APPLICATION NOTE: 101

Selection and Operation of RF Power Amplifiers for EMC Testing Applications

Introduction:

In our previous article, **RF Power Costs Money, How Much Do You Really Need?**, we briefly explored the basics of how to choose a power amplifier for your Immunity test applications. The information included antenna selection, determination of system losses and the corresponding minimum power required to generate the drive table. We also discussed the additional power required to linearly support the 5.1 dB increase in signal level from the 80% modulation that is applied during the actual test.

These are the highlights of the basic issues that will be addressed in greater detail in the following article:

- What is your regulatory burden? What level must you test to?
- What type of transmission transducers do you need? Antennas are used for Radiated Immunity and injection probes for Conducted Immunity.
- What is the system loss profile? How much power will be lost in the system before it finally reaches the antenna? (Coax, connectors, RF switches, etc.)
- How much power do you really need to properly run your tests? Don't forget to allow headroom for the additional 5.1 dB of modulation!
- Do you have a plan for routine maintenance of your amplifier and test system?

The chart in Figure 1 contains typical plots of antenna power requirements, power required to overcome the system losses, the additional 5.1 dB of power to accommodate the 80% modulation required by the test and the P1dB power level of the amplifier of choice for that particular system. Each of these factors will be referenced in their specific section within this article.

> *"Time to market is critical. Your EMC laboratory is a critical portion of the path to Market for your company's new products."*

What is your regulatory burden and what level must you test to?

Your regulatory burden is the overall envelope of product design, testing for conformity (archiving test data) and long term auditing to assure continued product conformity. The required tests will include primarily CISPR (U. S. and Europe), Japan, Korea, China, Australia and South America, the major variance countries.

The level of emissions and immunities are directly related to the installation location of the product, from well protected to unprotected electrical environments and the product installation class. Heavy industrial products allow for higher emissions, but must tolerate higher-level disturbances. The opposite holds true for consumer products, requiring lower emissions, but lower immunity or interference tolerance.

The Immunity standards require the use of RF power to generate the required test or disturbance levels. These levels are directly determined by the product installation class and installation location and are outlined in the Immunity standards. It is these test levels that principally determine the size requirement of the RF power amplifier, antenna and other transmission related items that will be used in the test system.

Time to market is critical and your EMC laboratory is a critical portion of the path to Market for your company's new products. Your company has invested in your laboratory to gain direct control of the regulatory portion of their marketing plan. You can help to maximize the return on that investment by selecting the most cost effective components which usually those with the lowest long term cost of ownership. A cheap price now may cost you later by limiting capability and unplanned down time from reliability problems. IEC testing does not provide for routine validation of your test system. However, Lab managers can routinely evaluate the system components for proper operation.

What type of transmission transducers do you need?

The next step in the selection process is to determine the type of antenna, clamp or other transducer that will be used. Antennas and field generators are typically used in Radiated Immunity applications and require a comparatively high level of RF drive power as compared to injection clamps and probes used for Conducted Immunity applications.

You will need to understand the antenna specifications and the printed catalog power curves normally published by the manufacturers. These are fairly accurate, but you should allow a significant power margin because that particular type of antenna may not perform the same way in your test system due to antenna VSWR and chamber coupling effects. Some manufacturers suggest adding 1 dB to the RF power drive levels just to be safe. The same amplifier that is used for radiated applications will usually be more than adequate for the conducted requirements.

> *"Antennas are more efficient at the upper frequencies requiring less power. Coax losses are proportional to frequency, with the losses increasing with frequency. These effects tend to balance allowing the use of a moderately priced coax cable."*

A plot of the typical power required at the antenna is shown in the yellow portion of the chart shown in Figure 1. This data is typically available from the antenna manufacturer. This information is imperative in determining the level of power required by a Radiated Immunity test system.

What is the system loss profile?

The size of your EUT will probably determine the length of the RF feed coax from the antenna to the penetration panel. Add this length to that of the feed from the amplifier to the panel and you will be able to account for most of the coax losses.

