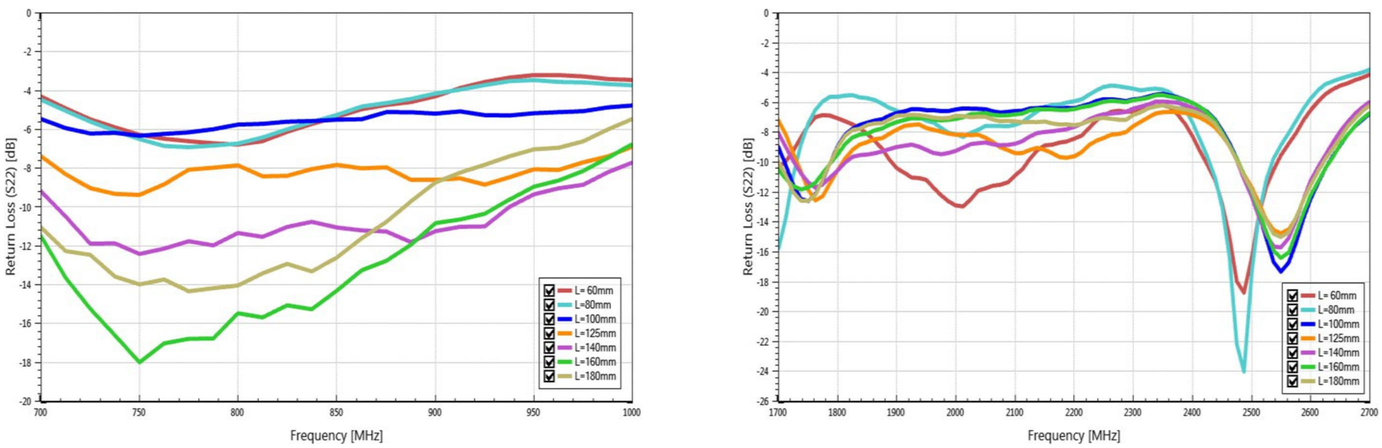


Figure 12: Return Loss plots Study 1 (700-100MHz, 1700-2700MHz)

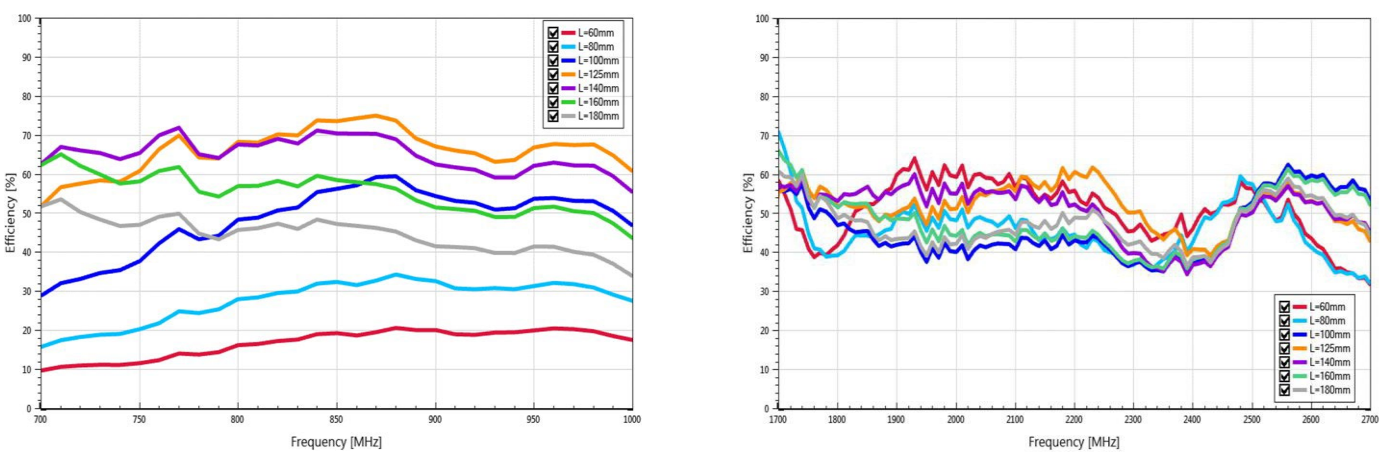


Figure 13: Efficiency plots Study 1 (700-100MHz, 1700-2700MHz)

