Automotive 600V/m Pulse Radar Test with a Dual-Mode Amplifier
Application note 118 (Component)

Purpose -

The information supplied in this application note is to provide a better understanding of the required power levels to meet the automotive specification defined by Ford and GM. These requirements are due to the increased applications of pulse modulation technologies that are being employed for communications and other high technology applications and are therefore being incorporated into commercial and military Radiated Susceptibility (RS) test standards. (See our application note 105 “antenna terms and related formulas” for more detailed information.)

Specification –

Automotive Manufacturer Standard			
General Motors Standard		**Ford Standard**	
Specification	*GMW3097	Specification	*EMC-CS-2009, Rev.1
Frequency Range:	1.2-1.4GHz	Frequency Range:	1.2-1.4GHz 2.7-3.1GHz

*These standards are followed by other automotive manufacturers

Introduction -

The standards referenced mandate 600 V/m automotive testing is necessary due to electromagnetic fields that exist in today’s busy airwaves/environment. In particular radar emissions (Pulsed RF) that are emitted from various civilian and military installations. Test labs & manufacturers emulate those radar emissions in a very controlled manner to ensure safe automotive operation and immunity from these signals. (similar in aircraft).

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Pulse field terms and characteristics -

For Pulse Modulation (Reference Figs. 1 and 2)

- **Carrier Level** - The pre-calibrated RF/microwave field producing signal
- **Modulation Depth** - The level or amplitude of the pulse modulation signal.
- **Pulse Repetition Frequency (PRF)** - The number of pulses per second (ON and OFF time included.)
- **Pulse Width** - The length or duration of an RF pulse “ON” time
- **Duty Cycle** – The ratio of the “ON” to “OFF” time of a pulse modulated signal

Pulse parameters –

In addition to understanding the amplitude aspects, working with pulsed fields requires the user understand the key pulse characteristics of pulse width, pulse repetition frequency or rate, and duty-cycle. By the application of basic mathematics, any third parameter can be calculated from the other two. (see figs 1 and 2)

Pulse Width –
Pulse width refers to the period of time that a pulse is actually on

Pulse Repetition frequency –
Pulse repetition frequency is the number of pulses in a measurement period, typically referred to as “pulses per second.” The pulse repetition time – **(PRT=1/PRF)** is the time period between the pulses which is the inverse of the frequency. The total time period is the sum of the ON and OFF periods of each pulse.

Duty Cycle = PW/PRF =
Duty cycle is the proportion of ON to OFF time during the pulse period.

Pulsed field levels and average power -
Upon pulse modulating a CW signal, the average power is determined by the signal pulse width, pulse repetition rate and subsequent duty cycle.

Pulse Parameters -
The following graphics show the relationships between a CW signal, a square wave modulated signal and a pulse modulated signal. The diagrams are the same as those shown in the DO-160 Standard. The waveforms do not have frequency or time references assigned.

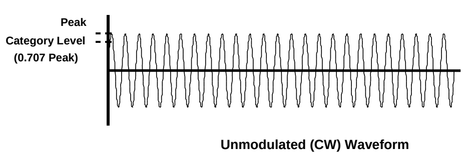

Figure 1 - Unmodulated (CW) waveform (100% duty)

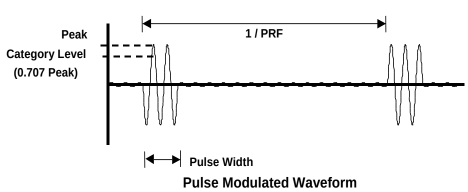

Figure 2 - Pulse modulated waveform (PM)

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RF power and field level examples -

As a quick review, these are the calculations of the RF input power required to produce a field level of 600V/m at a distance of 1 m using an antenna with an isotropic or numerical gain of 12.0. A 750 W RF signal will be required to produce a 600 V/m field at a 1 m distance from the antenna.

