Application Note 101

Using Scintera's SC1887 RFPAL in Microwave Backhaul Power Amplifiers Requiring ATPC

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1. Introduction

This document captures the requirements for linearizing RF power amplifiers (PA) in microwave backhaul applications. In these applications, Scintera's SC1887 RF PA Linearizer (RFPAL) are used at the radio's existing IF frequency. Included is a discussion on Automatic Transmit Power Control (ATPC) considerations and the basic system design considerations to implement a linearized microwave amplifier using the SC1887.

The governing specification document is **ETSI 302 217-2-2 v1.4.1**.

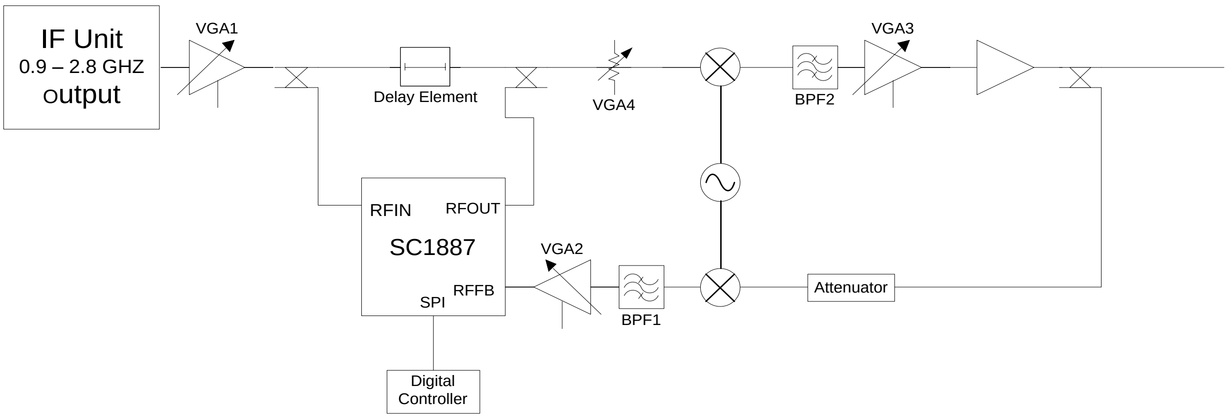

Figure 1. Typical Block Diagram

2. System Block Diagram

In microwave applications that operate using an IF, that IF typically operates at frequencies between 1.5 to 3.5GHz. The operating frequency range of the SC1887 is between 900 and 2800 MHz (contact Scintera to discuss higher frequency support). To use the SC1887 at microwave frequencies, it must be placed in the IF section of the transmitter as shown in Figure 1. This architecture can be adapted to many different transmitter configurations having different output powers, gains and frequencies. The RF power levels into the SC1887 must comply with the limits set in the SC1887 data sheet. Referring to Figure 1, multiple VGA elements are used for this purpose. The exact implementation of VGA1, VGA2, VGA3, and VGA4 is left to the discretion of the system designer. These functions can be achieved with variable gain amplifiers, fixed gain and variable attenuation, or with simple variable or fixed attenuators. The main requirement is that very linear elements are used at all points in the up conversion and feedback down conversion system. The only non-linear element in the system is the output PA itself, that the SC1887 is linearizing.

Mixers – the input power to the mixers is typically <<0 dBm to ensure linear operation. The IMD signals generated by the mixers must be < -60 dBc. To achieve this IMD performance typically requires that the input power to the mixer be 30 dB lower than the input IP3 of the mixer.

VGA1 – used to adjust the RFIN port power to the optimum level of -6dBm. VGA1 should not be adjusted dynamically as this power variation will conflict with internal gain control loops on the

SC1887. VGA1 may be used for slow gain control to account for temperature drift, aging, etc., if required.

VGA4 – The input power to VGA4 is controlled by the RFIN power level and the losses of the couplers and delay line. VGA4 must be adjusted to keep the mixer input power in a linear range under all gain settings.

VGA3, VGA4 – should be used to dynamically control the output power of the transmitter. ATPC power control is best done using these gain control elements. In this way, RFIN power will stay constant while the RFFB power is changing with ATPC. If RFIN power changes, the internal AGC setting of the SC1887 may change, forcing a restart of the correction process. This restart process requires a full adaptation cycle taking about 2 seconds while changes to just the RFFB power result in small updates to the SC1887 adaptation coefficients.

VGA2 – used to adjust the RFFB power levels when the transmitter power output is set to maximum available power (overdrive). At this maximum transmitter power level, the RFFB power setting should be near -12 dBm, with allowances for temperature variation and aging. In this fashion, as ATPC is used to vary the transmitter power, the optimum dynamic response of the SC1887 is achieved.

Additionally, VGA2 can be used to compensate for differences in gain between different modules and is aligned/calibrated at manufacturing to achieve the optimum RFFB power level.

External digital controller – will control the VGA elements. The controller interfaces to the SC1887 to read the input power indicators to set the RFIN and RFFB power levels.

BPF1 and BPF2 – Up conversion systems require filtering to eliminate image and LO signals from the transmitted signals. For the down conversion to RFFB, a filter may also be needed to prevent image or spurious signals from falling into the SC1887 operating band, depending on the frequency plan. The SC1887 will find any signal within the f_{MAX} and f_{MIN} frequency scan limits. Please refer to the SC1887 data sheet, hardware design guide, and release notes for additional detail on setting these frequency limits.

All of the filters used should have flat gain and group delay over the modulated signal plus IMD frequency region. Gain or group delay variation can increase memory effects thus reducing correction levels. The SC1887 injects an "inverse IMD" correction signal into the output PA and this signal should be passed through the up conversion chain with little or no distortion. Likewise, the SC1887 measures the PA IMD using the down conversion path and any distortion on this path will reduce the accuracy of this IMD measurement.

