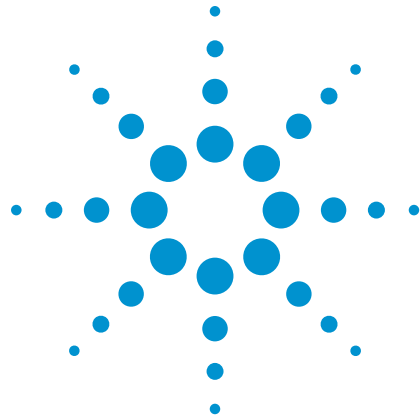


Agilent Video Leakage Effects on Devices in Component Test

Application Note



Abstract

This paper discusses what video leakage is and how it affects your devices under test (DUT) and measurements. A PIN diode switch transient simulation of video leakage produced using Agilent Advance Design System (ADS) is used to illustrate video leakage. The video leakage signal is analyzed in the time domain. The note explains why FET switches generate low video leakage. Video leakage measurement results comparing the various switch technologies, as well as typical video leakage measurement setup is shown in the last section of this application note.

Introduction

The word “video” was adopted from television, where the video signal (the picture) is carried on a VHF or UHF signal. As the name “video” suggests, video leakage or video feed-through signal spectrum is in the MHz to GHz range. Video leakage refers to the spurious signals present at the RF ports of the switch when it is switched without an RF signal present. These signals arise from the waveforms generated by the switch driver and, in particular, from the leading edge voltage spike required for high speed switching of PIN diodes. When measured using a 50Ω system, the magnitude of the video leakage can be as high as several volts. The frequency content is concentrated in the band below 200 MHz, although measurable levels can be observed as high as 1 GHz. The following section will elaborate on the video leakage using a typical PIN diode switch as an example.

Video Leakage in Switches

Most switches contain video leakage; the magnitude can be as low as a few mV to as high as 3V in a 50Ω system. The following section explains why the video leakage signal of a PIN diode switch is much higher than a FET switch.

PIN diode switches

In a typical PIN diode switch, the DC and RF signals share the same path, and a DC block is used to prevent current from going into the load. When the control voltage is changing states (low to high or vice-versa), it actually charges the DC block capacitor and discharges through the external load, causing a video leakage signal to appear at the load.

Figure 1 shows a simplified single-pole double-throw (SPDT) PIN diode switch schematic where *COMPort* is the input port and the output port is either *RF1* or *RF2* depending on the control voltage. This switch operating frequency range is from 50 MHz to 18 GHz. The control voltage toggles between +5V to -5V turning the PIN diode (*NLPIN1* and *NLPIN2*) ON and OFF respectively. When *Vpulse SRC1* provides the negative voltage, the PIN diode *NLPIN2* is turned ON; the DC current flow from ground passes through the L1, PIN diode, toggling L3 to the negative source. With this bias, *COMPort* and *RF2* essentially is shorted at RF frequency. The (PIN diode) *NLPIN1* is reversed biased (OFF) by the positive pulse of *SRC3*.

The capacitors C1, C2 and C5 are used as a DC block to avoid any DC signal going into the load. The L1 inductor is used to provide the DC path for turning the PIN diode ON and OFF. The R1, R2 and R4 are the 50 Ohm load. The inductor L2 and L3 are used as RF Choke, C6 and C7 are the bypass capacitors.

