Multicarrier Compatible (MCC) Technology™

Optimizing linear power and mitigating 'Memory Effect' On GaN Solid State Devices/Amplifiers Used in Multicarrier Applications

Produced by: the CPI Satcom Products Group

EXECUTIVE SUMMARY

- **Memory Effect is a phenomenon that can negatively affect linear RF power output, primarily when GaN amplifiers are used in multicarrier applications.**
- **The degree to which output power is affected is determined by tonal spacing and number of carriers.**
- **CPI has mapped this behavior using IMD sweeps and spectral regrowth charts.**
- **CPI has implemented this technology on its newest GaNLink™ line of CPI products to mitigate the effect. Other manufacturers may or may not be aware of this issue.**

INTRODUCTION

Over the past 5-10 years, gallium nitride (GaN) technology has become an increasingly popular selection for those wishing to purchase solid state high power amplifiers (SSPAs) for satellite uplink applications. GaN-based SSPAs have not only supplanted traditional applications dominated by their gallium arsenide (GaAs) based predecessors, such as the maritime and milsatcom markets, they have also been readily considered for wideband and multi-carrier applications long dominated by TWT-based amplifiers (TWTA). This is all possible because GaN devices are capable of providing a power density that GaAs devices cannot, on a more cost effective basis. However, a challenge has arisen for SSPA manufacturers selling into these new multi-carrier and wideband markets: a phenomenon which directly impacts the linear performance of SSPA transmissions, dubbed "memory effect."

The end result of memory effect is that it impairs the expected intermodulation performance of the HPA, sometimes by as much as 10 dB. This requires the user to back off the output power by more than the expected amount, negatively impacting the link budget and/or the overall performance of the earth station. Memory effect is not necessarily limited to GaN devices. It can also affect GaAs based SSPAs. However, GaAs SSPAs are more resilient due to fundamental device physics. The effect has never manifested itself in TWTAs, at least to a significant or measurable level.

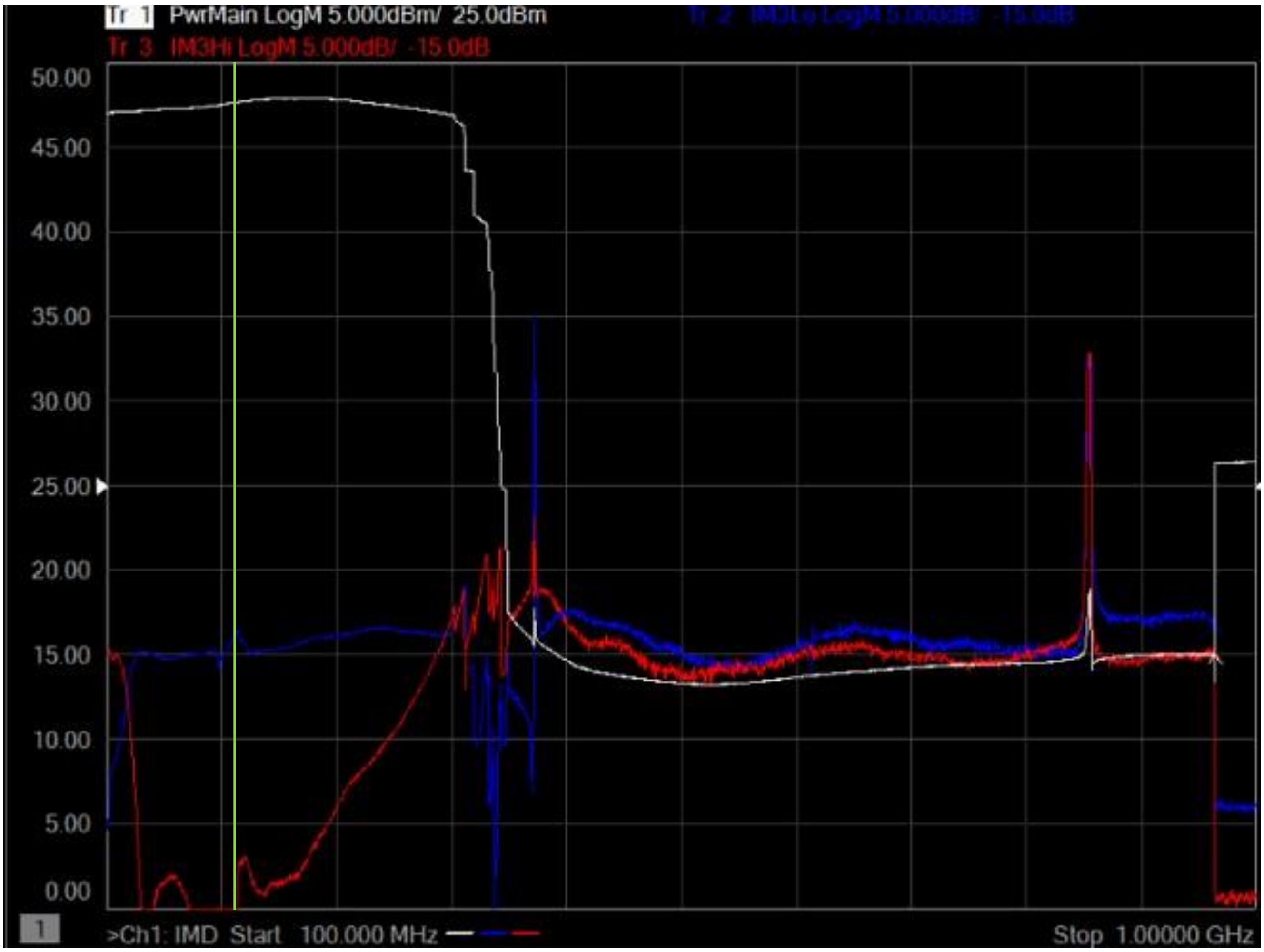
HOW DOES MEMORY EFFECT OCCUR?

