APPLICATION NOTE

Why VPEAK is the Most Critical Aperture Tuner Parameter

VPEAK and Voltage Handling: Selecting an Aperture Tuner with Insufficient VPEAK May Result in Degraded TRP, TIS and Phone Certification Failure

Abstract

There are multiple factors that designers of RF front-ends face today. One of the most challenging is tuning an antenna for best performance. Good antenna design combined with aperture tuning enables wider bandwidth operation, increased data rates, lower power operation, longer battery life, smaller footprints and reduced bill of material (BOM) costs. In this application note, we describe VPEAK or voltage handling, one of the most important antenna tuner parameters that needs to be understood well when choosing the right antenna tuning solution for aperture tuning.

Definitions

Important definitions, specifications, and other aspects to be considered in the design and selection of an antenna tuner include the following:

Aperture Tuning – Aperture tuning changes the electrical length of an antenna to shift its resonance to the desired frequency band of operation. Antenna aperture tuners improve the total radiated power (TRP) and total isotropic sensitivity (TIS) by increasing the effective size of an antenna or by altering its radiation pattern.

COFF – COFF is the capacitance presented by the antenna tuner while the antenna tuner switches are in the off state. Lower COFF increases the Q of the antenna tuner and therefore affects antenna efficiency and effective tuning range. COFF is typically measured in femto Farads (fF).

Impedance Tuning – Impedance tuning aims to match the impedance of the antenna to the impedance of the RF front-end thereby optimizing the power transfer to the antenna. Successful matching improves TRP and TIS.

Linearity (2fo, 3fo Harmonics, IP2 and IP3, IMD) – High-linearity switches are required to prevent degradation of TIS, TRP, and carrier aggregation performance. Linearity is typically measured in dBm.

RON – RON is the resistance presented by the antenna tuner while the antenna tuner switch is enabled. Lower RON typically results in higher antenna efficiency, and improved TRP and TIS. RON is typically measured in Ohms (Ω).

Total Isotropic Sensitivity (TIS) – Total Isotropic Sensitivity is a measure of an antenna system's receive sensitivity.

Total Radiated Power (TRP) – Total Radiated Power is a measure of how much power is transmitted by an antenna.

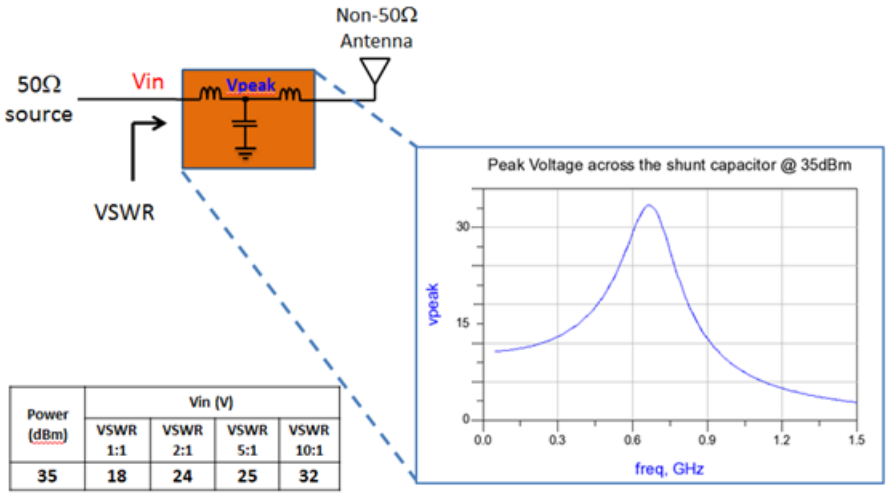
VPEAK – VPEAK specifies the maximum voltage the antenna tuner can support while still delivering acceptable harmonic performance. Skyworks guarantees that harmonics (2fo and 3fo) will be less than -36 dBm at the specified VPEAK value of the antenna tuner. VPEAK is typically measured in volts.

Why is VPEAK Important?