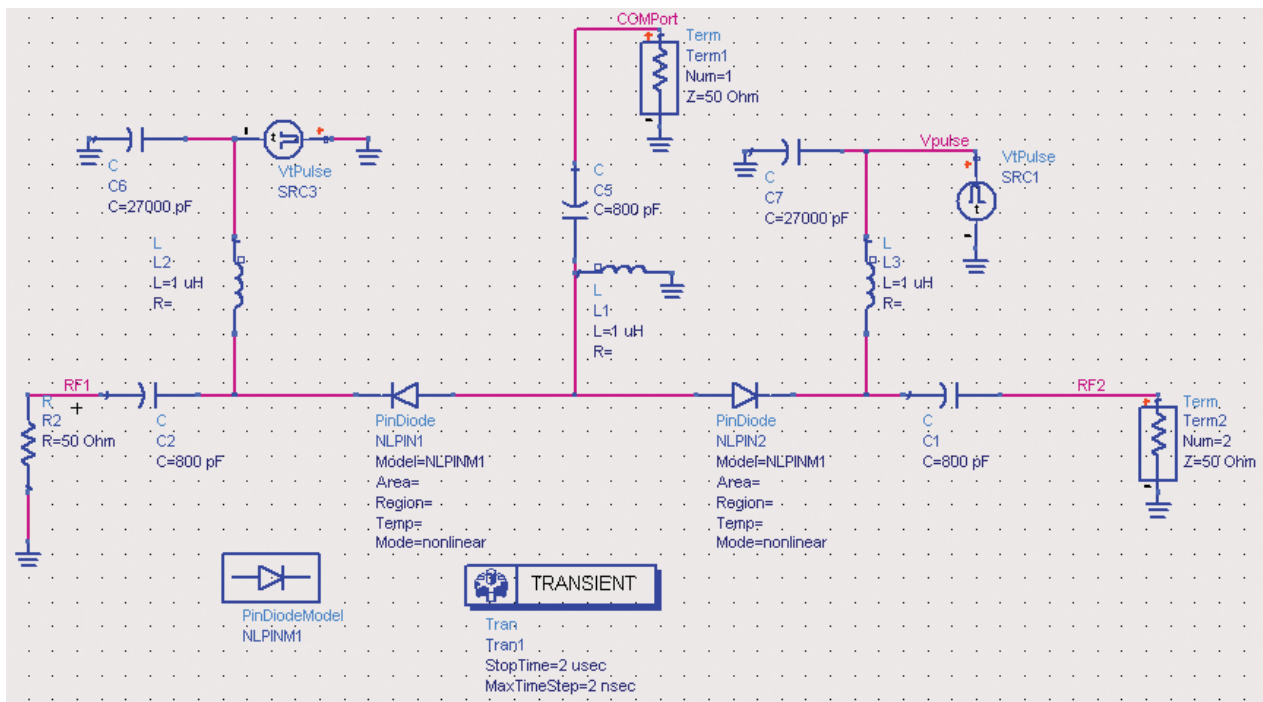


Figure 1. Simplified PIN diode switch schematic

Figure 2 compares the simulated transient response of a biased signal to the video leakage signal of a PIN diode switch. V_{pulse} is the biasing signal that turns on and off the Pin diode and $RF2$ is the observed video leakage signal that appears at output of the $RF2$ port. As shown in Figure 2, there are pulses appearing at $RF2$ when the biasing signal is at the rising and falling edge. These pulses are called video leakage, and the amplitude of the video leakage is approximately 3V peak with a rise time of around 50 ns.

The amplitude of the video leakage depends on the design of the switch and the switch driver. Video leakage can damage sensitive devices, such as satellite transponders, which use low-power level switching (-100 dBm ON/OFF) and instruments, depending on the amplitude of the video leakage.

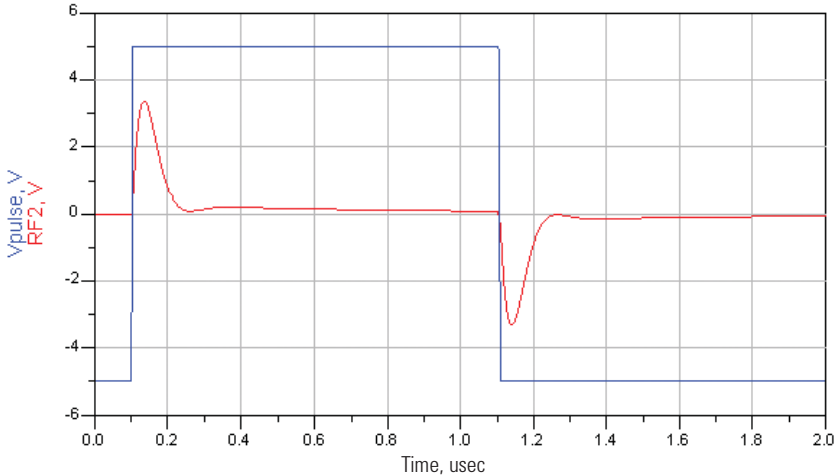


Figure 2. Transient response of PIN diode switch

FET switches

Generally, FET switches have very low video leakage compared to PIN diode switches. This is due to their design. In FET switches, the drain and source are connected through the "channel." The channel is controlled by the depletion layer of the gate bias. The input impedance of the gate is very high ($M\Omega$), hence the current drawn from the gate is very small (μA). The RF path travels from drain to source through the channel; hence the gate bias signal is essentially isolated from RF path. There will still be a very minimum DC current (μA) from the gate to the source or drain that will appear as the video leakage. But the video leakage is very small due to the voltage drop across the gate input impedance.