The severity of memory effect is determined by the manufacturing layout selected during the design and production of solid state devices/MMICs, and its interaction with the carrier spacing utilized in actual transmission. Carrier spacing has a significant effect on the level of intermodulation distortion (IMD) when the device is not sufficiently broadband. Furthermore, the addition of more carriers multiplies the effect.

The real world impact is that when reviewing an IMD specification on a product datasheet, the general statement of compliance to “below -25 dBc” up to the specified Plinear operating point appears to show compliance because it assumes a very “coarse” IMD product. However, during these resonance events, the increase in IMD is typically sharper, thus ending up in poor linearity performance, requiring further backoff to compensate.

The following are actual snapshots of two IMD sweep tests performed on a CPI GaNLink™ 160 W Ka-band GaN-powered BUC: one taken prior to the implementation of MCC-Technology™ (Exhibit 1 and 2, 5 and 6, 8), and the other taken after implementation of the MCC-Technology™ (Exhibit 3 and 4, 7).

Exhibit 1: PNA-X IMD sweep, two tones from 100 to 1000 MHz spacing
BEFORE MCC-Technology applied,
X-axis: tone spacing
Y-axis: dBm (output power) and dBc (intermods)
white trace: amplifier output power
blue and red traces: left and right intermods
(Note each horizontal division represents 90 MHz)



The vertical green line indicates the point in the sweep when the tones are 200 MHz apart. The Y axis shows the output power in white (dBm). For the sake of scaling the graph, the IMD products (dBc) are actually 10 dB lower than the labels on the Y-axis. For instance, where tones are 100 MHz apart on the far left, IMD = -25 dBc, not 15 dBc.

At this point in the sweep, usable linear power is still acceptable (around 47 dBm, or 50 W), however the left (blue) intermod IMD has crept just above -25 dBc while the right (red) intermod is very low. Exhibit 2 on the next page shows how the 200 MHz spacing manifests itself in the spectrum analyzer view. Note that IMD is output power minus peak intermod.