Study 2: Antenna performance variation using different PCB widths

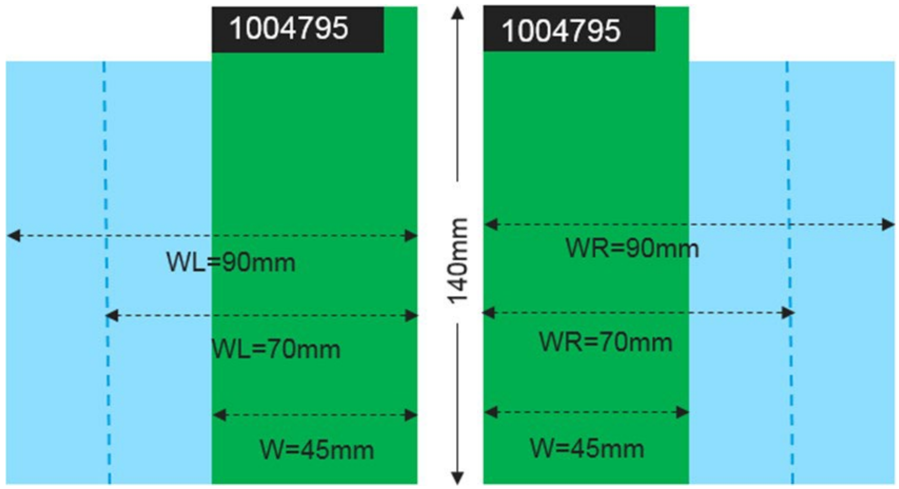


Figure 14: Study 2 Board width test setup

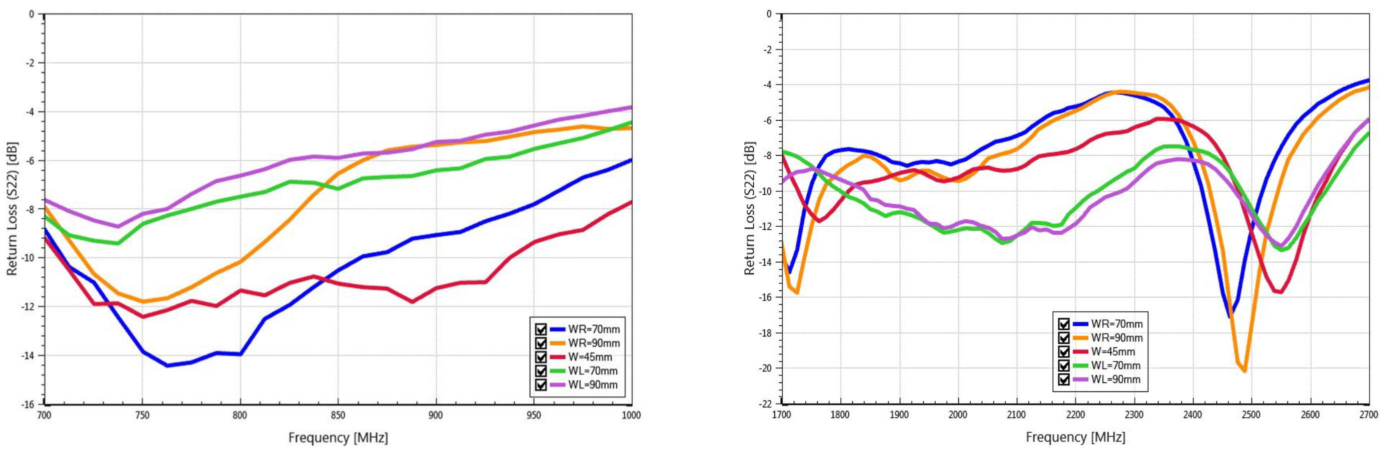


Figure 15: Return Loss plots Study 2 (700-100MHz, 1700-2700MHz)

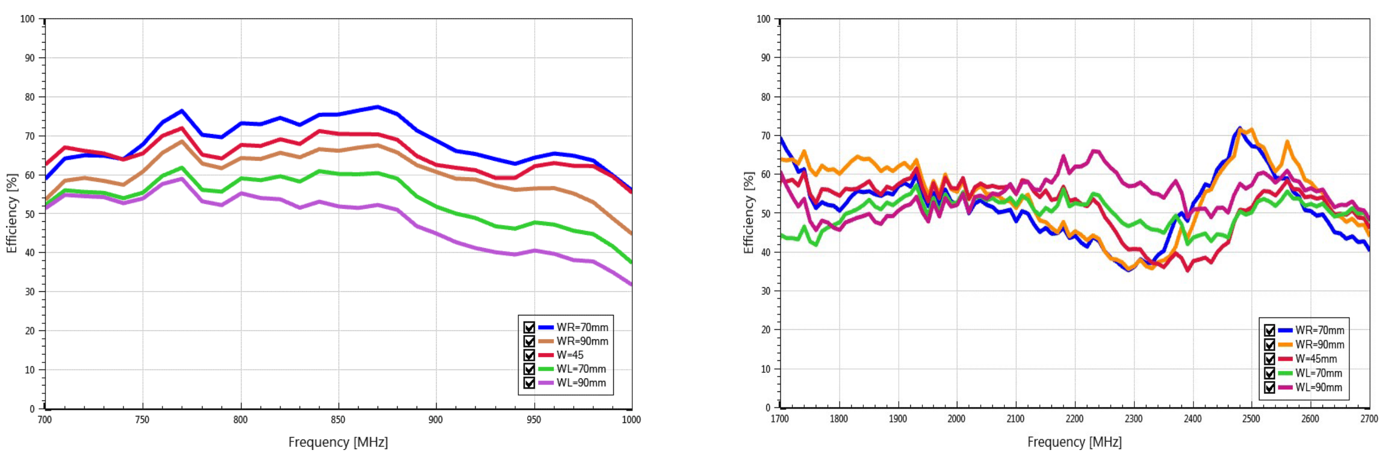


Figure 16: Efficiency plots Study 2 (700-100MHz, 1700-2700MHz)

