WHITE PAPER

High-Power Amplifier (HPA) Configuration Selection

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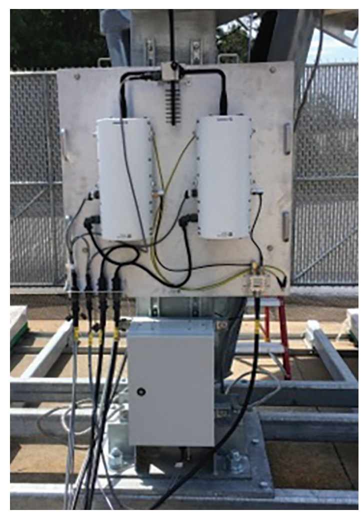
Abstract: *High Power Amplifier configuration is one of the most important decisions for Satellite Communication (SATCOM) systems. This paper will explore the pros and cons of using a Variable Phase Combiner (VPC) or a traditional waveguide switching configuration. While a VPC can provide double the power but not necessarily for double the price, a traditional 1:1 redundant system has its own advantages; and both have drawbacks. A summary of the pros and cons of the VPC and Traditional 1:1 configurations is discussed below.*

There are Many Aspects to Consider When Designing SATCOM Systems

Selection of the HPA configuration is one of the most important decisions in terms of price and ensuring data transmission. When working with systems engineers and HPA manufacturers, SATCOM engineers need to understand the two HPA configurations available: 1:1 (1 for 1) or 1+1 (1 plus 1) and the impact of either one on system performance. This paper attempts to help SATCOM engineers make more informed decisions when developing their HPA configuration.

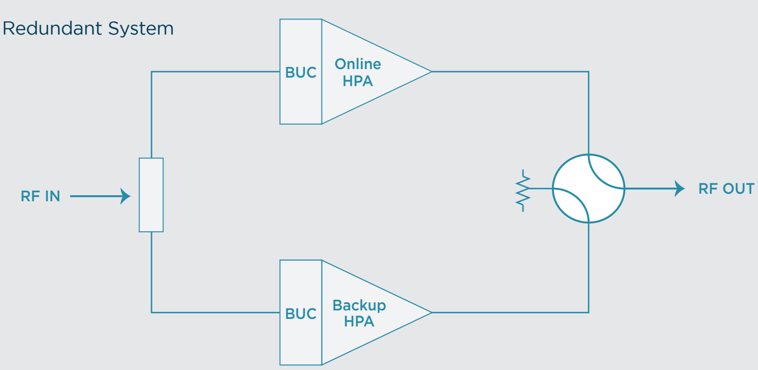
The Traditional 1:1 Redundant HPA Configuration

The more traditional HPA configuration is the 1:1 redundant system, as depicted in the simplified block diagram of Figure 1. This figure shows a configuration comprised of two identical HPAs with integrated Block Upconverters (BUCs) and a waveguide switching system. This is the most common configuration in today's SATCOM systems. The input signal is routed to the on-line HPA. If there is a failure in the on-line path, the redundancy control logic switches operation to the back-up (also referred to as the stand-by) HPA by first muting both HPAs, switching the output to the back-up HPA and then unmuting the now on-line HPA. The output of the faulted HPA is switched to the load. Switchover time comprises two components: 1) the switch time of the switch (typically 60ms) and 2) the loop time, which is the time it takes for the HPA to receive a fault message and subsequently send a voltage command to the switch. The loop time depends on the HPA logic and therefore varies from manufacturer to manufacturer. During the switchover period, there would be an effective loss of transmission and lock would be lost prior to the back-up HPA coming on-line.



Traditional 1:1 System

Figure 1: Block Diagram of 1:1 Redundant System



Advantages of 1:1 System

There are several advantages of a 1:1 system. They include:

- Simpler electronics than the 1+1 VPC system.
- Integrated BUCs that eliminate separate BUC system, thus lowering the weight and size of the system.
- Redundancy control can be built into the HPAs.
- Simpler design is less expensive than the 1+1 VPC system.

Limitations of 1:1 System

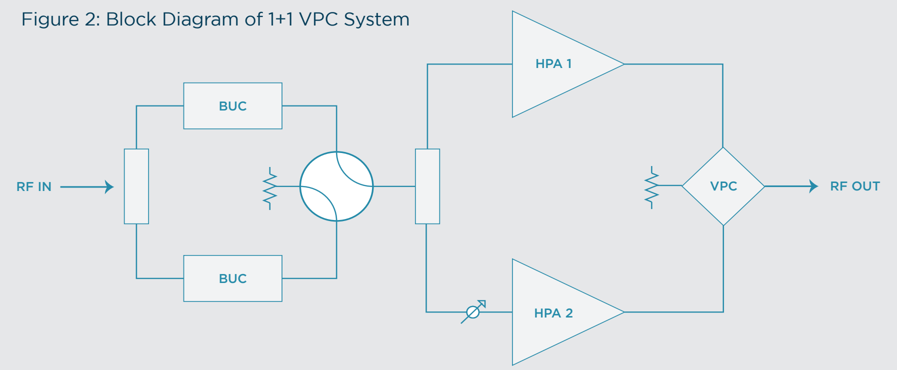
There are limitations of the 1:1 system that should be considered.