VPEAK is a key parameter for antenna aperture tuners. The peak voltage of the antenna tuner is set by the division of the RF voltage across the stack of field-effect transistors (FETs) that comprise the antenna tuner design. Using an antenna tuner with insufficient VPEAK for the application can result in permanent, catastrophic damage to the antenna tuner. Even if the tuner is not damaged, selecting a tuner with insufficient VPEAK could significantly degrade TRP and TIS, and could lead to excessive harmonics, causing the phone to fail certification and delaying product release.

An antenna tuner implementation may be thought of in terms of a resonant circuit. The peak voltage inside a matching or resonant circuit can be much higher than at its input or output. This occurs because the internal impedance can be locally higher than 50 Ω, even if the input and output of the matching circuit are matched to 50 Ω. An aperture tuner is typically placed near the antenna where the impedance is generally higher than 50 Ω.

The peak voltage on a tuning component depends on the input power level, the antenna or matching circuit topology, and the loaded Q of the circuit. For example, at PIN = +35 dBm, the peak voltage across a shunt capacitor inside a matching circuit could be as high as 32 V (Figure 1).



Power (dBm)	Vin (V)			
	VSWR 1:1	VSWR 2:1	VSWR 5:1	VSWR 10:1
35	18	24	25	32

Figure 1. Simplified Aperture Antenna (Tuner Installed Directly on Antenna Radiating Arm)

Aperture tuning consists of placing a tuning element in the appropriate location of the radiating structure not directly connected to the matching circuit of the antenna feed. This guarantees the highest antenna radiated efficiency and prevents the feed point impedance from changing during operation through the frequency spectrum. Aperture tunability is most effective when the tuning element is placed in a location with the highest voltage distribution.

Consequently, the VPEAK required of an antenna tuner is determined by where the tuner is placed along the antenna and its proximity to the shorting pin of the antenna. VPEAK is lower closer to the shorting pin of the antenna. VPEAK is higher further from the shorting pin (Figure 2). Due to these factors, the maximum voltage present across an aperture tuner may be much higher than the voltage present at the antenna feed point.