Study 3: Antenna performance variation using 135x140 mm PCB

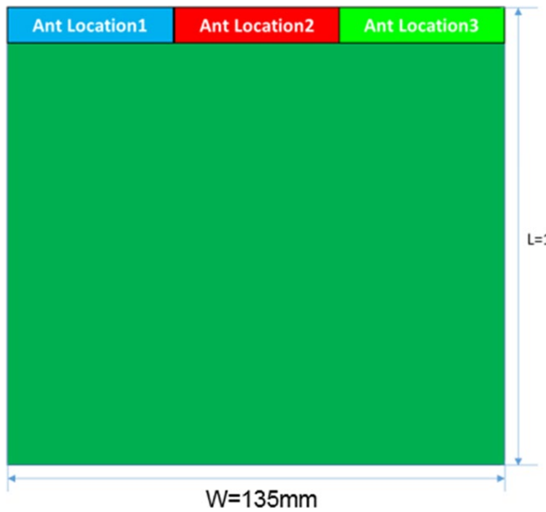
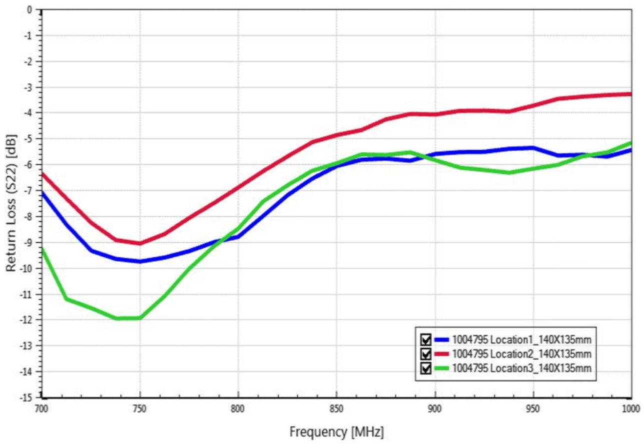


Figure 17: Study 3 140x135 mm PCB test setup



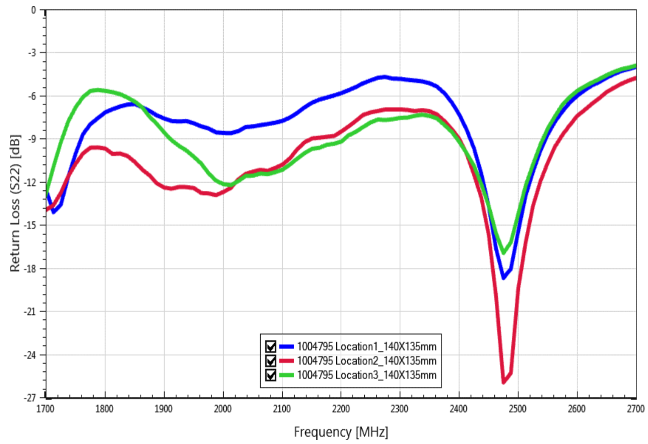
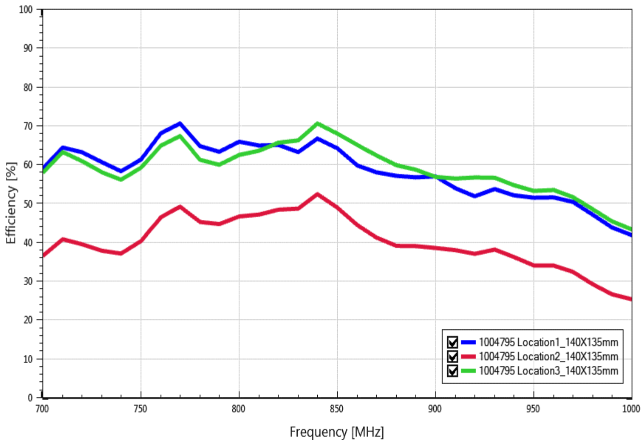


Figure 18: Return Loss plots Study 3 (700-100MHz, 1700-2700MHz)



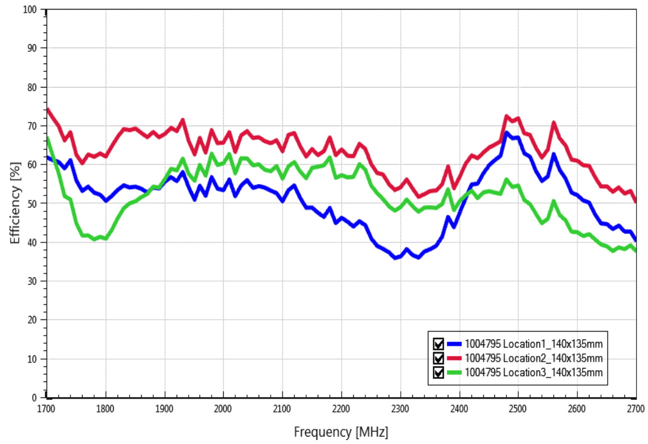


Figure 19: Efficiency plots Study 3 (700-100MHz, 1700-2700MHz)

Appendix 1 600MHz Tuning

The 1004795 and 1004796 can be tuned via matching circuit for low band coverage extending down to 600MHz. Additional bandwidth coverage in low band is achieved without modifying antenna pattern or board layout.