We believe that the coax should have a loss of no more than 1 dB at the low frequency end of the band. Most antennas are more efficient at the upper frequencies requiring less power. This is good, because the coax losses are proportional to frequency, with the losses increasing with frequency. These effects tend to balance allowing the use of moderately priced coax cable like LMR-600. Totally automated systems normally include a switch matrix. These losses must also be accounted for, but will generally be most significant at microwave frequencies above 1 GHz.

Lastly, you need to count the number of connector pairs starting at the amplifier chassis and ending at the antenna. A typical system has 3-4 pairs of connectors, the amplifier chassis, the test system rack output, the room penetration and the antenna. A loss factor of 0.1 db per pair is generally considered to be conservative for good quality connectors. Also, remember that connector losses increase with use as do coax cables subjected to constant stress at the connectors. Antenna connector and cable failures are typical since the antenna is subjected to constant changes in polarization, applying significant torque to the cable and connector. The loss of this connection increases faster than others in the system.

Adding the sum of the coax, connector and switching losses will give you the loss profile. To be conservative, we suggest that you add 1 dB to this total. This will adequately cover any unaccounted for losses and degradation of system components over time. The power amplifier rating must include enough extra power to overcome these losses. You can see how this effects the amplifier power requirements in the Green plot portion of Figure 1.

How much power do you really need to properly run your tests?

With the system loss profile and the antenna drive power requirements, you can calculate the RF power required to develop the drive table for the required field level. Equally important and generally more problematic, is understanding the requirements to support the 80%, 1 kHz modulation that is required

> *"The 80%, 1 kHz amplitude modulation adds about 5.1 dB to the peak power level requirement of the system and the amplifier must still be linear to faithfully reproduce the modulation peaks!"*

during the actual test. This amplitude modulation adds about 5.1 dB to the peak power level requirement of the system and the amplifier must still be linear to faithfully reproduce the modulation peaks!

Using an undersized amplifier forces the amplifier to operate above its linear power rating. In addition to clipping the modulation peaks, which in itself invalidates the test, it severely stresses the amplifier. Operation outside of the safe operating area makes the amplifier vulnerable to failure into high VSWR conditions which are common when driving broadband antennas in Radiated Immunity testing. We believe that this situation is often the basis for what users generally assumed to be reliability problems associated with tube type and solid-state amplifiers used in EMC applications.

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The chart below (figure 1) graphically illustrates the four key power levels that are critical to the successful design of a 20 V/M Radiated Immunity system using a Biconical antenna. The individual power levels are color coded as follows:

- Yellow – RF power required at the antenna to generated a specific field at a specified distance
- Green - RF power required to overcome system losses
- Light Blue - RF power required to support the 1 kHz, 80% AM modulation (+5.1 dB)
- Purple - The linear RF power rating (P1dB) of a proposed RF amplifier

The yellow curve indicates the power required by an antenna to make a specific field level at a specific distance. This data was taken directly from the manufacturer's published sales literature. For this example, lets use the 80 MHz data, so the RF input power at the antenna input is about 17 watts.

The Green curve indicates the power required to overcome the system losses from coax, connectors, and overhead loss factors that are assigned for this example:

- 1.0 dB for antenna VSWR (per manufacturer's recommendation)
- 1.0 dB for system for overhead losses (for added headroom)
- 0.5 dB for coax and connector losses

The total calculated system losses at 80 MHz are about 2.5 dB, increasing the RF power requirement to about 31 watts. This is the power level required to successfully create the drive table data for this frequency.

The light blue curve indicates the minimum power requirement to produce the required field with the 80%, 1 kHz modulation. This level is about 5.1 dB (3.24 X) above the 31 watt level required to create the drive table, which equals about 100 watts!

The purple curve shows a straight line assumption of the linear (P1dB) power specified by the manufacture of the amplifier used in this example. Actual data can be used if available. This is very helpful in situations where additional power is desired or actually needed to make field with the 80%, 1 kHz modulation present.

After completing this exercise, it is clear that all RF power factors must be understood and included in the RF power calculations to provide for a fully capable and reliable Radiated Immunity test system.