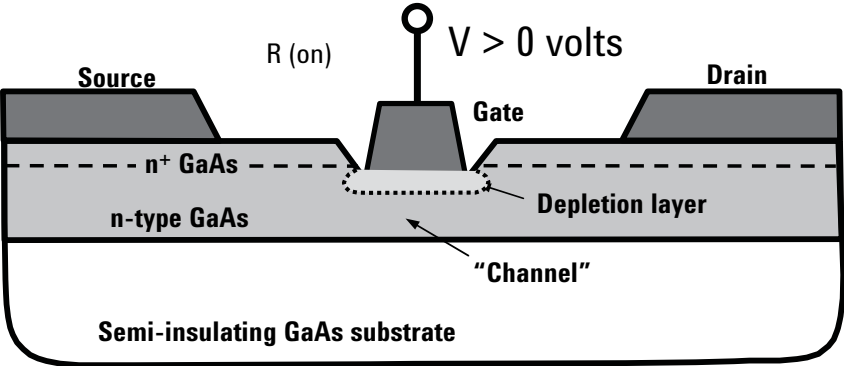


Figure 3. FET switch structure (cross-section)

Video leakage comparison of different types of solid state switches

Figures 4, 5 and 6 show FET and PIN diode switch video leakage measurements. These are summarized in Table 1.

Table 1. Video leakage in switches

| Switch types | FET switch | PIN diode switch |
|---------------|----------------------|--------------------|
| Video leakage | < ±30 mVpp (typical) | < ±1 Vpp (low) |
| | | < ±3 Vpp (typical) |
| | | < ±10 Vpp(high) |

Figure 4 shows that video leakage for a typical FET switch is only about 20 mV. This is due to the FET structure as explained earlier. Figure 5 shows the video leakage of a PIN diode switch which has low video leakage of 780 mVpp compared to the PIN diode switch which has video leakage as high as 2.7 Vpp. See Figure 6. Video leakage in PIN diode switches can sometimes be as high as 10 Vpp.

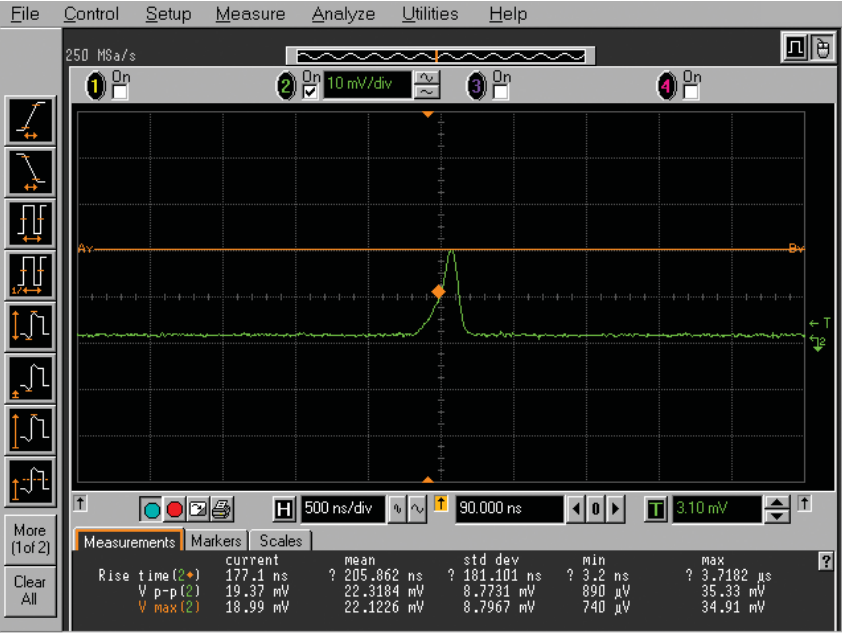


Figure 4. FET switch video leakage (typical)

