TRANSIENT SUPPRESSION IMPROVES RELIABILITY OF HIGH POWER AMPLIFIERS

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ABSTRACT

Intolerably high failure rates were experienced on a number of 1.8 G4z solid state amplifiers used in high power transmitters. Investigations revealed the existence of dangerously high transients on the DC power bus which extends from the power converter in the antenna pedestal to the amplifier located under the feed. Current and voltage requirements were such as to render commercially available transient suppressors, including zener diodes, ineffective. The problem was solved with a shunt regulator which normally draws no current, but effectively clips the transients.

INTRODUCTION

The use of solid state high power amplifiers near 2 GHz has become possible in recent years. Their advantages are reduced weight and size, greater efficiency, and increased reliability. The latter characteristic has proved to be quite elusive in the case of several high power amplifiers. MTBF goals of 20,000 hours could not be achieved as catastrophic transistor failures occurred in rapid succession, sometimes only 200 hours apart.

PROBLEM 1: THE HIGH POWER AMPLIFIER.

The power module of the HPA is a class C amplifier (figure 1). Consequently its current demand from its power supply is variable, depending on the signal level (figure 2).

Ground terminal operating procedure is to power-down the transmitter by removing the carrier signal from the amplifier input. This causes the almost instantaneous reduction of the power supply load from approximately 25 to 2 amperes.

For high frequency bipolar devices collector-to-emitter breakdown voltage is limited because with increasing frequency of operation the base region of a transistor must become narrower to reduce electron transit time. Devices with narrower bases are less capable of withstanding high collector to emitter voltages. However, to achieve the required high power levels, substantial collector voltages are indispensable. Consequently, high frequency, high power stages are typically operated with adequate, but not generous voltage margins. Note that the instantaneous collector voltage can rise to almost twice the value of the DC supply voltage. Therefore it is very important to control the DC supply carefully and prevent the existence of transients which could exceed the maximum voltage limits.

PROBLEM 2: THE POWER SUPPLY.

To control losses at S-band frequencies the power amplifier is located within the antenna. The power supply is located in the antenna pedestal; it is connected to the amplifier with power and sense lines, each approximately 30 meters long (figure 3).

The power supply is a commercial, rack mounted unit whose outout voltage is adjustable up to 30 volts; it is set to deliver 28 volts to the amplifier. The remote sense lines meter the voltage at the amplifier terminals. The performance specifications of the supply require the output voltage to return to within tolerance in 50 or less microseconds after a 15 ampere load has been turned on or off. Since the removal of the carrier signal from the amplifier causes a load reduction of about 20 amperers, a voltage transient of unspecified amplitude and up to 50 microseconds duration is generated. The 200 nanosecond delay within the voltage sensing feedback loop caused by the power and sense lines further increases the transient, as does the inductance of the power line. Transients of 12 volts amplitude were observed. However, since the tests at the antenna were conducted under difficult physical conditions, it is likely that even greater transients existed but were not observed.

THE SOLUTION

It was evident that the transients had to be suppressed if the required reliability (MTBF) was to be achieved. Commercially available transient suppressors, i.e., Zener diodes or non-linear resistance devices proved to be unsuitable because of high resistance and because their clipping voltage is too far above their operating voltage.

A series regulator is a circuit found in most regulated power supplies. In its simplest form it consists of a reference voltage, an error amplifier which compares a fixed fraction of the bus voltage with the reference, and a series element which controls the bus voltage.

A shunt regulator (figure 4) is quite similar. The control element shunts the supply bus which is coupled to the rectifier/filter with a resistor (Rs) to permit the shunt element to control the output voltage. It is characteristic of this device to draw zero current (except for the control circuits) up to the set bus voltage and draw as much current as it is capable of within a millivolt above the set voltage. Depending on the tolerance and temperature characteristic of the reference, the circuit must be set higher than the maximum bus voltage by a margin, to prevent its ever turning on at bus voltage. It must only respond to transient above the bus voltage. The coupling resistor (Rs) is deleted because the steady state DC voltage is not regulated by this circuit.

Figure 5 shows the schematic of the transient suppressor which was installed. For schedule reasons component selection was largely influenced by availability. Parts were required to be adequate and readily available, rather than optimum. The clipping level was set two volts above the (+28V) bus to allow for the temperature sensitivity of the voltage reference. The remaining 2 volt transients constitute no hazard for the amplifier.

Figure 6 is a set of oscilloscope photos showing the unsuppressed and suppressed transients observed in the laboratory test simulation.

CONCLUSION

The transient suppressor serves to protect the amplifier against transients on the DC line caused by turn-on, RF load reduction, or electromagnetic induction. It is a negligible current drain on the power supply and can be incorporated into the amplifier without adding significantly to either size or weight.

