Plasma vs. Solid State

A Discussion of the Tradeoffs of Gas Plasma vs Solid State Receiver Protector Technology

Introduction

This article addresses the advantages and disadvantages of gas plasma versus solid state microwave receiver protector (RP) technologies. By gas plasma, we are referring to RP's which employ TR Tubes and/or Pre-TR Tubes. All-Solid State products are normally Diode Limiters. A more detailed explanation of various RP technologies may be found in an earlier article entitled "Receiver Protectors: Theory of Operation" (RF Globalnet Newsletter – July 2019)

The prevailing view these days seems to be that, for a variety of reasons, an all solid state RP is always better than a gas based product. This, however, is not always the case. There may be times when a TR Limiter, for example, is a better choice than an all solid state product. The purpose of this article is to evaluate the tradeoffs in order to help the customer make an informed choice, when such a choice is possible.

The following discussion compares the technologies in broad technical areas. We wish to caution that, because the discussion below, necessarily, will be conducted in general terms, great care must be taken in applying it to any specific application. The requirements for each system application are unique and must be evaluated on their own merits. This should be done only by CPI EDB's technical staff.

Electrical Performance Characteristics

In recent years, great progress has been made in increasing the RF power handling capability of solid state limiters. A discussion of the specifics is beyond the scope of this article. However, it is safe to say that solid state receiver protectors may be used in many more applications today than they could years ago. It should also be understood that most applications continue to require receiver protectors with power handling capabilities that are beyond the state of the art for all-solid state products. Thus, by far, most applications will continue to need RP's with some gas plasma based element.

In spite of all the advances made in RP technology, the venerable TR tube still maintains its status as the RP element which gives the best value. They have a very great dynamic range. They can operate over a very wide range of input powers while still maintaining reasonable spike and flat leakage levels. TR Tubes are very forgiving. Gas based RP's usually sustain no permanent damage if over-stressed by even a moderate amount of excess RF power.

On the other hand, great care must be taken when operating solid state limiters. Diodes are not at all forgiving. In many state of the art applications where all solid state products are used, the RP is operating very close to its maximum power handling threshold. So, even a slight increase beyond the specified power rating could cause the product to burn out. Further, a good rule of thumb is that one can only expect about 15 - 20 dB of limiting from a single diode stage. Many diode stages are often required to replace a single TR tube, thus driving up insertion loss, cost, complexity, etc.

Active single pole - single throw switches (SPST) can be used as receiver protectors at power levels higher than passive diode limiters. However, this technique does have the disadvantage that the protector will be useful only against the synchronous signals from the system's own transmitter. It will do nothing to protect against asynchronous signals coming from outside the system. It is possible to combine active and passive operation in one product. But the passive operation will be at lower power levels.

Recovery time is a mixed bag. Although it is not always the case, in general, a diode limiter will

exhibit faster recovery times than a TR tube. This is especially true for wide pulse applications at low RF frequencies. However, just like a TR tube, the recovery time of a diode limiter will increase as incident power and pulsewidth increase. Pre-TR tubes, on the other hand, tend to recover much faster than diode limiters and can often be usefully employed in concert with them to produce a high power, fast recovery RP.

Any amount of protection can be provided with either technology. As noted above, it will usually require a number of diode stages to replace a gas tube. Therefore, it can be possible that, for a given amount of protection, an all solid state product will have higher insertion loss than a tube based product. This is more likely to be true as the frequency increases.

Out of Band Characteristics

When designing a radar system, the presence of "out of band" signals must always be considered. For purposes of this discussion, an "out of band" signal is a high power signal at a frequency outside the fundamental transmitter frequency range. Out of band signals can come from two sources:

1. Most transmitters generate some amount of "out of band" energy. This could be in the form of harmonics or the transmitter operating in an odd mode. Sometimes, the "out of band" energy is present only on an intermittent basis.

2. High power signals which reach your system from other, nearby systems.

High power "out of band" signals can be just as deadly to a receiver as "in-band" signals. Therefore, radar designers must concern themselves with the possibility of their presence and the effects they will have on the system.

Gas based receiver protectors, especially those containing a TR tube, are inherently good filters under high power conditions. All solid state devices, on the other hand, are not. Solid state products tend to protect only in the frequency range for which they are designed. Therefore, when the option of a tube or solid state protector is available, the radar designer should take into account the fact that an all solid state product may have to be supplemented with some type of filtering, whereas a tube based product may not. Thus, choosing an all solid state RP may also mean that the system has to bear the extra insertion loss and cost associated with an additional filter. On the other hand, the filtering present in a tube is part of its natural state and comes for free.

The above issues must also be taken into account when one is considering replacing a tube based product with an all solid state one. We have seen a number of instances where "out of band" signals were present in a system, but not recognized by the system designer because they were being masked (and being naturally protected against) by the TR tube. When this product was replaced by an all solid state device (which neither had nor gave any natural protection against "out of band" signals), the system ran into trouble as the "out of band" energy started burning out receivers and/or receiver protectors.

Environmental Factors

In general, both solid state and tube technologies are equally good in most normal operating environments. However, there are some areas in which the solid state technology is clearly superior. These are operating life and radioactivity.

Although shelf life is usually not an issue, gas based receiver protectors do have a limited operating life. Therefore, depending upon their design and operating characteristics, they must be replaced on a periodic basis. Properly designed and operated solid state products have no such limitation.

Another issue that is of more concern these days is radioactivity. Tube based products must be "primed" with a small radioactive source. CPI EDB's tube based products conform to US Nuclear Regulatory Commission regulations and, if properly handled, present no particular health risk to those who handle or use them. However, there is increasing worldwide sensitivity to the presence of radioactivity, as well as increasing concern about the disposal of spent tubes. This issue can make it difficult to operate gas based RP's in some areas. Solid state products, which are not radioactive, have no such problems.

Cost

The relative cost of a solid state product versus an equivalent tube based product is difficult to assess. There are many factors which can influence a product's cost. Each application must be evaluated on its own merits. In general, however, all solid state products tend to be more expensive than gas based products at higher operating frequencies and higher power levels.

Risk and Reliability

Accurate, formal reliability data for gas based receiver protectors does not exist. Therefore, formal calculations which compare the reliability of all-solid state RP products to gas-based products cannot accurately be made.

One way to make this comparison is to look at reliability from the point of view of serviceability. In other words, we can ask the question -- "Once a product is properly installed and operated in a system, how likely is it to perform its function without failing unexpectedly?"

From this point of view, both gas and solid state technologies are equally good, based on anecdotal evidence. In fact, most products that are returned for some defect come back because they were mishandled in the field, had a manufacturing defect, or reached normal end of life. Well-made products of either technology, properly installed in a system, virtually never fail unexpectedly.

While both technologies are equally reliable, they are not equally risk free. It is absolutely true that a tube based product tends to be more forgiving than a solid state product in the event of an unexpected occurrence, such as a power overload. Therefore, in the event that something should happen to cause the RP to be stressed beyond its specified design limits, it is far more likely that the gas based product will survive and continue to perform its function than the all solid state product.

Summary

Conventional wisdom is that all solid state products are, somehow, "better" than tubes -- whatever that means. In this article, we have attempted to show that this is not always the case. Certainly, there will be many applications in which all solid state is the best choice. But it is also true that there will be times when it is not. Receiver protectors are among the most complex and least understood microwave components. It is very important, when choosing a receiver protector for a new system or making a change to an old one, to carefully consider all aspects of its operating environment. Consultation with CPI EDB's engineering staff during the design phase of a new application will help greatly in preparing a proper specification for a suitable receiver protector which will identify and prevent future problems.

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