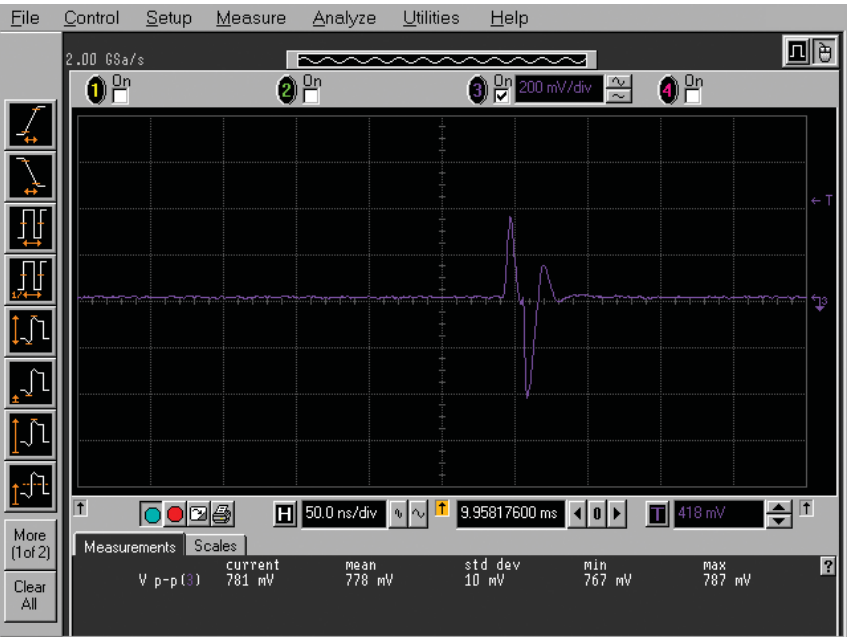


Figure 5. PIN diode switch with low video leakage

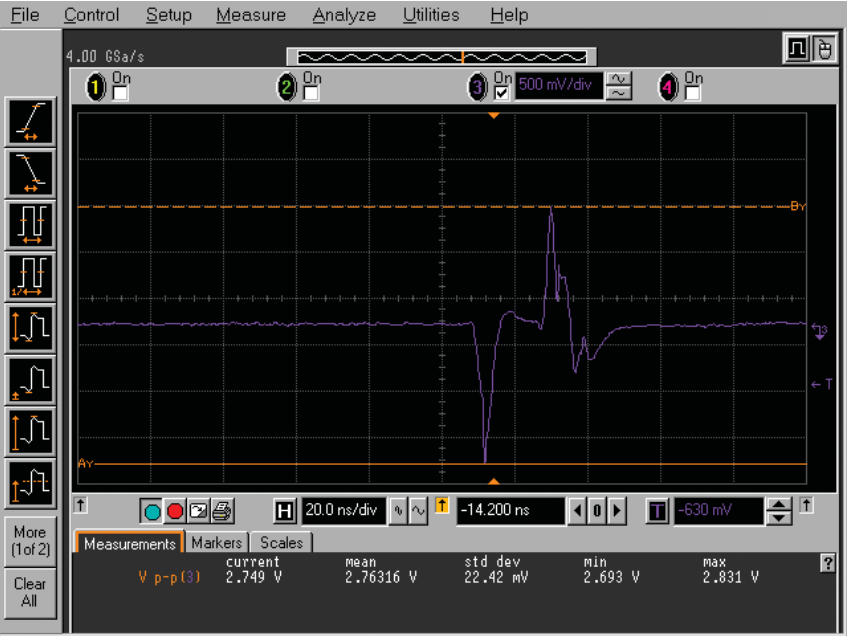


Figure 6. PIN diode switch typical video leakage

Measurement Setup

Figure 7 shows the video leakage measurement setup, an oscilloscope, power supply and function generator or pulse generator are used to measure the video leakage. The switch needs to be biased and all the ports are terminated by a 50 Ohm load except one, which is connected to the oscilloscope's 50 Ohm input channel. The function/pulse generator is connected to the control line of the switch to toggle the switch on and off, the video leakage will be captured on the oscilloscope screen. The measurement unit of the video leakage spectrum is in mV or V.