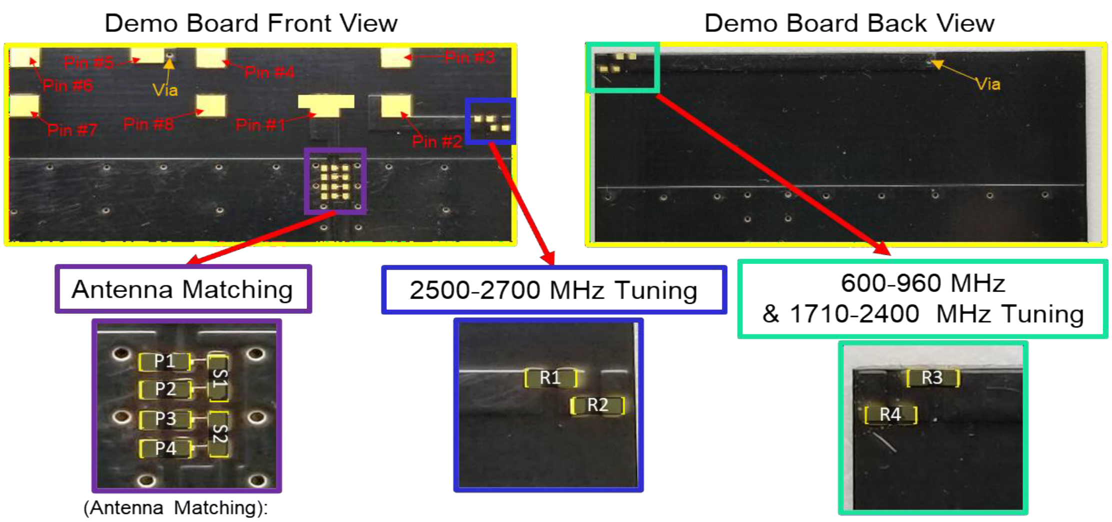
Electrical Specifications

Typical Characteristics Measurement taken with a matching circuit on a 45 x 125 mm ground plane.

LTE Cellular Antenna (MHz)	600-698	698-960	1710-2400	2500-2700
Peak Gain	1.5dBi	1.2dBi	2.4dBi	0.9dBi
Average Efficiency	61%	55%	52%	48%
VSWR Match	<5.5:1	<3.7:1	<2.5:1	<3.0:1
Feed Point Impedance	50 ohms unbalanced			
Power Handling	2-Watt cw			
Polarization	Linear			

Matching Networks

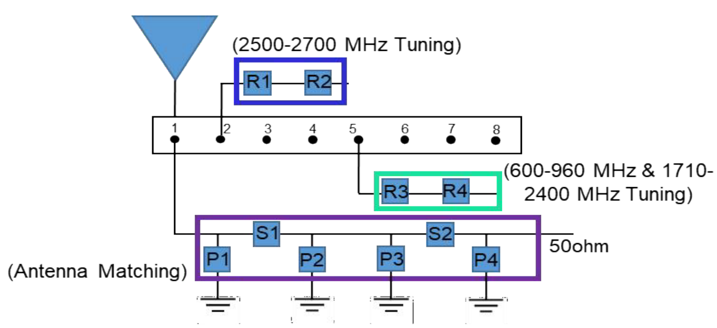
Figure 20 below shows Matching Circuit values to increase low band bandwidth to cover 600MHz.



(Antenna Matching):
pads are directly inline with
the antenna feed trace.

Pin Descriptions

Pin#	Description
1	Feed
2	Antenna Tuning
3	Dummy Pad
4	Dummy Pad
5	Antenna Tuning
6	Dummy Pad
7	Dummy Pad
8	Dummy Pad



	P1	S1	P2	P3	S2	P4	R1	R2	R3-R4
Default Matching	10nH	3.3pF	DNI	DNI	0 Ohm	DNI	0 Ohm	DNI	0 Ohm
Tolerance	± 0.1nH	± 0.1pF	N/A	N/A		N/A		N/A	

Figure 20: Appendix 1 Matching Circuit

Appendix 1 Major tuning

The 1004795 and 1004796 can be tuned via matching circuit for low band coverage extending down to 600MHz. Additional bandwidth coverage in low band is achieved without modifying antenna pattern or board layout.

Major Tuning Through the Tuning Pad Printed on the PCB

A common effect of shield cans, housing and other close by components on the antenna performances is frequency shift. To offset the detuning effect, the PCB includes printed Tuning Pad. The low band tuning pads mainly control the 2nd frequency mode of low band and high band tuning pads impact the 2nd frequency mode of high band. The general control rule is that the larger number of tuning pads are connected, the lower the is frequency shifted.
Figure 21 represents the tuning pads on the back of the antenna footprints.
Table 3 defines the (600-960 MHz & 1710-2400MHz) tuning configurations
Table 4 defines the High band (2500-2700 MHz) tunings configurations