Note: The amplifier needs to have sufficient margin to compensate for the additional insertion losses associated with the external dual directional coupler and RF transmission cable. Keep in mind that cable insertion loss is determined by cable type and length.

CW field calculations:

600 V/m at 1M

Antenna parameters:

Antenna Gain - G(dBi) = 12.0
Antenna Gain - G(linear) = 16.0

Variables:

E(V/m) - E field level - **600 V/m**
R(m) - Distance in meters – **1m**
Pt(w) - RF power input to antenna

Typical Broad-Band Antenna

(commercially available covering 800MHz-5.0GHz.)

Antenna Gain Conversions

G (dBi) = 10 Log G(linear)
G(linear) = Antilog [G(dBi)/10]

Field Strength

$Pt = E^2 x R^2 / 30 x G(linear)$ = *RF power at antenna*

Calculation

$Pt = ((600.0)^2 x (1)^2)/(30 x 16)$ = ***750 watts***

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Field level measurement -

The direct measurement of a CW or pulse field is basically straightforward. The test system must be assembled in accordance with the standard for the specific Equipment Under Test (EUT) and then the field sensing device located in the correct proximity to the (EUT). Assuming that E-Field probes have the necessary dynamic range and can react/respond to pulse RF Power, then the pulse field level can be measured and system drive levels determined as if it were a CW field.

Calibration methods -

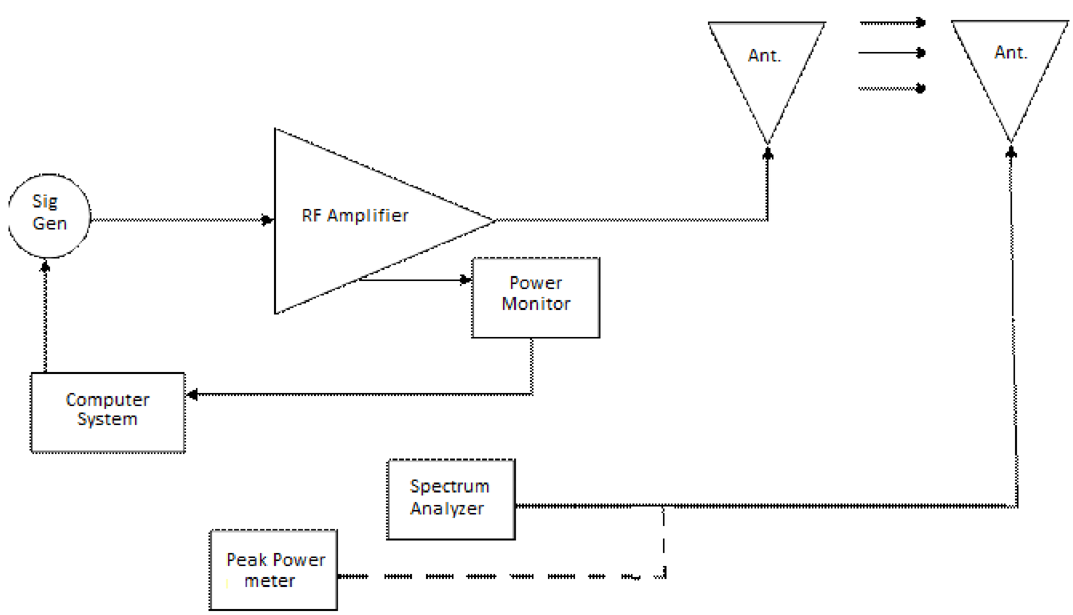
Calibration methods are more stringent for ***Ford's test procedure***. Therefore we will discuss the approved Ford methods. ***Antenna-to-Antenna method is used for pulse applications.*** This method is described in Annex A, paragraph A3 of the Ford standard. The key issue with the calibration of a high power pulse field test is to validate the field level in a manner consistent with the test standard and acceptable to the customer.