- The most significant limitation is that transmission is lost during the switchover period.
- There is degradation in system efficiency and reliability since the stand-by HPA is not being run and does not contribute to the system output power.
- An additional load switch is needed to switch the output off.

The 1+1 Variable Phase Combined System

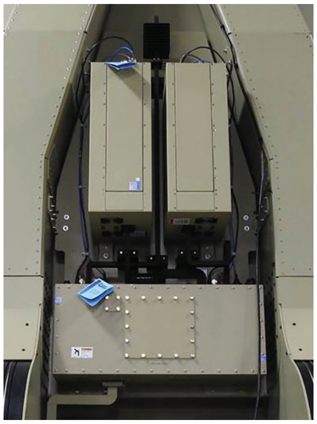
An alternate configuration is the 1+1 VPC system shown in the simplified block diagram of Figure 2. As shown, the BUCs are not integrated into the HPAs. Although theoretically possible, it is not recommended. The VPC can be adjusted to 4 positions:

Figure 2: Block Diagram of 1+1 VPC System



- Position 1: HPA 1 output to antenna and HPA 2 output to load.
- Position 2: HPA 1 and HPA 2 outputs phase (power) combined to antenna.
- Position 3: HPA 1 output to load and HPA 2 output to antenna.
- Position 4: HPA 1 and HPA 2 outputs to load.

Therefore, the 1+1 VPC system has 2 operational modes: power combined (1+1) mode and 1:1 mode. The maximum switching time between adjacent positions of the VPC module is 30ms. Fault detection and VPC drive is estimated to require an additional 10ms. In the 1+1 mode (VPC in Position 2), the recovery modes are Position 1, if HPA 2 goes off-line and Position 3, if HPA 1 goes off-line. The maximum switchover time in this operational mode is 40ms since the recovery is between adjacent positions of the VPC. In the 1+1 mode, if one of the HPA goes off-line (i.e., has a failure), the system output power is initially reduced by 6dB from the original combined power. After the single-position VPC change is completed, the system output power recovers with operational gain and power 3dB lower from the combined output gain and power. Since the power is only reduced, and not lost, a VPC system can be considered a soft-fail system. For some demodulators, this allows them to maintain lock and results in no interruption of service.



VPC System

Operation in the 1:1 mode is the same as the 1:1 redundant system previously addressed with the VPC in the either of the following positions:

- Position 1 (HPA 1 on-line) switches to Position 3 if HPA 1 goes off-line.
- Position 3 (HPA 2 on-line) switches to Position 1 if HPA 2 goes off-line.

In the 1:1 mode, the VPC module is being used to transition between the on-line and off-line HPAs and no actual waveguide switching is involved. A two-position VPC change is necessary to react to a fault in the 1:1 mode. Therefore, the maximum switchover time in this mode is 80ms. If the system is initially configured in the 1:1 mode with both HPAs operational and the system is phase aligned, a switchover does not result in transmission loss and lock on the satellite would be maintained. During the switchover period, the system output power would be the combined output (1+1) power, i.e., a 3-dB increase. After the switchover period, the system output power would recover 3dB lower to that of a single HPA. However, if the switchover is the result of an HPA fault, the output power would drop since the faulted HPA would automatically shut down. During the switchover period, there would be an effective loss of transmission and lock would be lost prior to the stand-by HPA coming on-line.

The mode of operation of the VPC system is dependent on the VPC configuration prior to enabling auto-switching. To configure operation in the 1:1 mode, the operator would select HPA 1 (or HPA 2) to the antenna and HPA 2 (or HPA 1) to the load. Once the system is configured, auto-switching is then enabled. With a fault in the on-line HPA, the system would reposition the VPC to bring the off-line (i.e., back-up or stand-by) HPA online by routing its output to the antenna and the faulted HPA output to the load. To configure the 1+1 mode, the operator would select both HPA 1 and HPA 2 to the antenna. With a fault in either of the HPAs, the system would reposition the VPC to route the other HPA output to the antenna and the faulted HPA output to the load.

In both modes, selection of Position 4 causes the combined power to be directed to the load and the output signal to the antenna to be near zero, assuming correct phase and gain adjustment of the system.

Figure 3 shows the output power transitions for the 1:1 redundant system and 1+1 VPC system assuming an on-line HPA fault. As previously discussed, in the 1+1 VPC system there is only a reduction in output power and service is not interrupted. Whereas, in a 1:1 redundant system, there is a loss of output power and service is interrupted during the switchover time.

Table 1 provides the typical gains relative to the HPA output for VPC systems operating at C-, X-, Ku-, DBS- and Ka-Bands. The first column provides the combining gain when the VPC is in Position 2. The single port pass-through gain (i.e., 1:1 mode when the VPC is in Position 1 or Position 3) is provided in the second column.