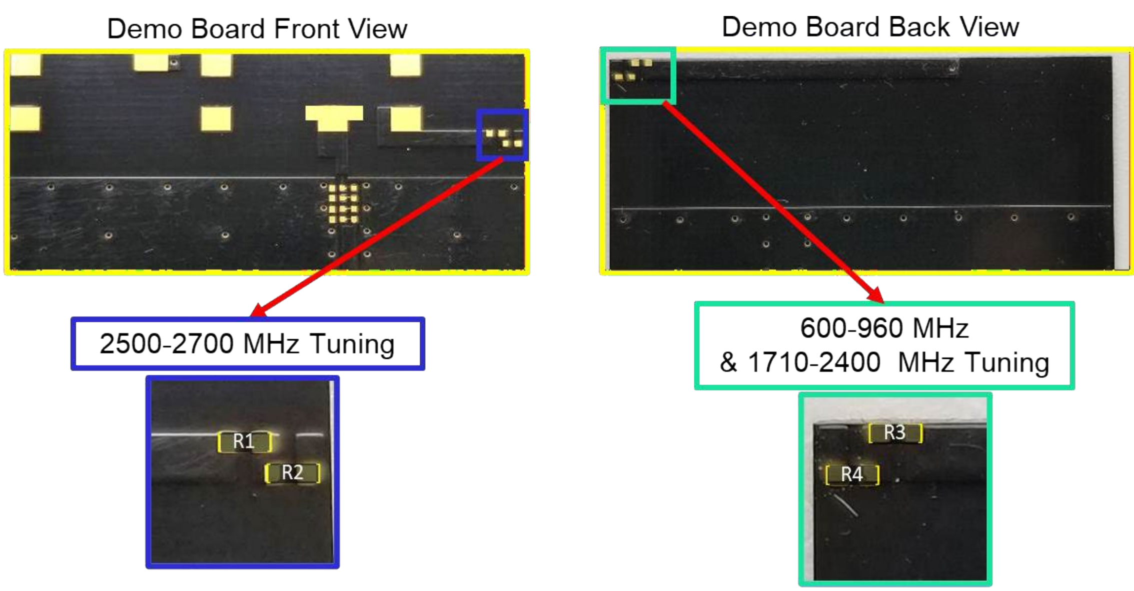


Figure 21: Tunings pads on the front and back of the antenna footprints

Mode	T1	T2		T3	
*R= 0 Ohm PADS	Connect: R3 & R4	Remove: R4		Remove: R3 & R4	
Outcome: (Ref: Baseline)	BASELINE	(600-960 MHz) ~20 MHz shift high	(1710-2400 MHz) ~20 MHz shift high	(600-960 MHz) ~30 MHz shift high	(1710-2400 MHz) ~35 MHz shift high

Table 3: (600-960 MHz & 1710-2400MHz) Tuning Pad Configurations

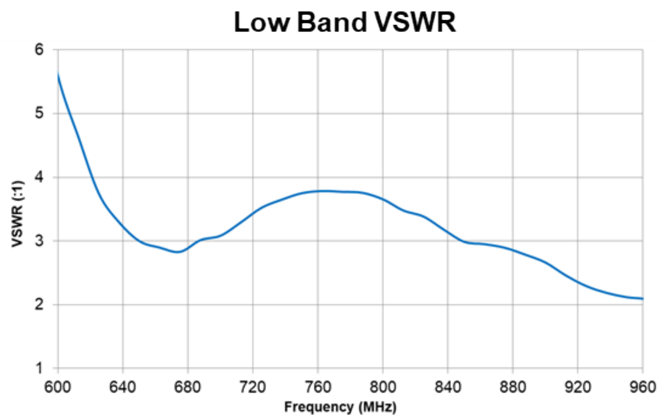
Mode	T4	T5	T6
*R= 0 Ohm PADS	Connect: R1	Connect: R1 & R2	Remove: R1 & R2
Outcome: (Ref: Baseline)	BASELINE	(2500-2700 MHz) ~60 MHz shift low	(2500-2700 MHz) ~70 MHz shift high

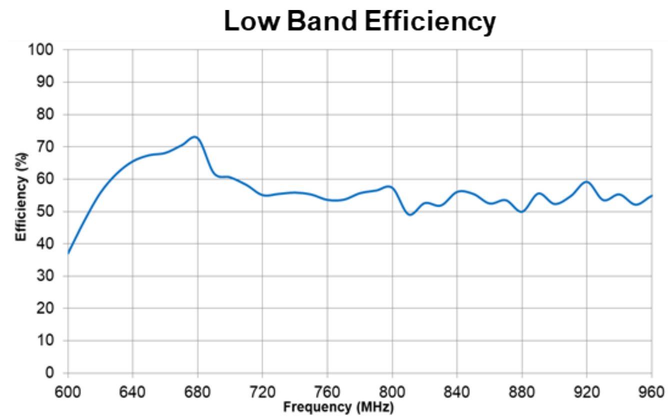
Table 4: (2500-2700 MHz) Tuning Pad Configurations