Constructing the drive table -

The drive table is a list of drive levels, by frequency, that will be produced by the system signal generator. These signals, when applied to the RF power amplifier system, will produce the output power required to obtain the desired field level at all of the frequencies contained in the list.

The drive table can be constructed manually or automatically under software control. Either way, the table is constructed one frequency at a time by successively increasing the signal generator output level (driving the RF amplifier system) until the correct field level is indicated on the field measuring device. The resultant drive level can then be recorded manually or by the software. This process is done repeatedly for each frequency until the list is completed.

Illustration 1.0 – Radiate Immunity block diagram and drive table construction



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Constructing the drive table – *(Continued)*

The drive table is a list by frequency of exactly how much RF input level is required by the RF power amplifier to produce the correct RF output into the antenna which actually generates the voltage field. The field probe senses the field voltage level and provides that information to the user and/or the computer. Either the user or the computer will use the probe information to determine when the correct field level has been achieved. The drive level from the signal generator is then recorded for each frequency that will be included in the test. The complete list of frequencies and drive levels constitute the drive table. The RF output power level data can be maintained separately.

CAUTION: RF/microwave measurement equipment can be seriously damaged by excessive peak power and E-field levels. Great care must be taken when developing a manual or an automated drive table to ensure that the system output power levels do not excessively exceed the level expected for the test equipment being used. Most software packages provide for maximum signal generator limits and they should be used. It is far better to restart a constructed test scan because a preset drive safety level was reached than to replace damaged hardware.

The Standard test levels and parameters –

The standards require that the test signal be pulsed to achieve the required field level specified. The resultant average power is relatively low allowing a pulsed amplifier source to be utilized that is capable of producing the required high peak power. This concept is the key in being able to produce high power pulse field levels. A CW rated amplifier producing the same peak level would be larger in size and of course a more costly amplifier system. Pulse amplifiers are far more economical for generating high power pulse field levels.

For this reason, IFI's Dual-Mode Amplifier, Model S31-500-900P, delivers the best of both worlds. It supplies both CW and Pulsed power (at a higher levels than CW) to conform to both Ford and GM Standards.