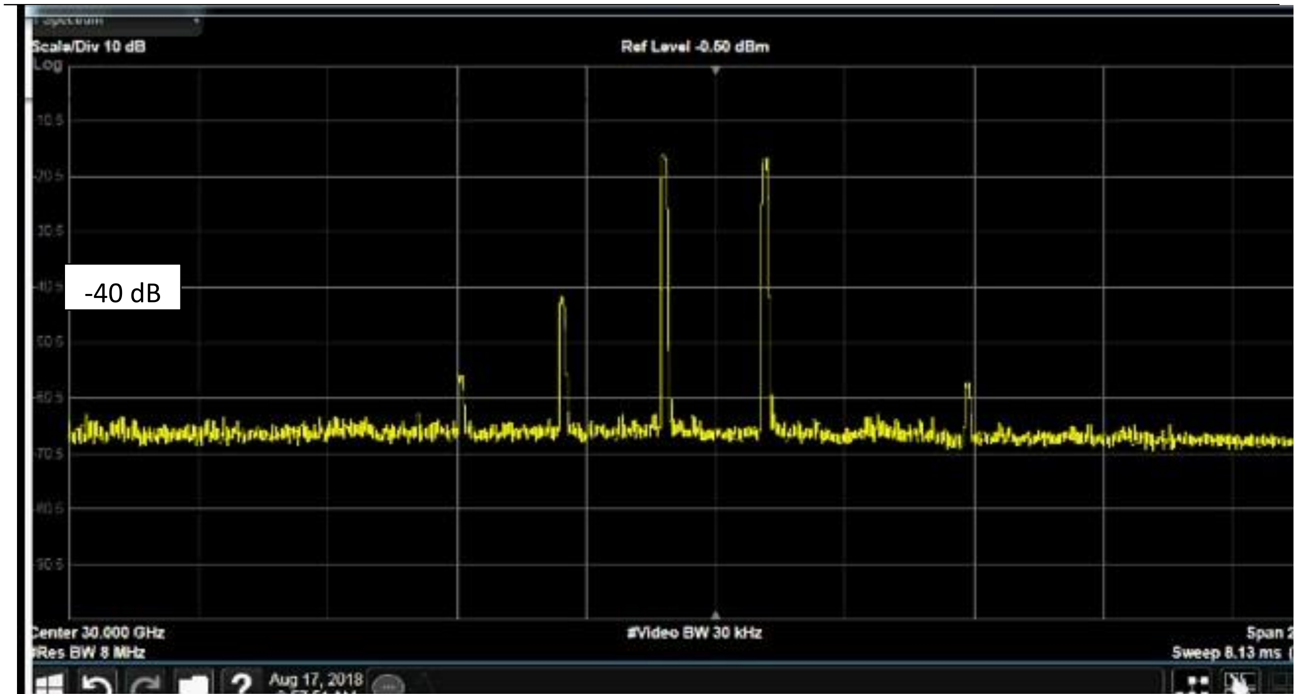
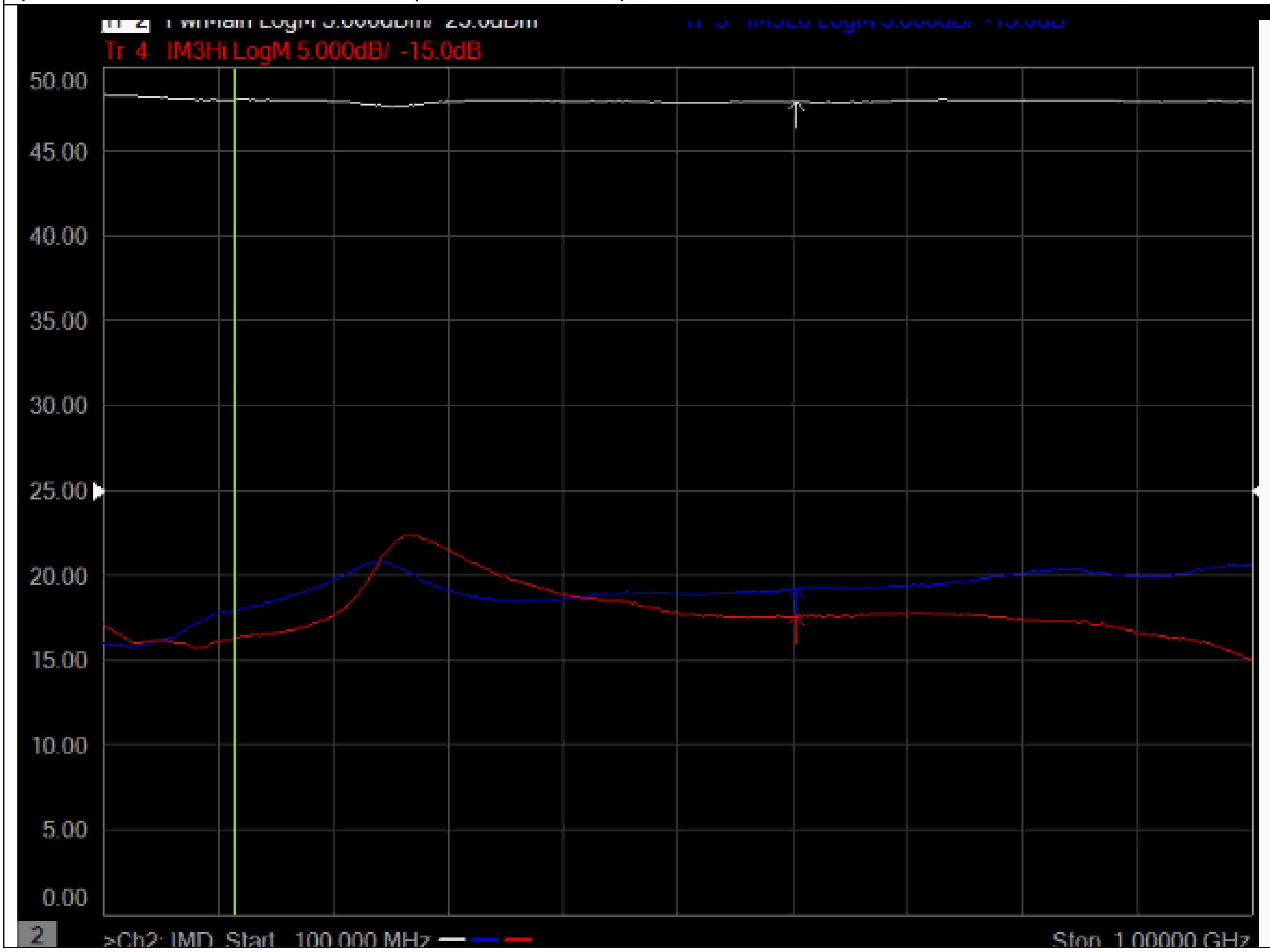


Exhibit 2. Spectrum Analyzer, before MCC-Technology, tones 200 MHz apart.
The two tallest spikes are usable output power, which is expected, while the nearest left spike shows the intermod (also shown in Exhibit 1, in blue). The right intermod (which is in red in exhibit 1) is in the noise on the sweep here. The difference between the carrier signal and the left intermod is approx. -25 dB.

Exhibit 3. PNA-X IMD sweep, two tones swept from 100 to 1000 MHz apart
MCC-Technology Applied
X-axis: tone spacing
Y-axis: dBm (output power) and dBc (intermods)
white trace: total HPA output power
blue and red traces: left and right intermod, respectively
(Note each horizontal division represents 90 MHz)



The beginning of this sweep shows the Ka-band HPA AFTER application of MCC-Technology, when the tones are 200 MHz apart (indicated by the green vertical line).