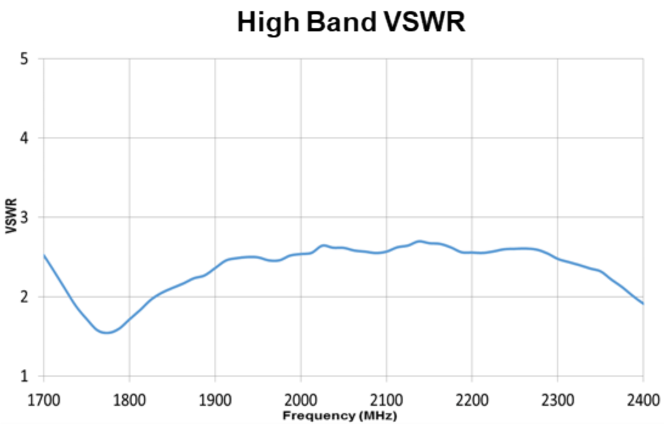
Appendix 1 Measured Data

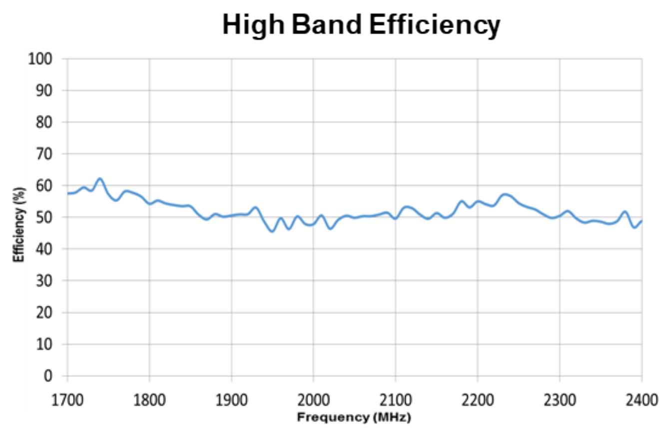
VSWR and Efficiency

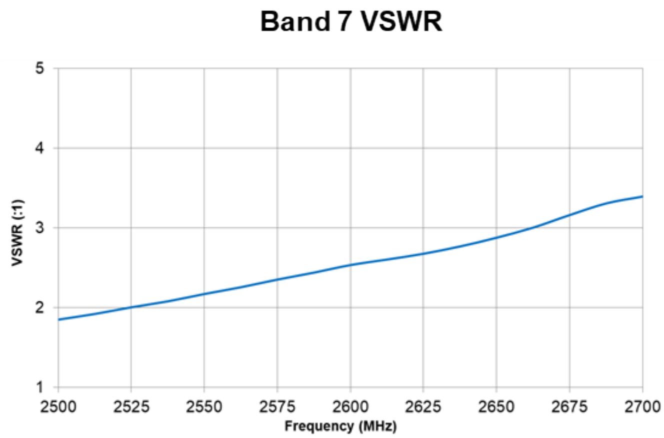
Below are the typical performances using KYOCERA AVX standard demo-board 1004795-01 and 600MHz matching circuit values. Performances will be similar to the 1004796-01

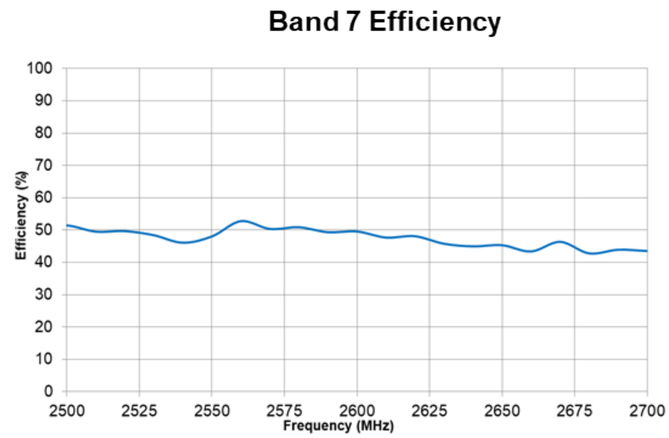












Appendix 1 Radiation Patterns (600,700,800,900,1800,1900,2100) MHz

Figure 22 represents the test setup orientation

Performances will be similar to the 1004796-01

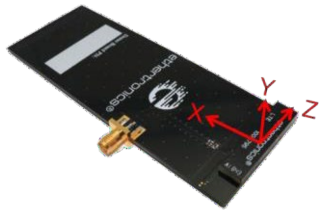
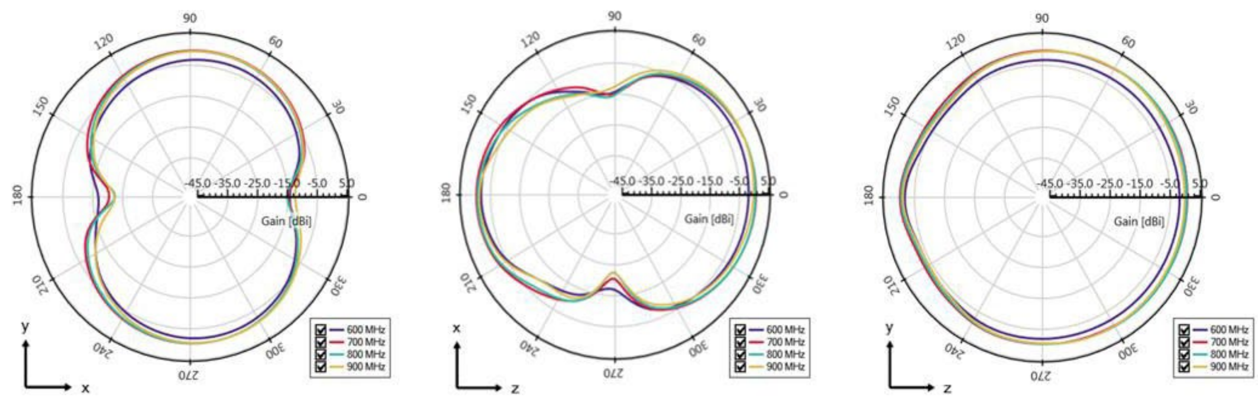
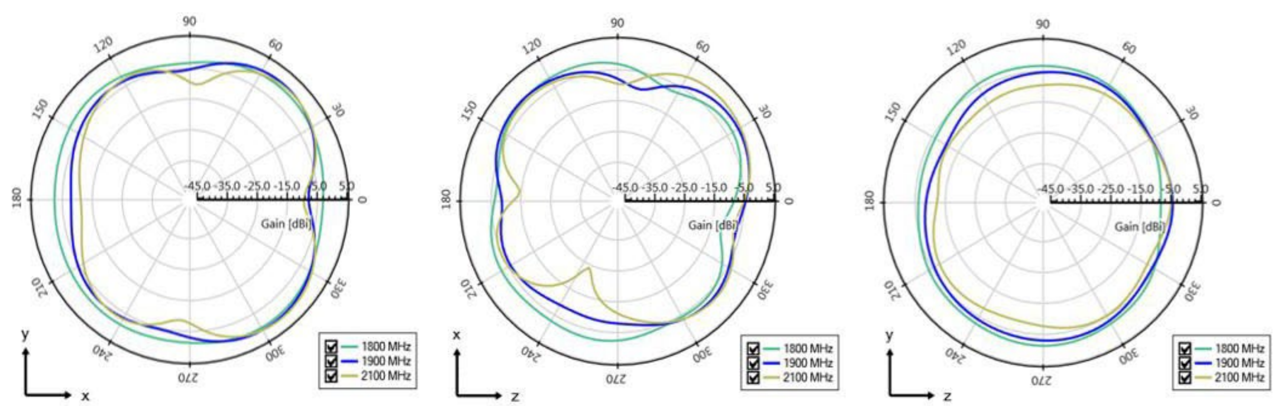