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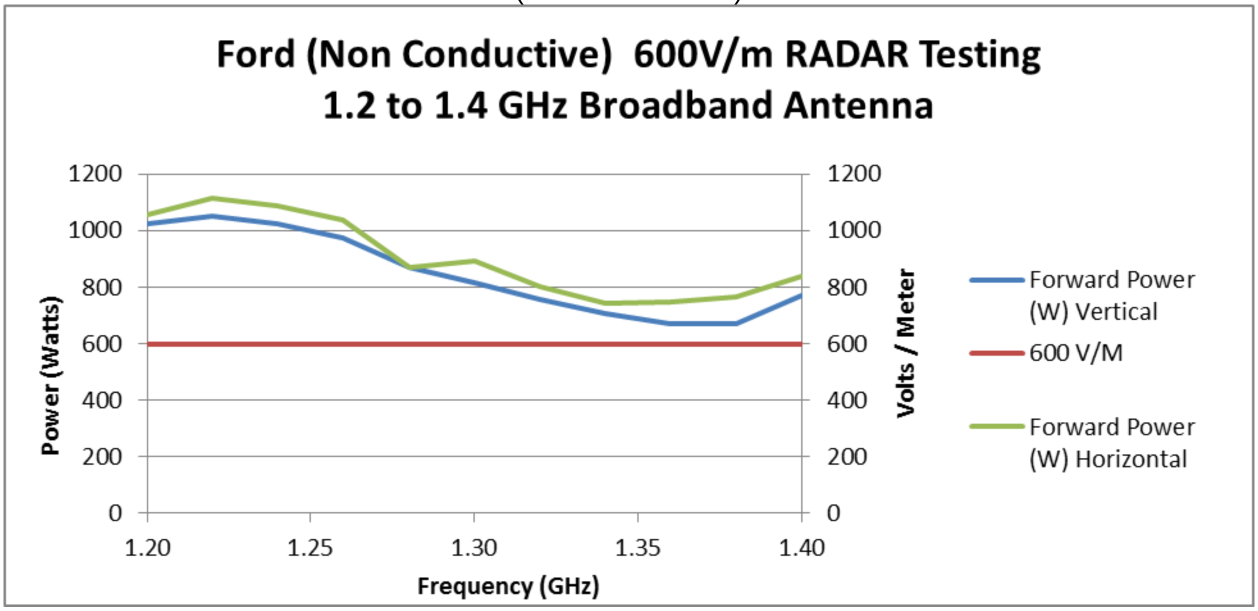
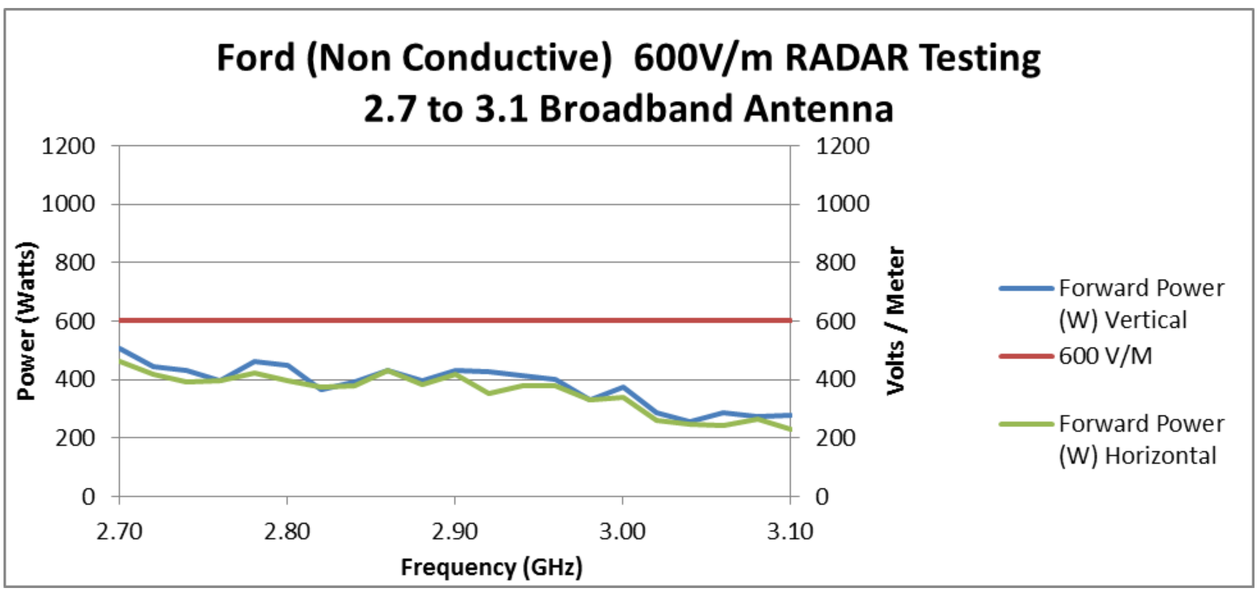
Test results – (with a broadband antenna)

(ant-to-ant method)



Advantages
1. Ease of setup
2. One setup only, extensively saves lab time
3. 600V/m full-band one sweep
4. Not limited to automotive, general purpose broadband testing as well
5. Only one amp is needed, no switches for a simple elegant approach