The intermods are now behaving as expected. This is confirmed on the spectrum analyzer view (Exhibit 4)..

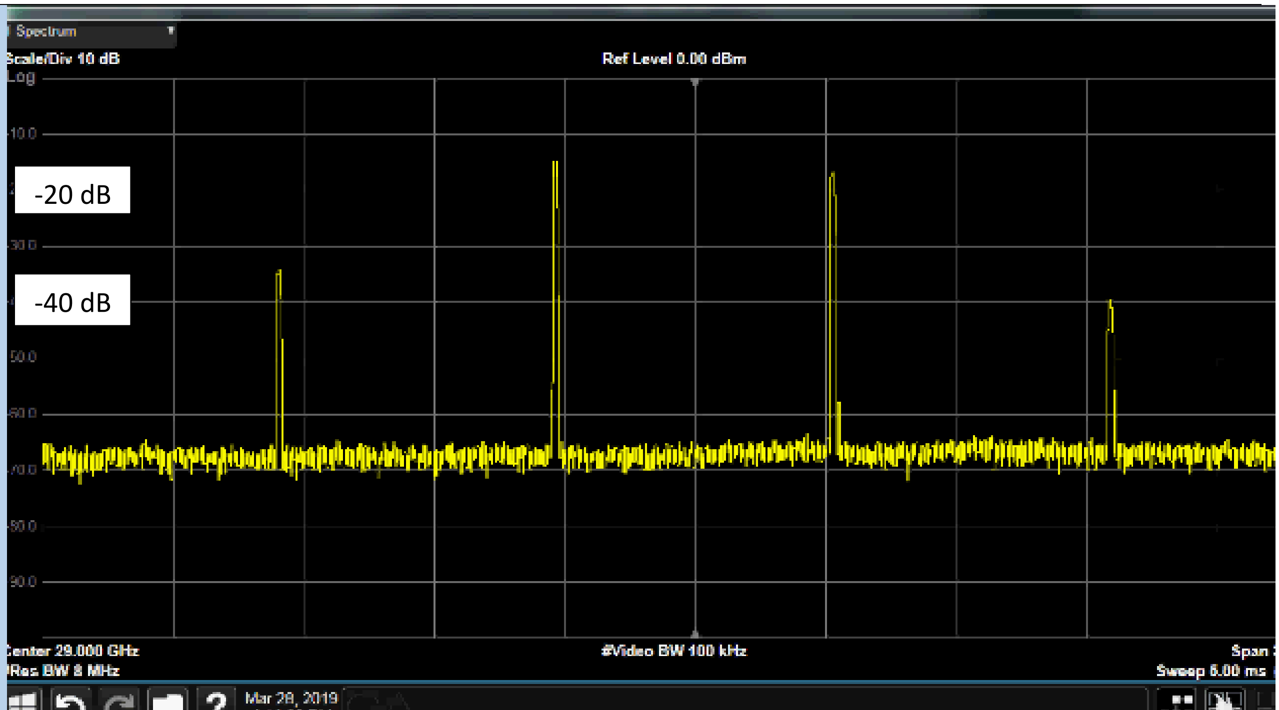
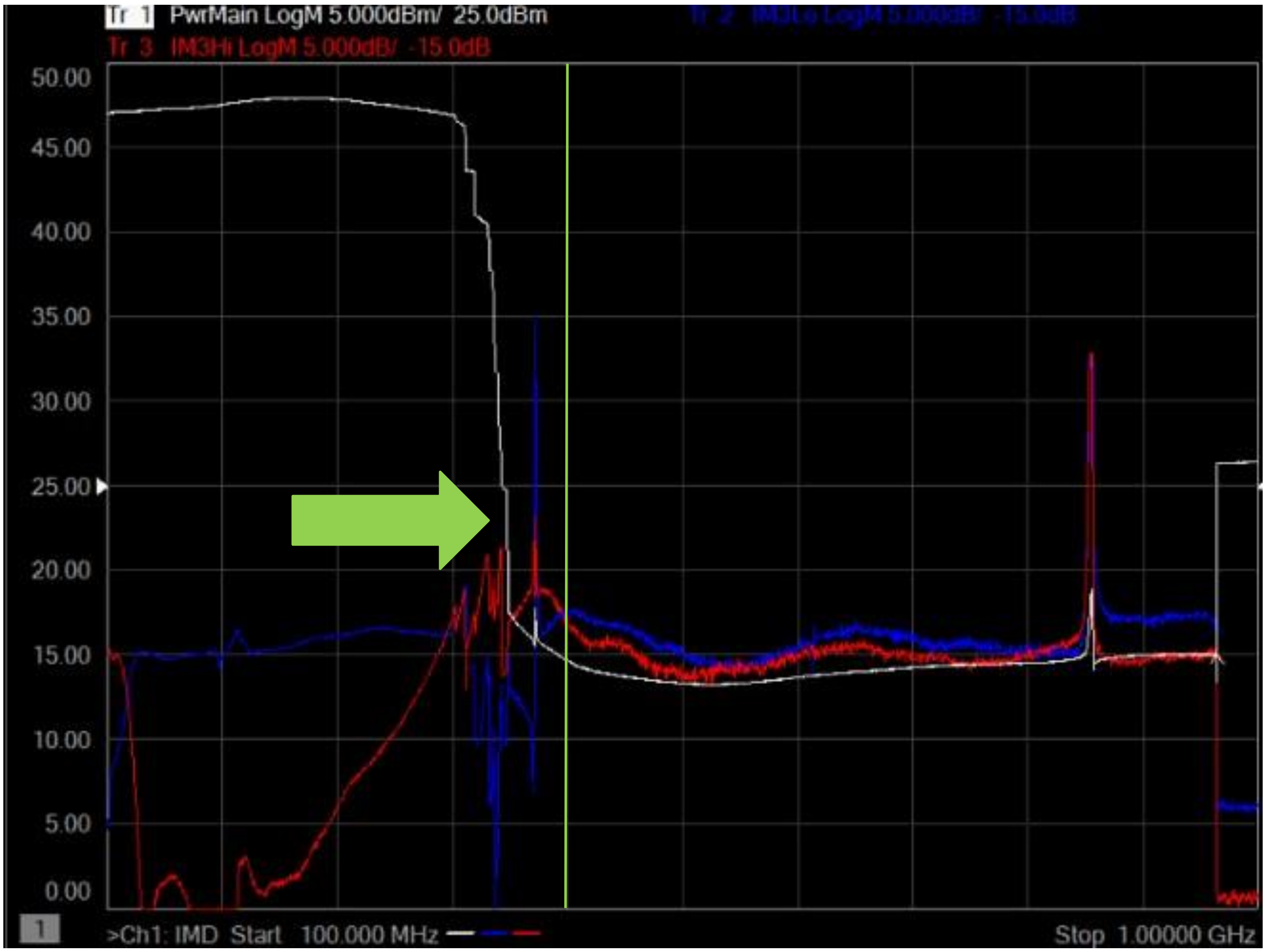