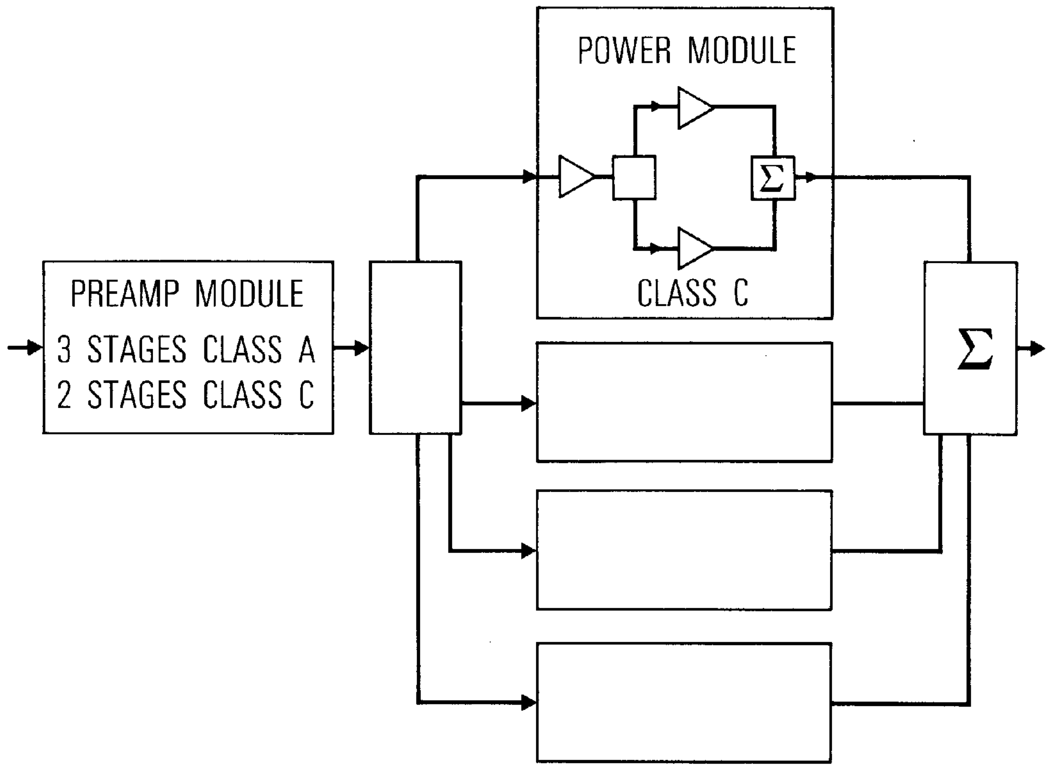

FIGURE 1. HIGH POWER AMPLIFIER

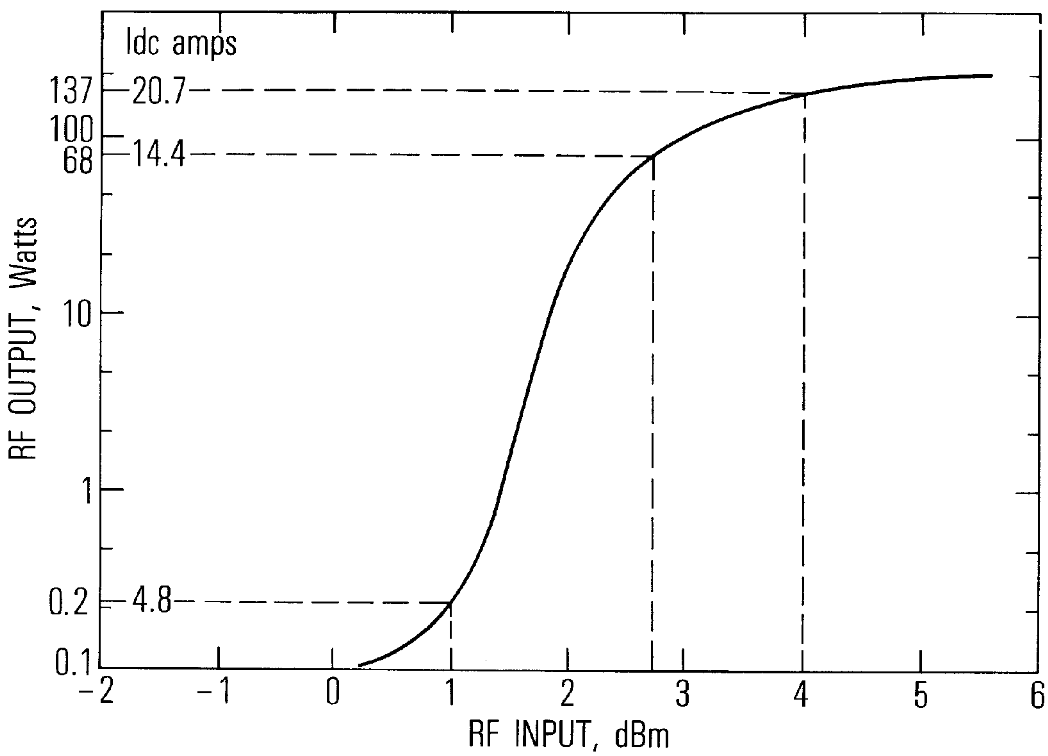

FIGURE 2. CLASS C AMPLIFIER