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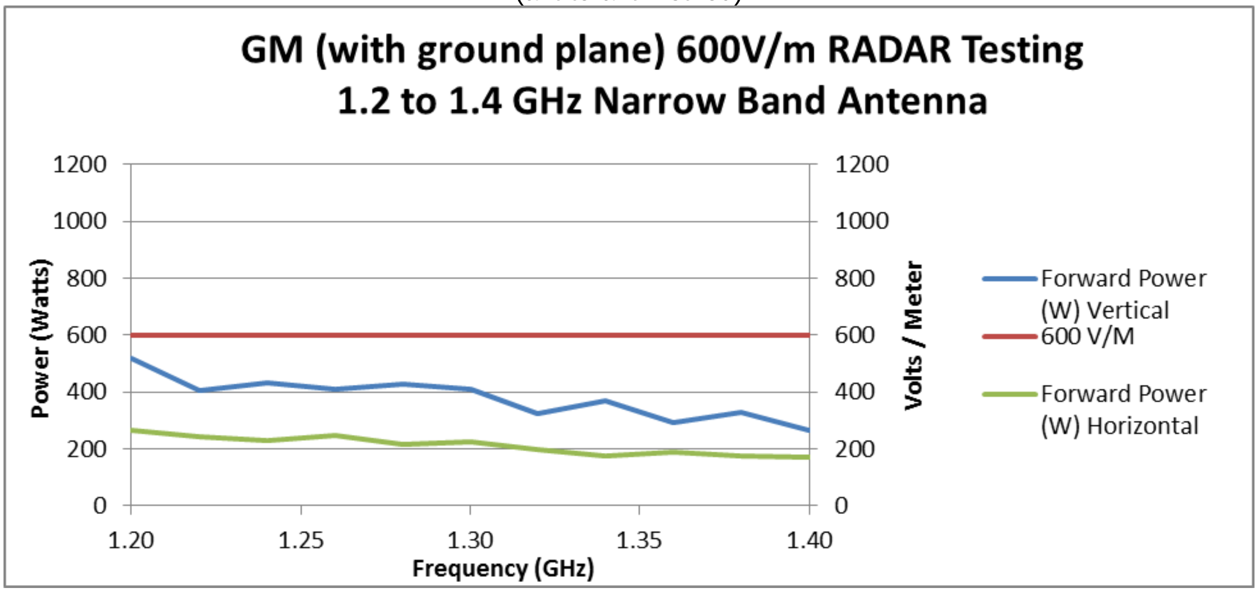
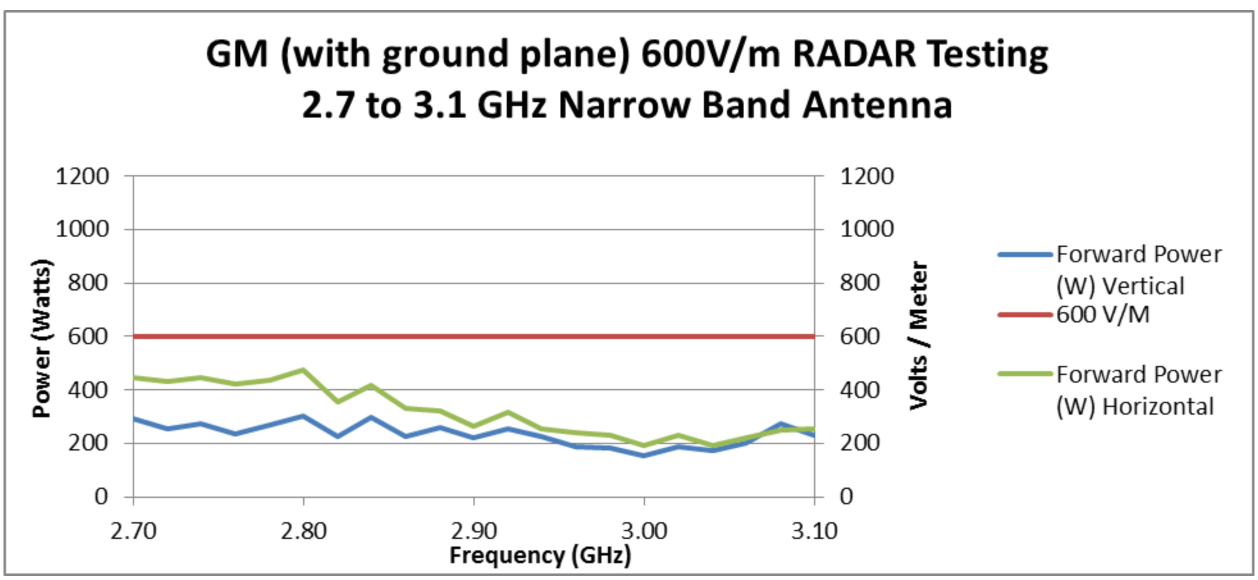
Test results – (with two Narrowband antennas)