Exhibit 4. In the improved HPA, the two carriers show output power, and the two intermods are reasonably close to each other in output. Difference between the signals and intermods is around -22 dBc.

Exhibit 5. PNA-X IMD sweep, two tones swept from 100 to 1000 MHz apart
BEFORE MCC-Technology applied
X-axis: tone spacing
Y-axis: dBm (output power) and dBc (intermods)
white trace: Total HPA output power
blue and red traces: left and right intermod
(Note each horizontal division represents 90 MHz)`



Now observe the middle of the sweep (indicated by the green line) for the unimproved amplifier (Exhibit 5 above). Between the 3rd and 4th horizontal division (~400MHz) there is a big event (indicated by the green arrow) which one can refer to as “the resonance.” The IMD spikes up quite sharply, almost to the same level as output power, demanding a huge change in power from the power supply, which causes the HPA to self-protect. Some of the FETs turn off during this event, thus the output power (white trace) has dropped significantly.

Exhibit 6. For the unimproved HPA, the spectrum analyzer shows the smaller differences between the signals and the intermods.

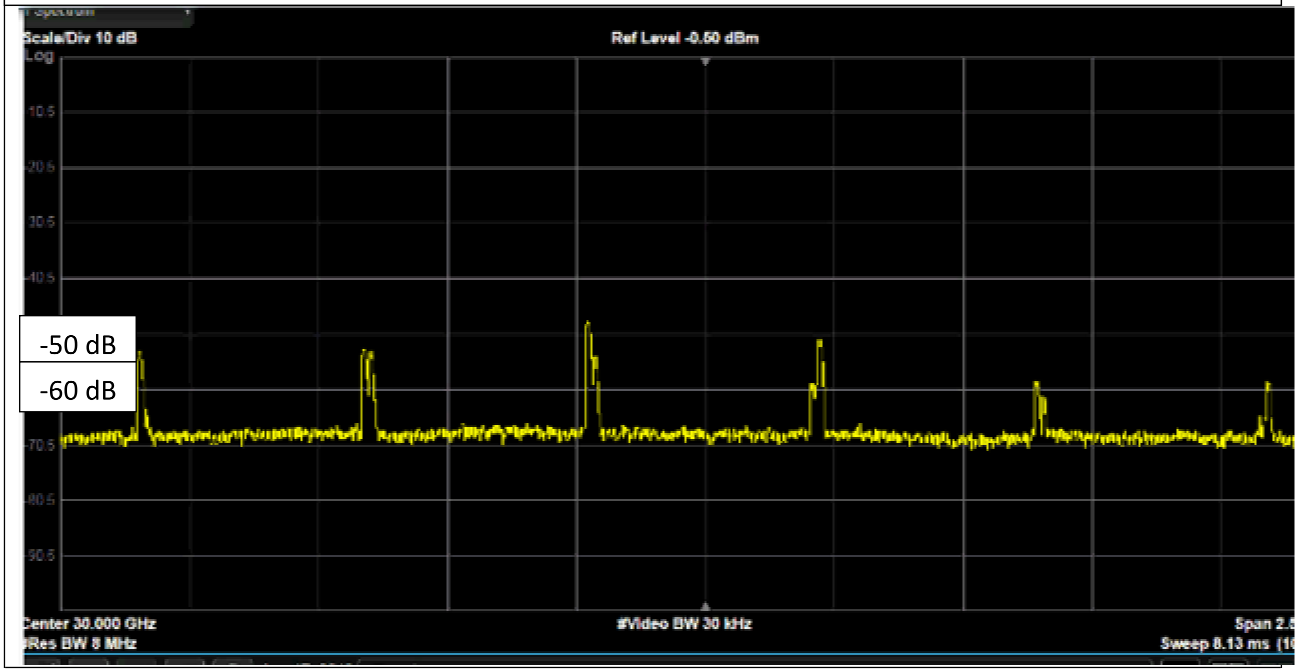


Exhibit 7. PNA-X IMD sweep, two tones from 100 to 1000 MHz apart
MCC-Technology applied, middle of sweep
X-axis: tone spacing
Y-axis: dBm (output power) and dBc (intermods)
white trace: amplifier output power
blue and red traces: left and right intermod
(Note each horizontal division represents 90 MHz)

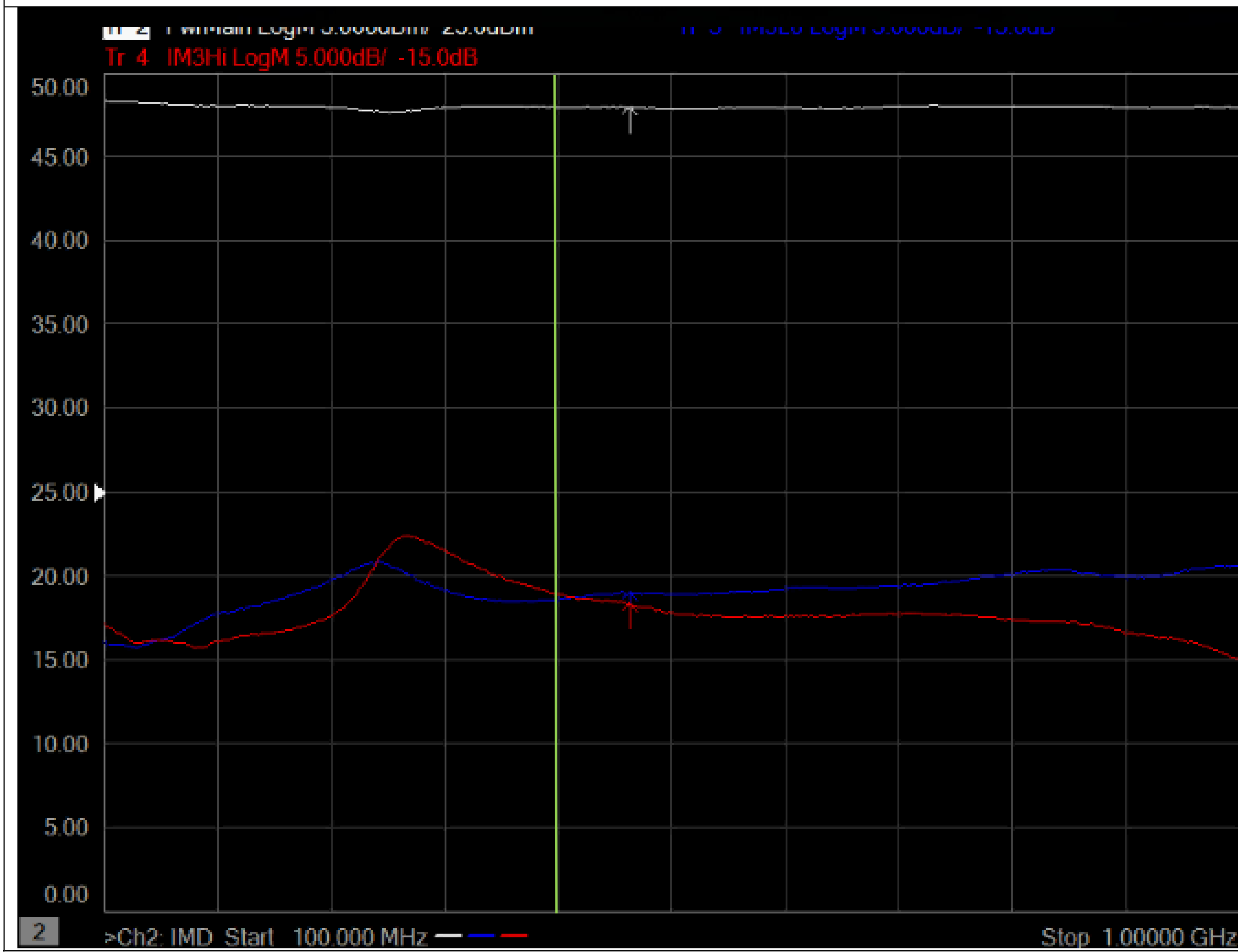
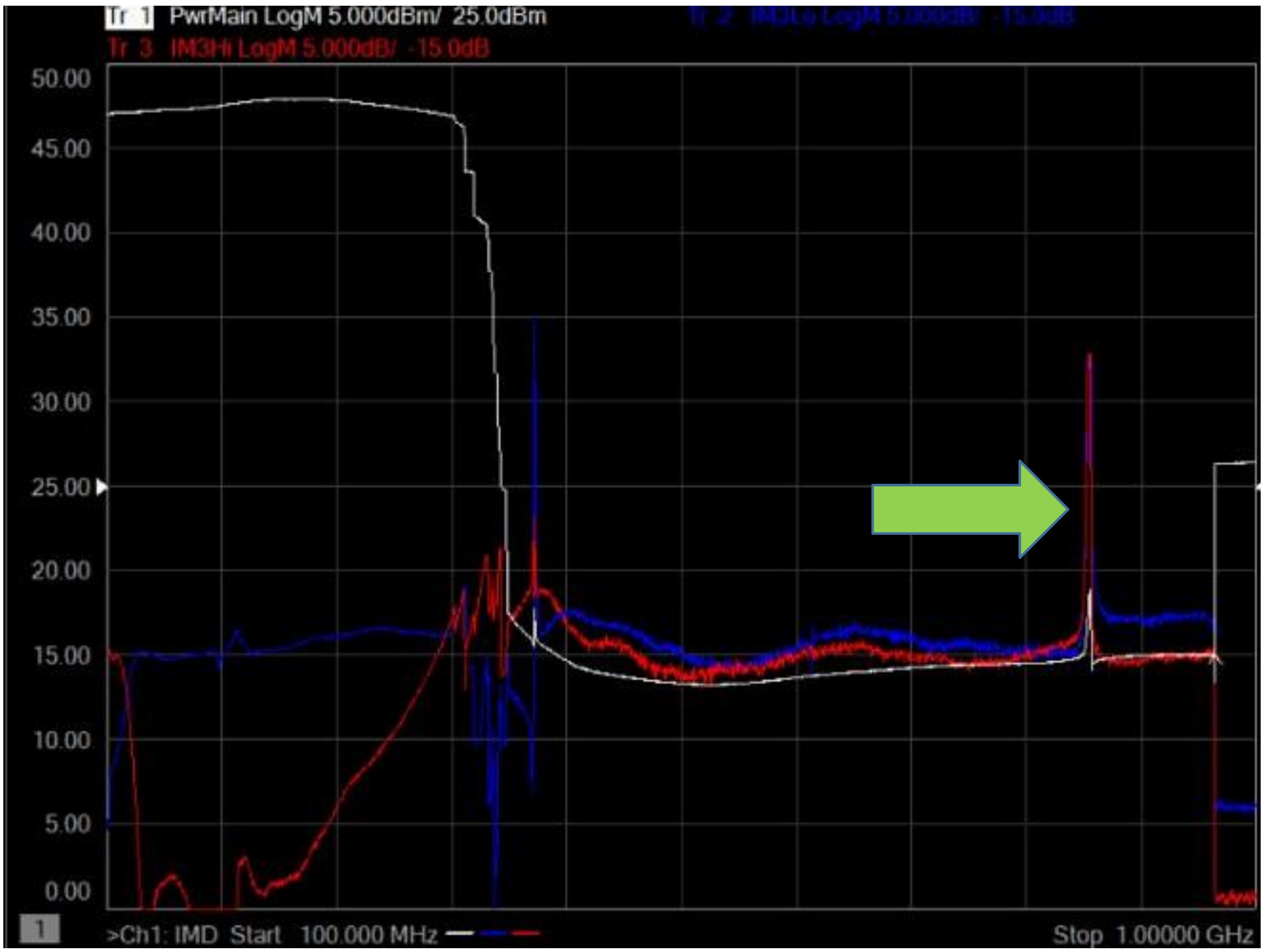