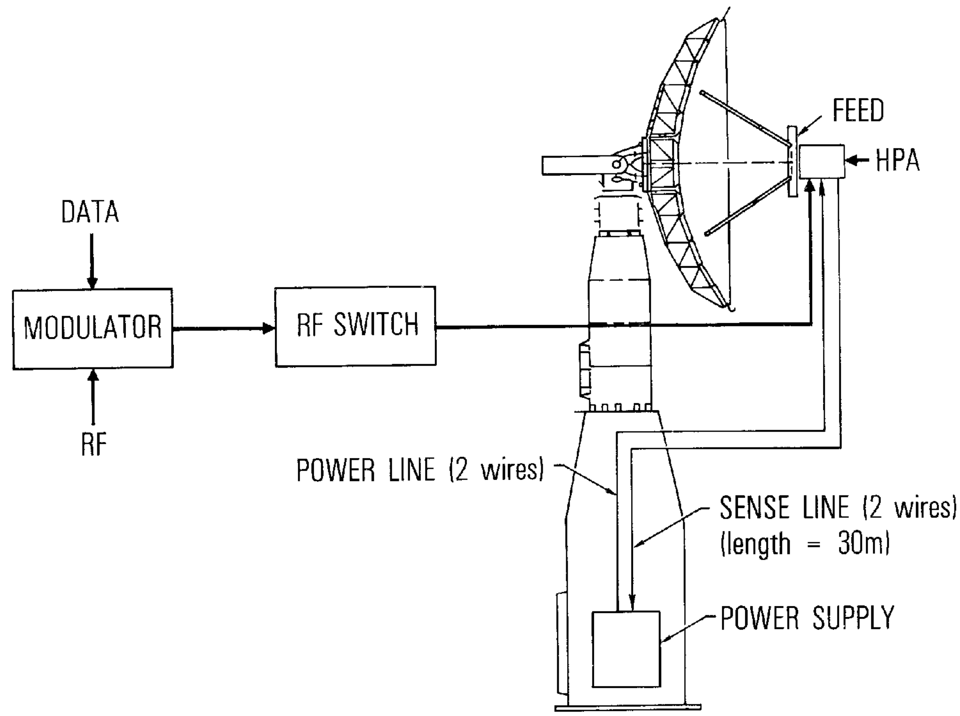

FIGURE 3. UPLINK

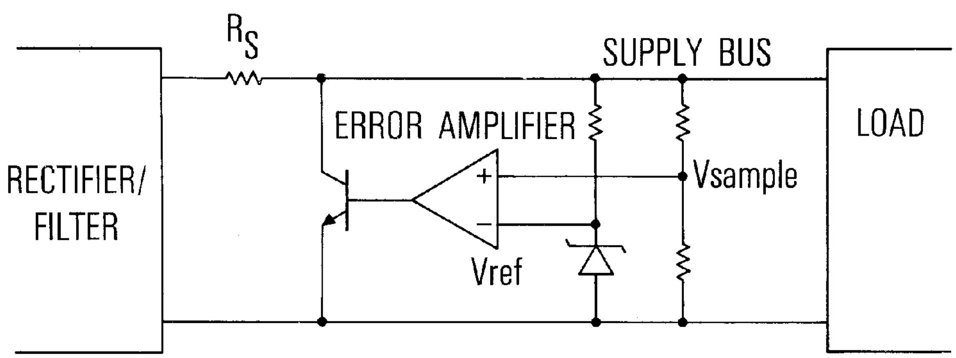

FIGURE 4. SHUNT REGULATOR