(ant-to-ant method)



Disadvantages
1. Significantly more involved setup
2. Multiple setups for E & H planes
3. Multiple setups per frequency band, extremely time intensive
4. Large heavy antennas to store, move and
5. Not useable for broadband testing in accordance to the standard



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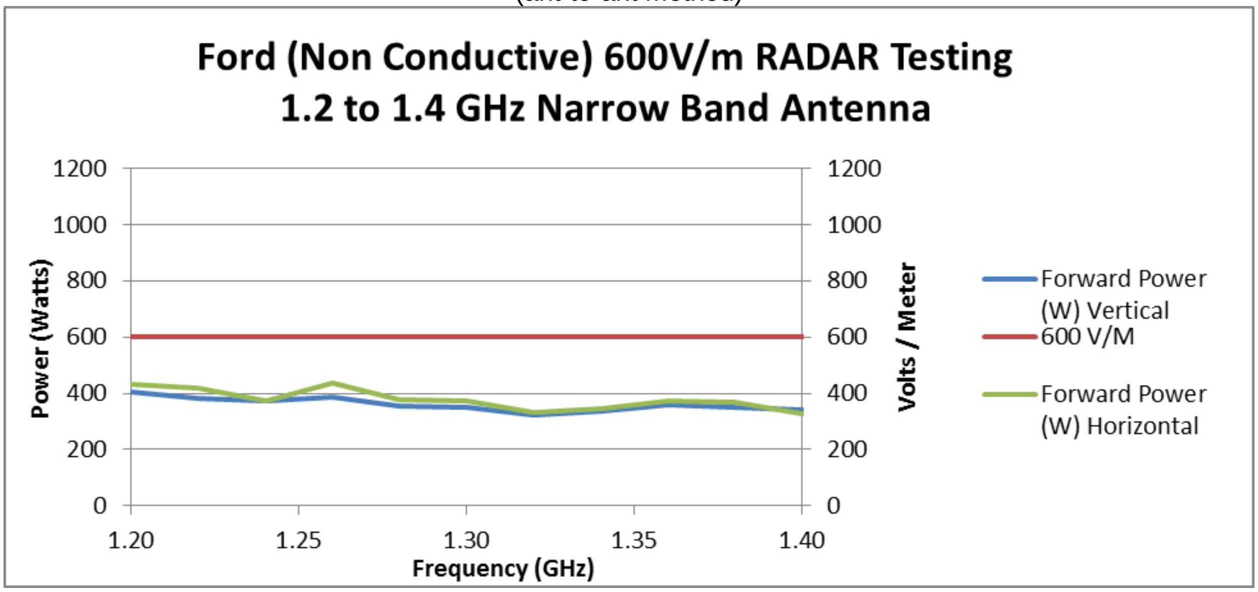