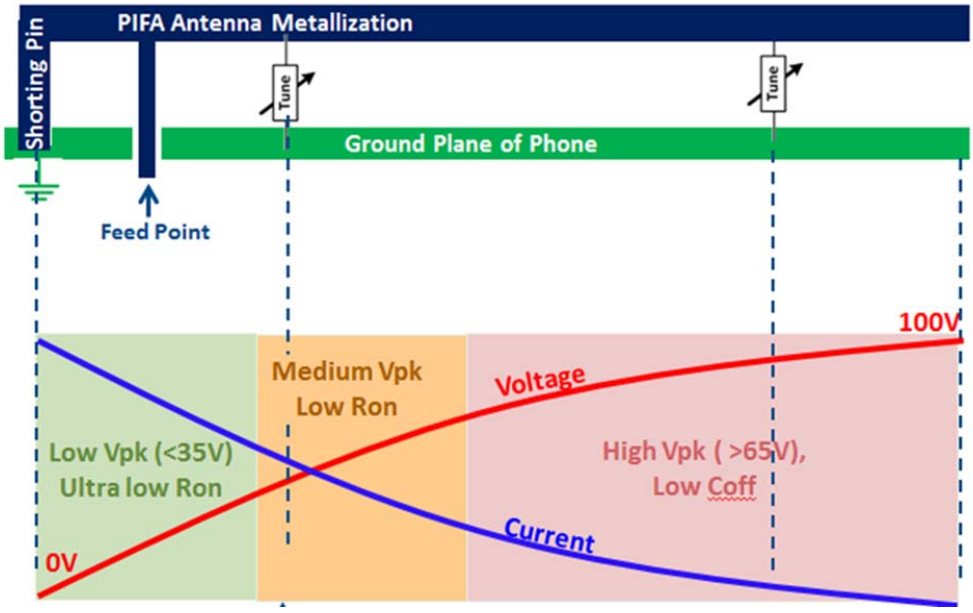


Figure 2. Effect of the Tuning Element Location on VPEAK

Recommending the Appropriate Tuner for an Application

There are several factors to consider in selecting the appropriate aperture tuner. While RON, COFF, and VPEAK are all critical parameters that define an antenna tuner, the first step in selecting the right antenna tuner is determining the VPEAK requirement. Tuning devices are used to set the resonant frequency and as such, typically experience the highest voltage or highest current in the circuit. Selecting a tuner with insufficient VPEAK will likely result in poor TRP and failed radiated spurious emissions (RSE) certification. When the VPEAK is exceeded, the tuner begins a breakdown cycle, linearity deteriorates, and the tuning switch emits potentially harmful harmonics.

VPEAK cannot be measured on an antenna because the act of measuring and touching the antenna changes its RF characteristics. Simulation is needed to predict the maximum VPEAK expected across antenna tuner. Skyworks' Antenna Systems team assists customers with simulating the VPEAK across their antenna. Once the necessary VPEAK is defined, the next step is to select the RON or COFF required to achieve the TRP goal. Depending on the specific antenna design and tuning bands of interest, either RON or COFF may be more dominant in determining the antenna efficiency. Skyworks experts also provide customers with efficiency simulation for selecting the appropriate antenna tuner.

Product Data Sheet VPEAK Specification

The RF semiconductor industry has not converged on a common method for testing and specifying VPEAK. Some vendors simply specify a VPEAK value in the absolute maximum ratings table of the data sheet. This is sufficient for describing the voltage beyond which the part may be damaged, but it does not guarantee that the part will perform adequately so as not to fail system-level RSE testing. Other vendors may include a VPEAK value in the electrical specifications table, but do not indicate what level of performance is guaranteed. The bottom line is that customers must be certain that when they use a tuning device anywhere up to the VPEAK level, sufficient performance is guaranteed.

Skyworks uses harmonic performance to specify VPEAK. Input power is swept and 2fo and 3fo harmonics are measured. VPEAK on a Skyworks data sheet will identify the point where harmonics exceed the -36 dBm level. A harmonics level of -36 dBm has been chosen in order to comply with *3GPP Spurious Emissions Requirement (section 9.2)*. Spurious emissions are caused by unwanted transmitter effects such as harmonics emission, parasitic emission, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

For example, the Skyworks SKY19250-001 is an SPST antenna tuner with a rated VPEAK of 80 V. Characterization test results are shown in Figure 3. The harmonic performance is better than -36 dBm beyond 80 V.

The consequence of using a tuner above the VPEAK point is that harmonics are injected into the system, which could result in excessive RSE and/or antenna efficiency to be lower than expected.

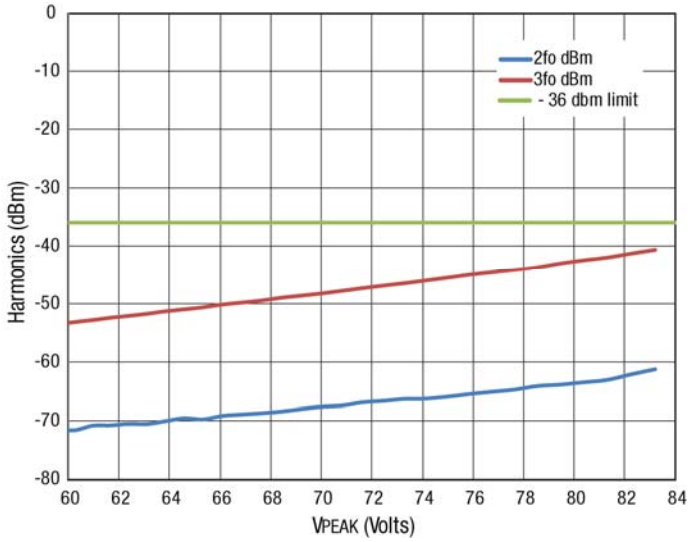


Figure 3. SKY19250-001 SPST Antenna Tuning VPEAK

Measurement Setup

Skyworks has standardized a VPEAK measurement system (Figure 4) that is carefully maintained and calibrated.