Exhibit 7 above shows that linear output power is quite stable, as it has been over the entire sweep so far (here the green line indicates the same point as in Exhibit 5), while intermods are behaving as expected.

Exhibit 8. PNA-X IMD sweep, two tones ~975 MHz apart
BEFORE MCC-Technology applied, end of sweep
X-axis: tone spacing
Y-axis: dBm (output power) and dBc (intermods)
white trace: amplifier output power
blue and red traces: left and right intermod
(Note each horizontal division represents 90 MHz)



The sweep for the unimproved HPA is almost complete (Exhibit 8). Once the resonance occurs in the middle of the sweep, the intermods begin to oscillate, and the growth of more intermods as the tones are spaced further and further apart keeps the HPA from operating at full linear power. Another resonance event (green arrow above) occurs when the tones are separated by about 850 MHz.

SUMMARY OF TESTING

For the improved HPA, the sweep and the spectrum analyzer continue to show expected behavior as in Exhibit 7.

What we see above is that for the unimproved amplifier, it behaves normally as long as the tones are close together, and the IMD (blue/red) traces are below -25 dBc on the Y-axis.

We have demonstrated that the phenomenon manifests when the tone spacing is wider. On product data sheets, the general statement of compliance to “below -25 dBc” up to the specified Plinear operating point appears to show compliance because it assumes a very “coarse” IMD product. However, during the resonance events displayed in this paper, the increase in IMD is typically sharper, thus ending up in poor linearity performance which require further backoff to compensate.