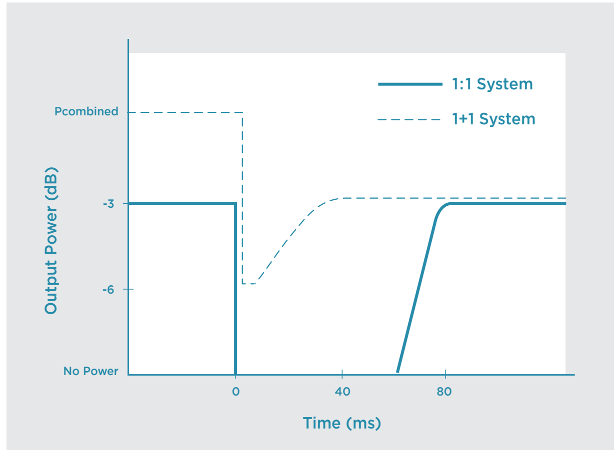


Figure 3: Switchover Time for 1+1 and 1:1 Systems

	1+1 Mode System Gain Relative to HPA Output (dB)	1:1 Mode System Gain Relative to HPA Output (dB)
C-Band VPC System	2.62	-0.38
X-Band VPC System	2.50	-0.50
Ku-Band VPC System	2.45	-0.55
DBS-Band VPC System	2.34	-0.66
Ka-Band VPC System	1.80	-1.20

Table 1: Typical System Gains for VPC System

Typical linear powers for 1+1 VPC system and 1:1 redundant system using X-Band HPA

Table 2 provides an example of the typical linear powers achieved for a 1+1 VPC system and a 1:1 redundant system using an X-Band HPA that has a linear power of 200W (53.0 dBm). In the 1+1 mode, the HPAs are power combined and the typical system output linear power is 355W. This effectively doubles the output power when compared to a traditional 1:1 redundant system. When the VPC system is operating in the 1:1 mode or when an HPA is off-line in the 1+1 mode, the typical system output linear power is 178W. This is the same linear power as a traditional 1:1 redundant system.

	Watts	dBm
HPA Linear Power	200	53.0
1+1 Mode System Linear Power	355	55.5
1:1 System Linear Power	178	52.5

Table 2: Typical Output Linear Power for 1+1 and 1:1 Systems

Advantages of a 1+1 VPC System

There are several advantages of a 1+1 VPC system. They include:

- The 1+1 VPC system output power is doubled that of a 1:1 redundant system configured with the same HPAs.
- All HPAs in the 1+1 mode of the VPC system contribute to the system output power.
- In the 1+1 VPC system, both HPAs can be directed to the load port switching the output off.
- A 1+1 VPC provides the added benefit of running the HPAs that is better for the overall reliability of them and the system.
- The most significant advantage of operating the VPC system in the 1+1 mode is that there is no loss of transmission when the system is adjusting. In general, HPAs are reliable devices that will allow the user to operate the VPC in the 1+1 mode providing for additional fade margin in their links during normal conditions and a lower fade margin during the soft-fail condition.

Limitations of a 1+1 VPC

While the advantages of using a 1+1 VPC system are compelling, there are drawbacks and limitations that need to be considered.

- It is recommended that the BUCs not be integrated into the HPAs, but instead be provided as a separate 1:1 redundant system. For outdoor, antenna-mounted systems, the 1:1 redundant BUC system can be included in the VPC assembly or in a separate enclosure.
- The need for an external BUC system along with the 1+1 VPC itself, increases the complexity of the system over a traditional 1:1 redundant system.
- The complexity of the 1+1 VPC system increases the price and physical size over a traditional 1:1 redundant system.
- The physical size of the VPC system with the 1:1 BUC system tends to be heavier than that of a traditional 1:1 redundant system. This size and weight increase could pose issues with antenna-mounted systems and would require careful consideration and planning.

Pros	Cons
Doubled Output Power with Same Quantity of HPAs	Integrated BUCs Not Recommended
Transmission Maintained	Higher Price on Front End
More Efficient	Larger Physical Size

VPC System vs. 1:1 Redundant System

Summary

Both systems have advantages and disadvantages. The VPC system is an innovative approach to provide higher output power (i.e., fade margin) as well as providing redundancy. It is a soft-fail system that allows for satellite lock to be maintained when an HPA fails, thus ensuring data integrity and protecting the mission. If the satellite link has been designed with proper fade margin to operate with the output power of one HPA, the VPC system allows the user to operate the system at a higher power thus increasing the fade margin and overall system availability. Since HPAs are normally highly-reliable devices, there is a low probability that the VPC system will be reduced to operating with only one HPA online.

The 1:1 redundant system provides HPA back-up in a simpler, lighter and less expensive solution, with less power than a 1+1 VPC system using the same HPAs.

Ultimately, the HPA configuration that an organization decides to go with will depend on various factors most pertinent to its organization including resources, manpower, budget, and system limitations amongst other things.

THE AUTHOR

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