Peak voltage is verified by a high-power measurement in a 50 Ω environment, and involves very high power levels that may be destructive to the device under test (DUT).

To measure VPEAK, Skyworks configures the antenna tuner in a shunt configuration with all arms in the "Off" state (Figure 5).

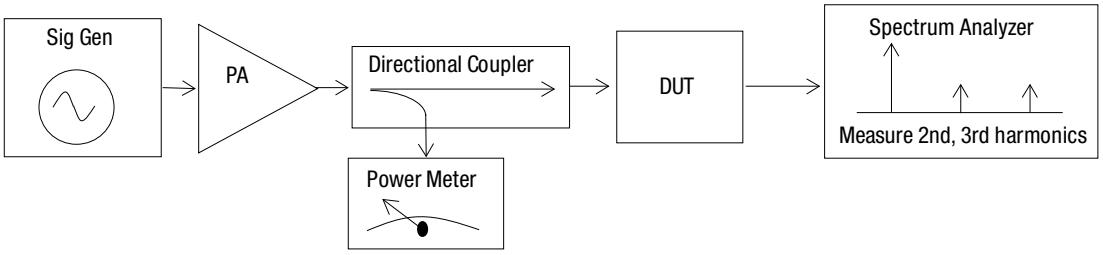


Figure 4. Skyworks VPEAK Measurement System

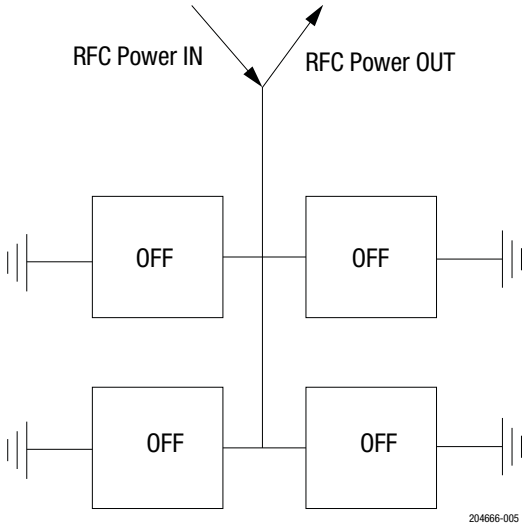


Figure 5. VPEAK Measurement Shunt Configuration with All Arms in the "Off" State

Summary

Antenna tuner VPEAK is critical to the performance of the RF system. Using an antenna tuner with inadequate VPEAK may result in poor TRP, TIS and certification failure. Simply relying on VPEAK as specified in the absolute maximum rating table of a data sheet is not sufficient.

System performance is related to the antenna tuner harmonic performance. Harmonics are the best indicator of true VPEAK performance and VPEAK should be clearly specified in the data sheet electric specifications table. VPEAK measurement set-up and test conditions must be clearly identified to compare antenna tuner components in order to select the appropriate one.

It is extremely important to choose the correct aperture tuner component that meets the RON, COFF, and VPEAK criteria to match the antenna design. Skyworks clearly specifies the VPEAK value on its data sheets, providing customers with confidence that the tuner they select will perform to the VPEAK level specified in the data sheet.

Skyworks Offers a Comprehensive Portfolio of Antenna Aperture Tuners

The Skyworks family of aperture tuners offers VPEAK ratings from 35 V to 80 V, allowing customers to choose the aperture tuner that is right for each specific application. In addition, Skyworks provides advanced process and design techniques to deliver the best RON and COFF performance for a given VPEAK voltage. With VPEAK performance meticulously guaranteed in the product datasheet electrical specifications table, customers can be assured that every Skyworks tuner meets the VPEAK voltage specified. Finally, the Skyworks team assists customers with antenna simulation and recommends the best antenna tuner for the application.