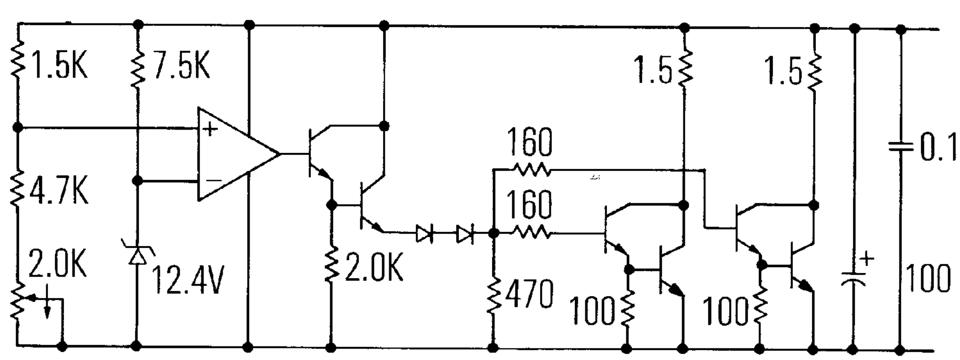

FIGURE 5. TRANSIENT SUPPRESSOR

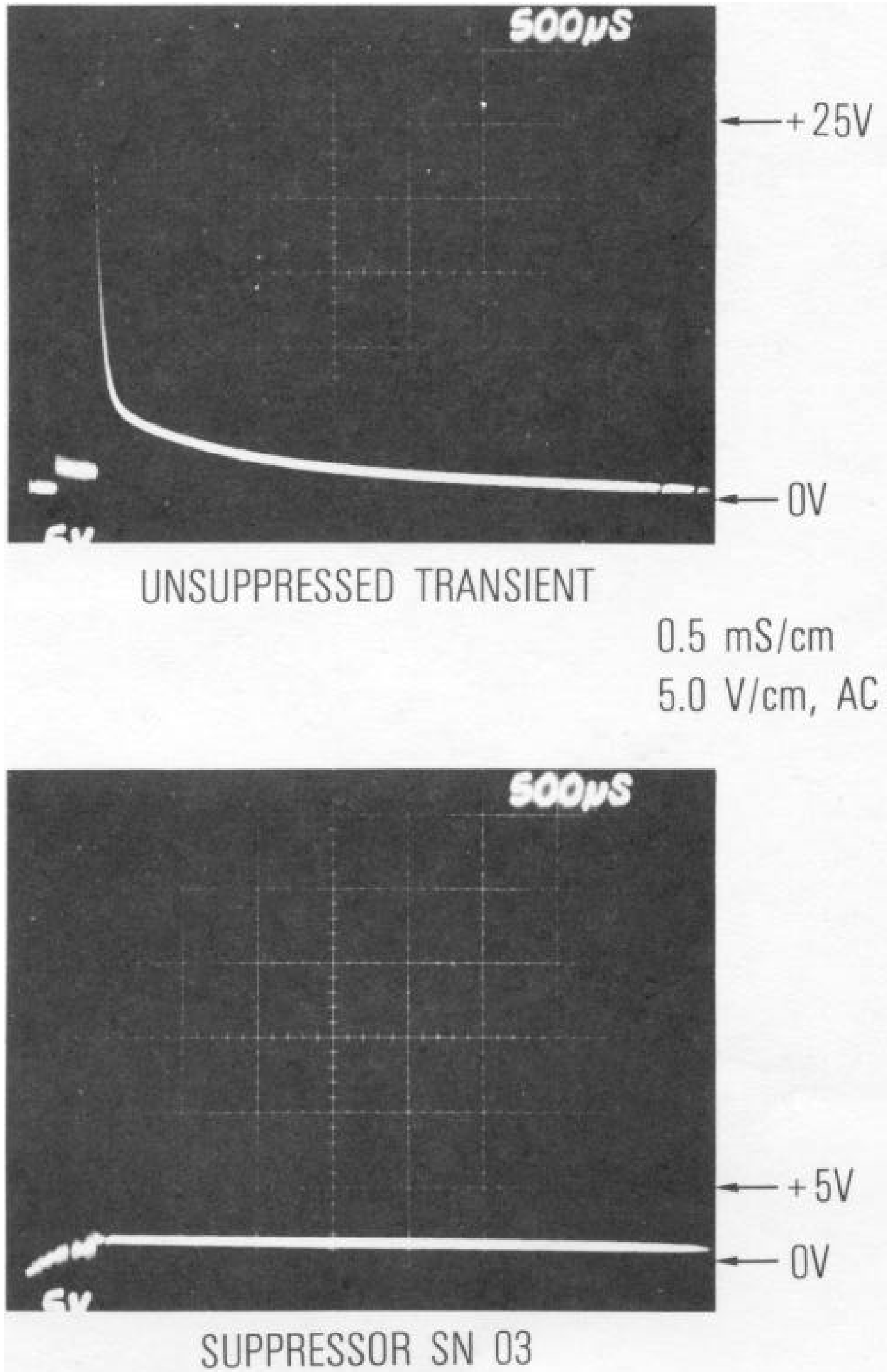

FIGURE 6. SCOPE DISPLAYS