Figure 22: Test Setup (orientation)

Low Band measured at 600, 700 800, 900 MHz



High Band measured at 1800, 1900, 2100 MHz



Appendix 1 Radiation Patterns (2350, 2600) MHz

Figure 23 represents the test setup orientation.
Performances will be similar to the 1004796-01

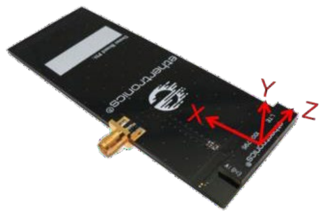
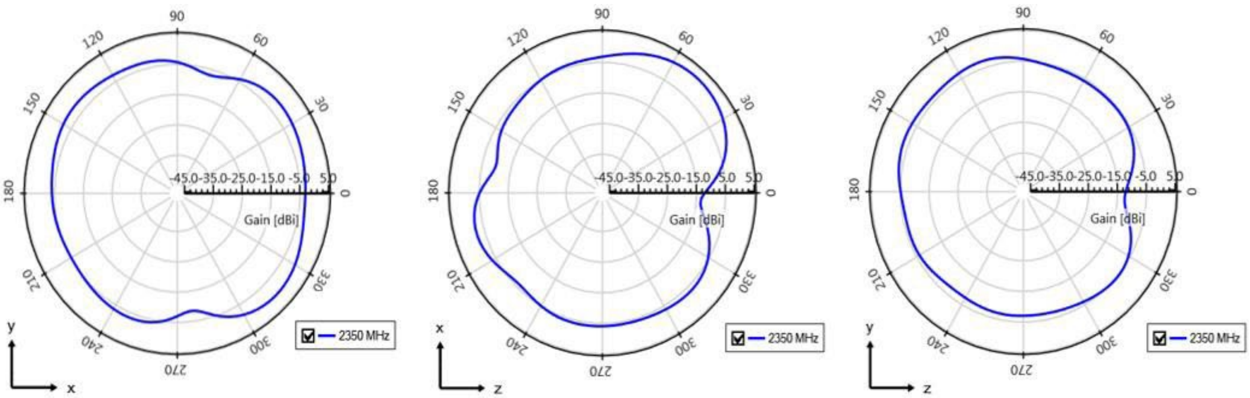
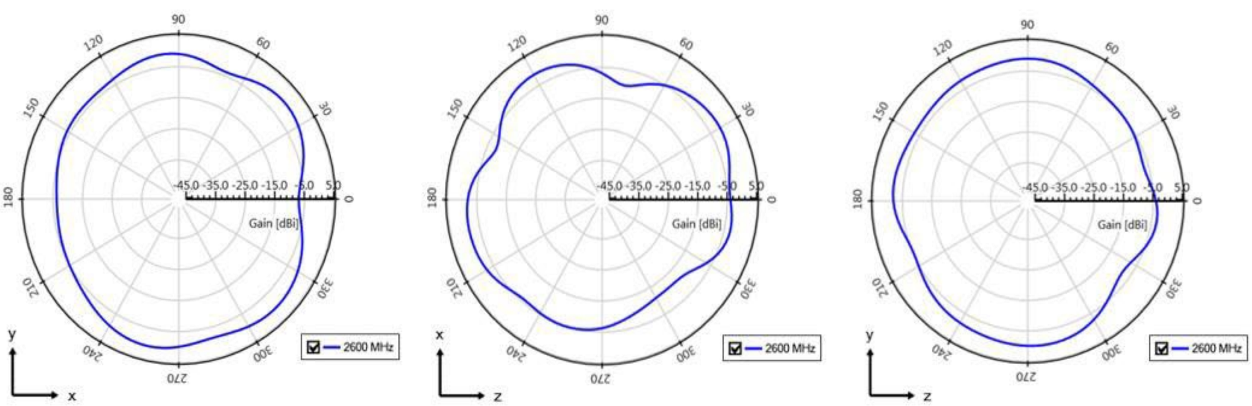