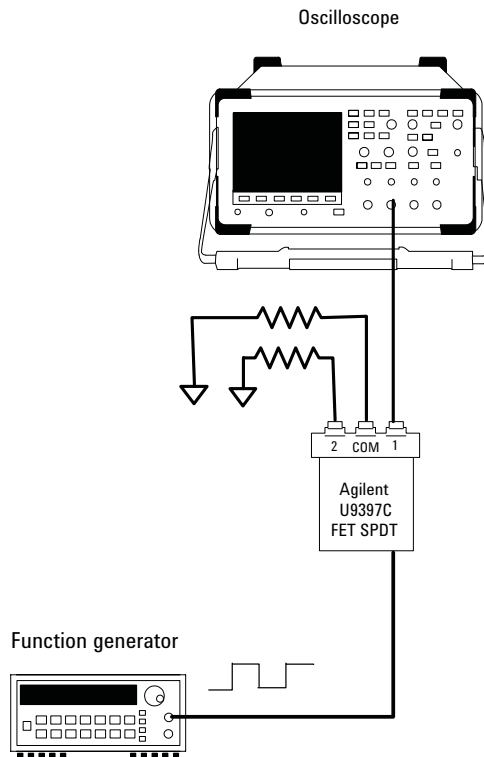


Figure 7. Video leakage measurement setup

Power amplifier measurement example

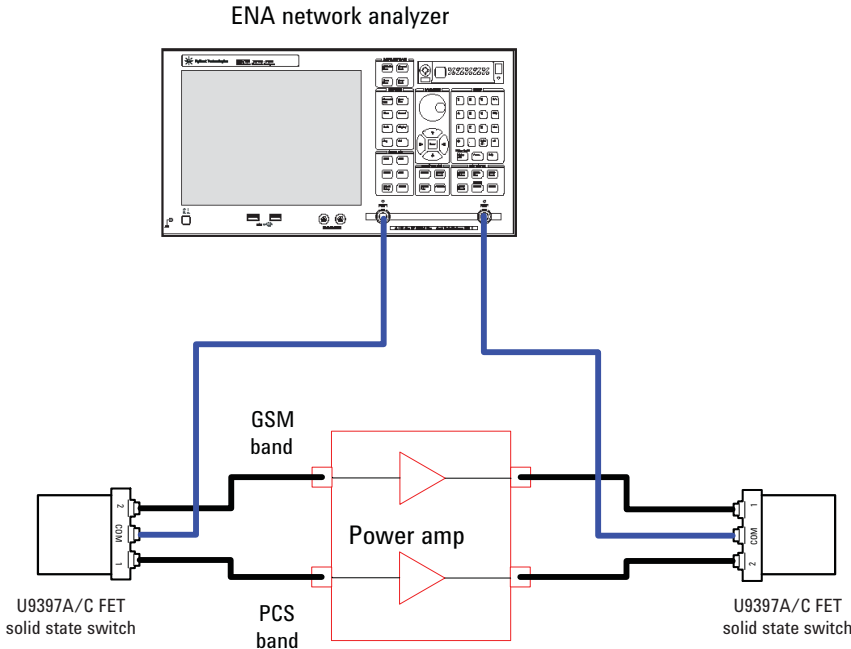


Figure 8. Dual band mobile handset power amplifier test setup

Figure 8 shows a typical dual band mobile handset power amplifier S-parameter test setup. The switch is used to switch between the GSM and PCS bands. PIN diode switches cannot be used in this application because they generate high video leakage during switching which can cause the power amplifier to be overstressed or damaged. The power amplifier maximum input power is less than 10 dBm, so it is best to use FET switches which have video leakage less than 10 mVpp.

Channel amplifier with ALC for satellite transponder measurement example

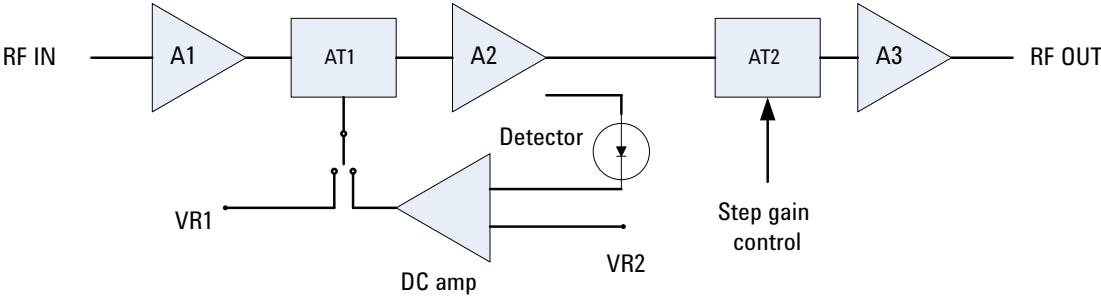


Figure 9. Block diagram of channel amplifier with ALC for Satellite transponder

Figure 9 shows a typical channel amplifier with an automatic level control (ALC) system for satellite applications. The ALC controls the input of the final power amplifier (TWTA) which is dependant on the input power level of the channel amplifier. If a pin switch is used to test this device, the video leakage signal could perturb the detector causing the gain of the device under test to alter significantly and possibly causing the TWTA to be overstressed or damaged. In this situation, the device cannot be installed in a satellite for fear of early failure.

Conclusion

Video leakage is not a widely identified parameter and, its impact on measurement accuracy and devices is not very well understood. This application note has shown the effect of video leakage has on devices-under-test and measurement equipment. The differences in video leakage of PIN diode and FET switches were also discussed. Poor video leakage performance degrades DUT measurement accuracy and might even damage sensitive components or expensive instruments. In many cases, using a FET switch can minimize the issues associated with video leakage.

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Taiwan:

(tel) 0800 047 866
(fax) 0800 286 331

Other Asia Pacific Countries:

(tel) (65) 6375 8100
(fax) (65) 6755 0042
Email: tm_ap@agilent.com
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