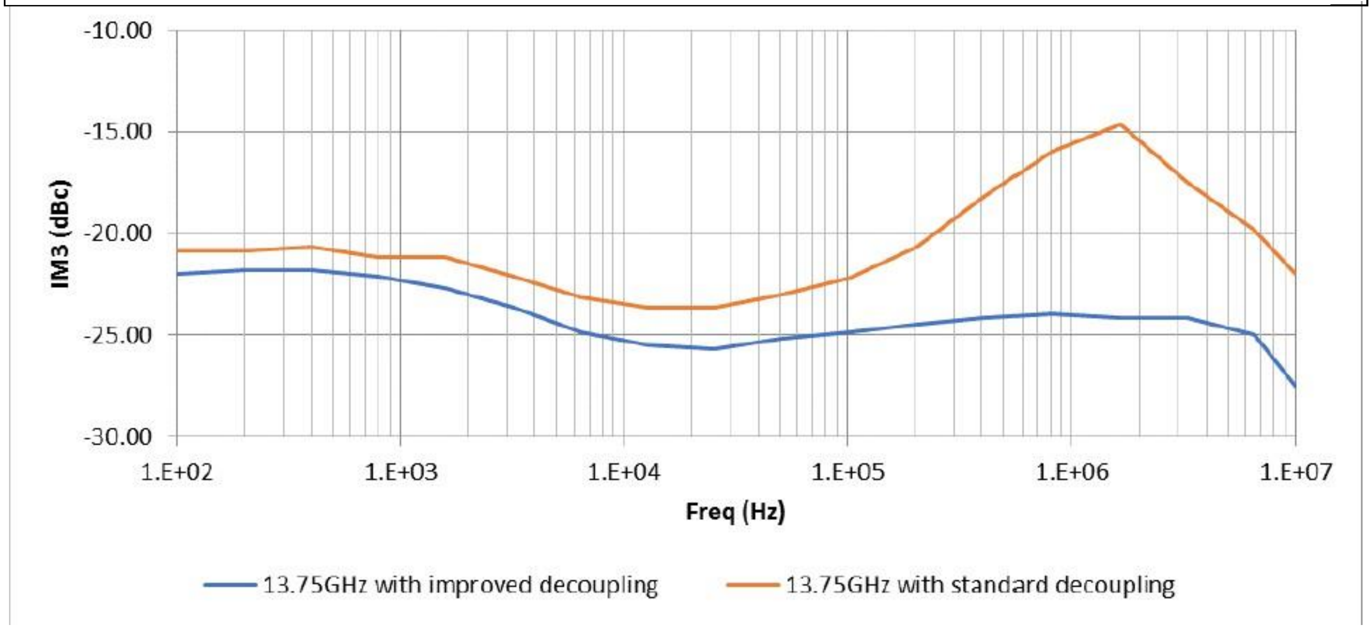
It should be noted that we have never seen this effect appear in TWTAs, and CPI has thousands of TWT- based HPAs being used in wide-band multi-carrier applications.

CPI has conducted further tests with GaN SSPAs and found that increasing the number of carriers compounds memory effect. The results shown in this paper are with only two carriers. However, for CPI SSPAs with MCC-Technology, memory effect has been reduced and the amplifiers perform as they should, including in multicarrier applications.

System designers should be aware of the threat that unmitigated memory effect is to linear EIRP and should take the necessary steps to ensure that any HPA they are considering is properly designed for wide-band multi-carrier applications.

The graph on the next page shows the results for a FET used in the CPI 80 W Ku band SSPA.

50 W Ku-Band Amplifier – Improvement in IMD via application of MCC-Technology



CPI SOLUTION

CPI has decades of experience producing amplifiers that are used in broadband, multi-carrier environments. CPI has been able to apply that knowledge in the development of its GaN based products, to fulfil the promise of exciting GaN technology. There are many products available on the market that provide a simple specification to make it appear that they will function well in an uplink system. However, satcom technical requirements are more complex and nuanced. Complex transmission schemes require state of the art technologies coupled with advanced engineering.

CPI has invested significant resources to study the problem in an effort to produce a product that can reliably operate no matter the transmission type, resulting in our Multi-Carrier-Compatible (MCC) Technology™ package. These efforts include (but are not limited to):

- Unique design methodology
- Meticulous manufacturing techniques
- Thorough component processing and screening
- Rigorous qualification testing

…and ensure that CPI's GaNLink line of BUCs are ready for any multicarrier application.

Not all GaAs and GaN amplifier devices behave the same way. Some are less impacted than others. Therefore selecting the best GaN devices is also key to the overall HPA performance. GaNLink™ BUCs from CPI with MCC-Technology™ technology ensure that you can say no to excessive backoffs to achieve your linearity targets for GaN amplifiers.

For more information on CPI's MCC-Technology™ or our latest GaNLink™ line of amplifiers/BUCs, and amplifier technology in general, please do not hesitate to contact your local CPI sales office. Visit us at www.cpii.com/satcomsales to find the CPI office closest to you. Or Download the CPI Mobile app on iOS or Android.

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