Figure 23: Test Setup (orientation)

High Band measured at 2350 MHz



Band 7 measured at 2600 MHz



Material Specifications

Item	Material
Antenna Substrate	FR4
Contact Finish	Hot Air Solder Level (HASL) or Au

Manufacturing and Assembly Guidelines

KYOCERA AVX's Prestta™ antennas are designed for high volume board assembly. Because different product designs use different numbers and types of devices, solder paste, and circuit boards, no single manufacturing process is best for all PCBs. The following recommendations have been determined by KYOCERA AVX, based on successful manufacturing processes.

These antennas are designed for automated pick and place surface mounting. However, as with any SMT device, KYOCERA AVX antennas can be damaged by the use of excessive force during the handling or mounting operation.

Component Handling Recommendations

The following are some recommendations for component handling and automated mounting:

- KYOCERA AVX Standard 1004795/1004796 antennas ship in tape and reel.

KYOCERA AVX's antennas are not moisture sensitive, and the ceramic antennas meet the requirements for a Level 1 classification of J-STD-020A (moisture/reflow sensitivity classification for non-hermetic solid state surface mount devices from the Institute for Interconnecting and Packaging Electronic Circuits). Nevertheless, as a precaution to maintain the highest level of solderability, KYOCERA AVX antennas are dry-packed.

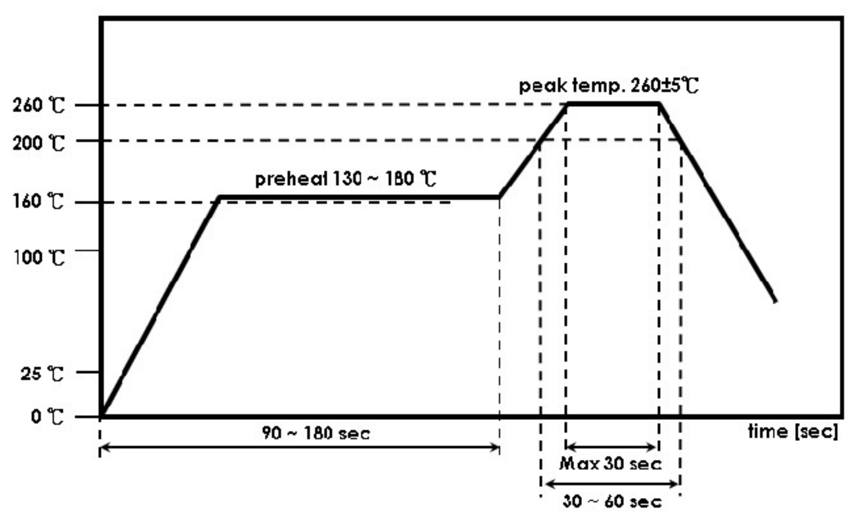
Paste Stencil Recommendation

KYOCERA AVX recommends application of paste stencil to a thickness of 0.1mm, applied to within 0.125 mm of the solder mask surrounding each exposed metal pad on the PCB. PCB layouts for each antenna are provided in earlier section of this document

Soldering Recommendations

The recommended method for soldering the antenna to the board is forced convection reflow soldering. The following suggestions provide information on how to optimize the reflow process for the antenna:

*Adjust the reflow duration to create good solder joints without raising the antenna temperature beyond the allowed maximum of 260° C.



Additional Manufacturing Recommendations

Care should be taken during certain customer-specific manufacturing processes including PCB separation and Ultrasonic Welding to ensure these processes don't create damage to the components

Cleaning Recommendations

After the soldering process, a simple wash with deionized water sufficiently removes most residues from the PCB. Most board assembly manufacturers use either water-soluble fluxes with water wash, or "no clean" fluxes that do not require cleaning after reflow.

Acceptable cleaning solvents are CFC alternatives, Isopropyl Alcohol (IPA), and water. If the application uses other types of solvents, please consult with KYOCERA AVX.

Cleaning processes that should be avoided are ultrasonic cleaning and any abrasive techniques, such as scrubbing with a cotton swab or with an abrasive material.

Rework & Removal Recommendations

There may be a need to rework or remove the antenna from the PCB. Although KYOCERA AVX'ss antennas are designed for ease-of-use, use care when separating them from the PCBs. Careless heating or removal of the antenna can cause thermal, mechanical or lead damage. These degradations may render the antenna useless, impeding any failure analysis and preventing the reuse of the device. Therefore, it is recommended to observe the following precautions:

- The component can be reworked and soldered by hand using a soldering iron. However, care should be used so the temperature does not exceed 260°C. The soldering iron should not touch the composite material while soldering the leads of the antenna.
- The component can be reworked and soldered using a hot air rework station. However, care should be taken to ensure that the temperature does not exceed 260°C.
- Once the solder on the PCB is sufficiently heated, use a vacuum pen to lift the antenna straight up off the PCB. Avoid twisting or rotating the device while removing it.

Tape & Reel Specifications

Product will be shipped in Tape and Reel packaging.

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