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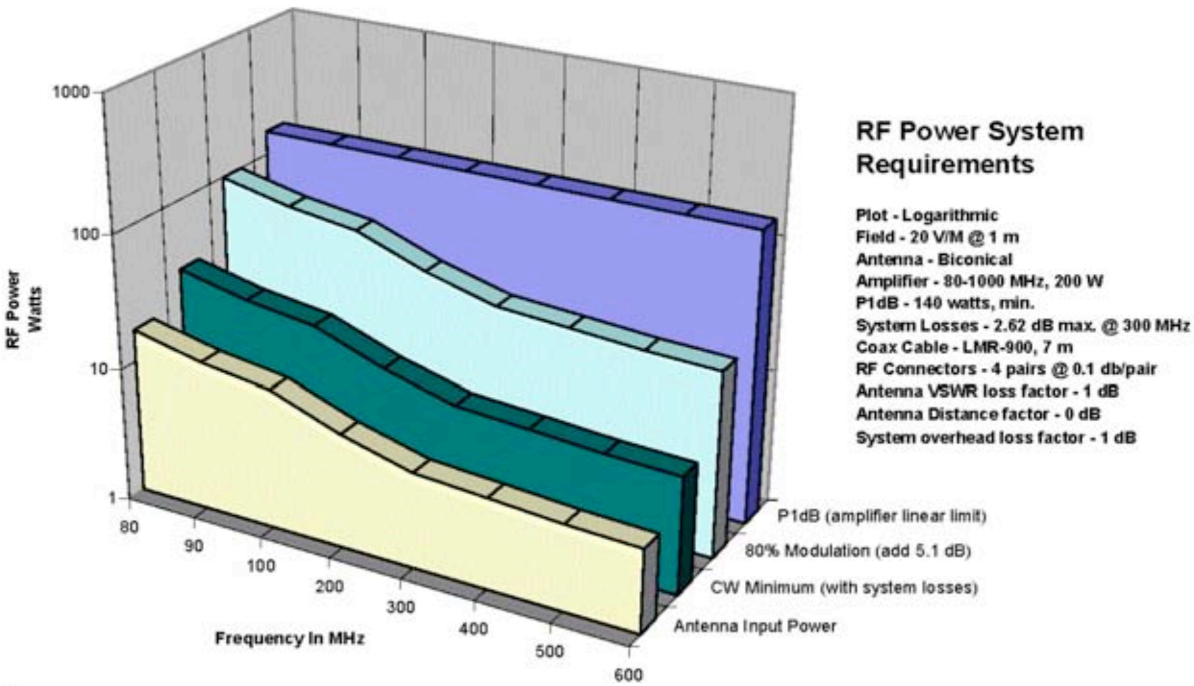

Notes:
1. Antenna drive data is taken from the Manufacturer's published specifications (derived from AF)
2. CW minimum power level calculation includes losses from coax cables, connectors, antenna VSWR loss and distance factors, and system overhead (as applicable)
3. 80% modulation level increases the power required by 5.15 dB = 10log $(1.8)^2$
4. P1 dB is the linear power rating of the amplifier at 1 dB compression

Figure 1

Do you have a plan for routine maintenance of your amplifier and test system?

Radiated is uniquely hard on RF power amplifiers, so they require routine maintenance. Your Cal Lab should test them annually and compare the fresh data with the original manufacturer's production test data supplied with the amplifier system.

Be sure to archive your test data for the test equipment in your systems, especially the RF power amplifiers. You must track the amplifier's performance over time. We like to recommend simply comparing drive tables. Run new drive tables at least once every 6 months and compare them with your original drive tables for that particular system. This comparison will tell you if the drive levels are increasing, indicating that the system performance is declining. This is a good time to evaluate the performance of your RF power amplifier as well as the rest of your system.

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There are several other components that also require routine maintenance:

- Turntables (bearings, gears and digital position sensor)
- Towers (bearings, belts, air cylinders)
- Shield room doors (hinges, latches, sealing fingers)
- Antennas (Integrity of elements, balun and RF connector)
- Coax cables and connectors (Connections fail from constant movement)

Summary

RF power amplifiers are probably the least understood and poorly treated asset in your laboratory. Systems are routinely underpowered causing the amplifiers to be driven hard into varying and mostly high VSWR loads. Although tube amplifiers are famous for withstanding this environment, they as well as their solid state counter parts slowly degrade with time. A simple routine maintenance program will assure that your system is performing as designed, thereby maintaining the integrity of your testing qualifications.

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