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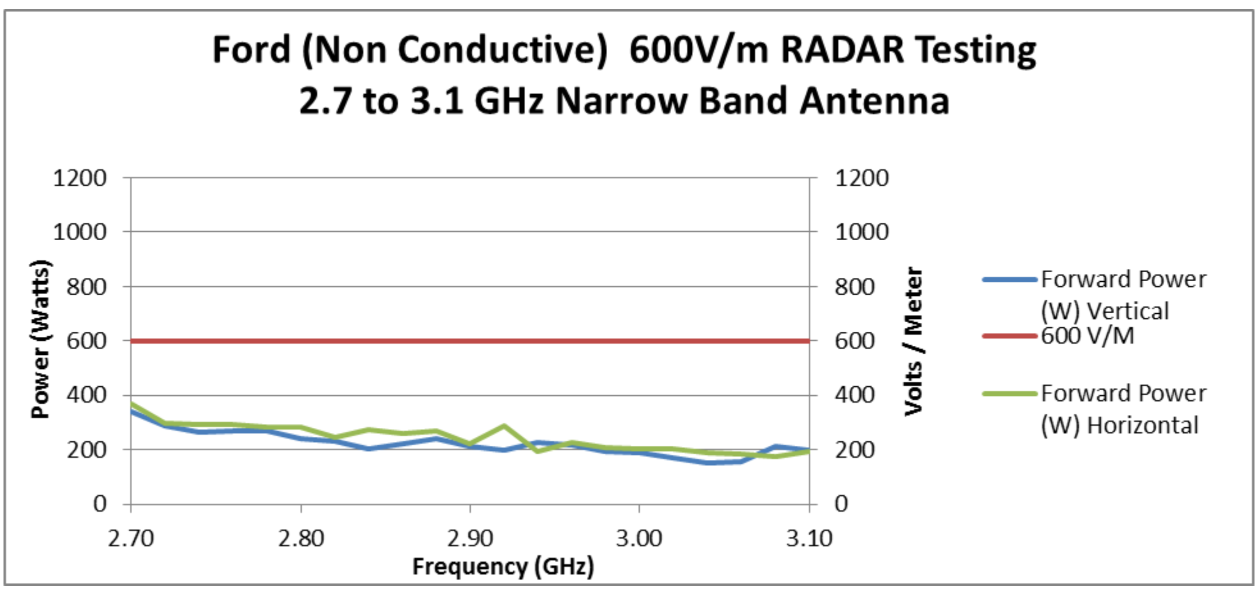

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Required Equipment –

Amplifier: Automotive 600 V/M Radar testing requires high power CW and Pulse RF power. IFI's dual mode amplifier, S31-500-900P, the best of both worlds. It supplies both CW and Pulsed (at a higher levels than CW) to conform to both Ford and GM Standards operating from 0.8-3.1GHz instantaneously.
Antenna: Broadband Antenna for ease of testing *or* High Gain narrow band which requires less power at the input of the antenna to achieve the specified field
Cable: It is always recommended that RF Cables be as short as possible to minimize insertion loss and maximize the deliverable power to the antenna.

.***Preferred Approach # 1:***
Broad Band Dual-Mode Amp IFI Model S31-500-900P (0.8-3.1GHz Instantaneously)
with a broadband antenna having a nominal dBi gain of 12 or greater
CW or Pulse Signal Source
Pulse Generator
Spectrum Analyzer or Peak Power Meter
External Dual Directional Coupler

Preferred Approach # 2:
Broad Band Dual-Mode Amp IFI Model S31-500-900P (0.8-3.1GHz Instantaneously)
with high gain narrow band antennas
CW or Pulse Signal Source
Pulse Generator
Spectrum Analyzer or Peak Power meter
External Dual Directional Coupler

Preferred Approach # 3:
Broad Band CW Amp IFI Model S31-1000 (0.8-3.1GHz, 1000 watts Instantaneously)
with broadband or narrowband antennas having a nominal dBi gain of 12 or greater
CW or Pulse Signal Source
Pulse Generator
Spectrum Analyzer or Peak Power meter
External Dual Directional Coupler

Summary –

The S31-500-900P (0.8-3.1GHz instantaneous power amplifier) Dual-Mode Amplifier is an excellent solution for automotive radar pulse testing & general testing services. Although the radar pulse requirements can be achieved with various power level amps and antennas, the S31-500-900P was designed and configured to acceptably satisfy the automotive requirements. These standards can be met with typical lab broadband antennas so no additional hardware is required and therefore greatly simplifying the overall testing process for labs and manufacturers.

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