3. Microwave Application

In a microwave application, the typical transmit output power is operated over a 25 dB ATPC power range along with Adaptive Modulation changes which are covered later. This ATPC gain control is best performed "inside the loop" or between the SC1887 RFOUT port and the RFFB port, as shown in Figure 1. As such, the input (RFIN) level will remain relatively constant while the RFFB level will vary over the full output power operating range (see VGA1 operation guidelines in the previous section).

Most Microwave point-to-point manufacturers have a family of products that cover a frequency range from 4 GHz to 80 GHz. These radios currently use a single channel with 3.5 MHz to 56 MHz of instantaneous signal bandwidth that is continuously occupied. Modulation modes can be from QPSK to 256 QAM, having crest factors or Peak to Average Ratios (PAR) of 4 to 10 dB. The system output power is typically controlled via look up tables calibrated at the OEM factory. These look up tables are then used to set the antenna output power at the each operating frequency, temperature, and power level.

4. Automatic Transmit Power Control (ATPC)

When ATPC is used and the microwave link propagation losses are nominally low, the radio is operated at a lower output power level that maintains the required SNR or BER. This is by regulatory requirement to reduce interference. However, operating the link with just enough power to maintain the required BER makes the system vulnerable to fading conditions created by heavy rain or multipath, for example. When the receiver detects a fade condition, it then transmits a message back to the transmitter to increase power in order to maintain the link budget.

- ✓ The key issue requiring special consideration is the rate of change of the non-linearity of the amplifier under test. It's important to note that change in output power usually means changes in non-linearity but this is not always the case. The SC1887 will adapt the predistortion function rapidly when the power level changes. To ensure that this re-adaptation happens, the RFFB (feedback) power should track the output power of the PA. The SC1887 will sense the power change and re-adapt as needed to minimize the IMD.

See Figure 2 and Figure 3 for details on the ATPC power ramp sequence. In order for EVM / ACP to remain within specification, the SC1887 must be able to adapt to the ATPC power ramp and changing predistortion function fast enough. The maximum rate of power change can be up to 100dB/second. Realistically, the maximum rate of power change is more often limited by the *receiver* demodulator time constants than by the *transmitter* circuits. In such a system, the SC1887 is able to adapt during this ATPC power ramp. One method to determine the optimal power ramp speed is to measure the end-to-end system BER performance with the SC1887 while adjusting the speed of the power ramp.

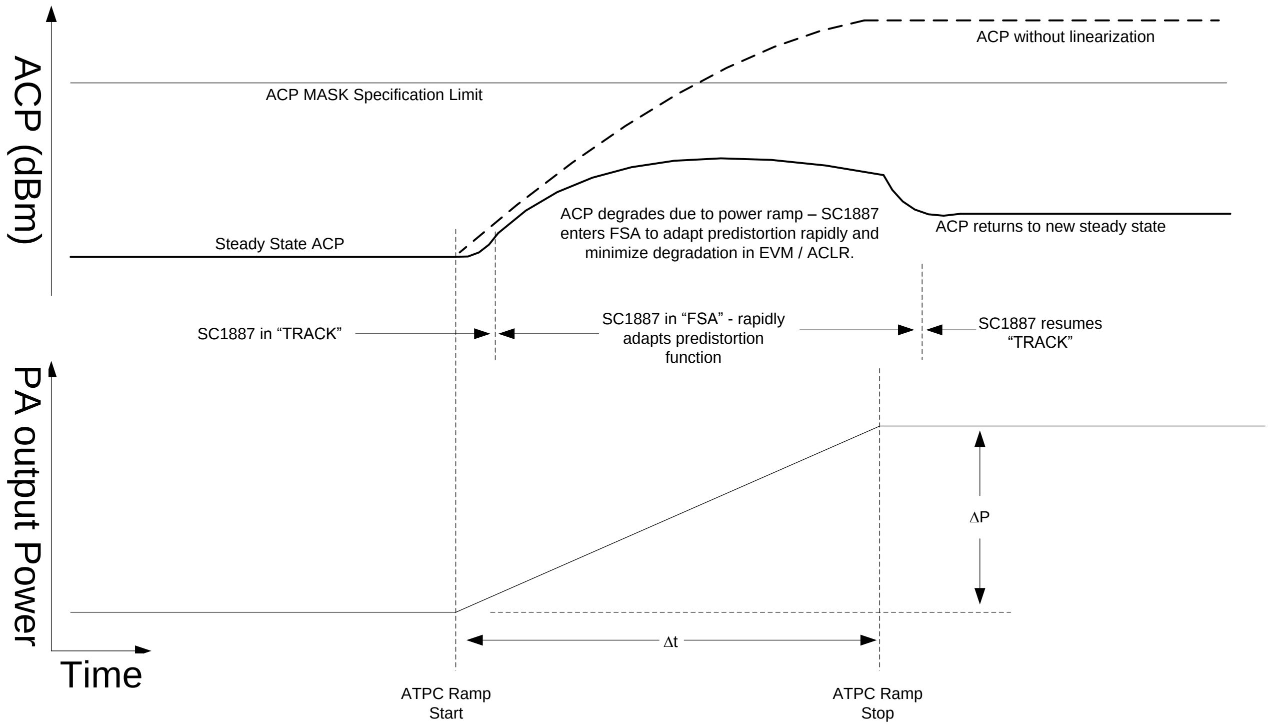

Figure 2. ATPC Power Ramp Sequence when SC1887 is active in TRACK mode

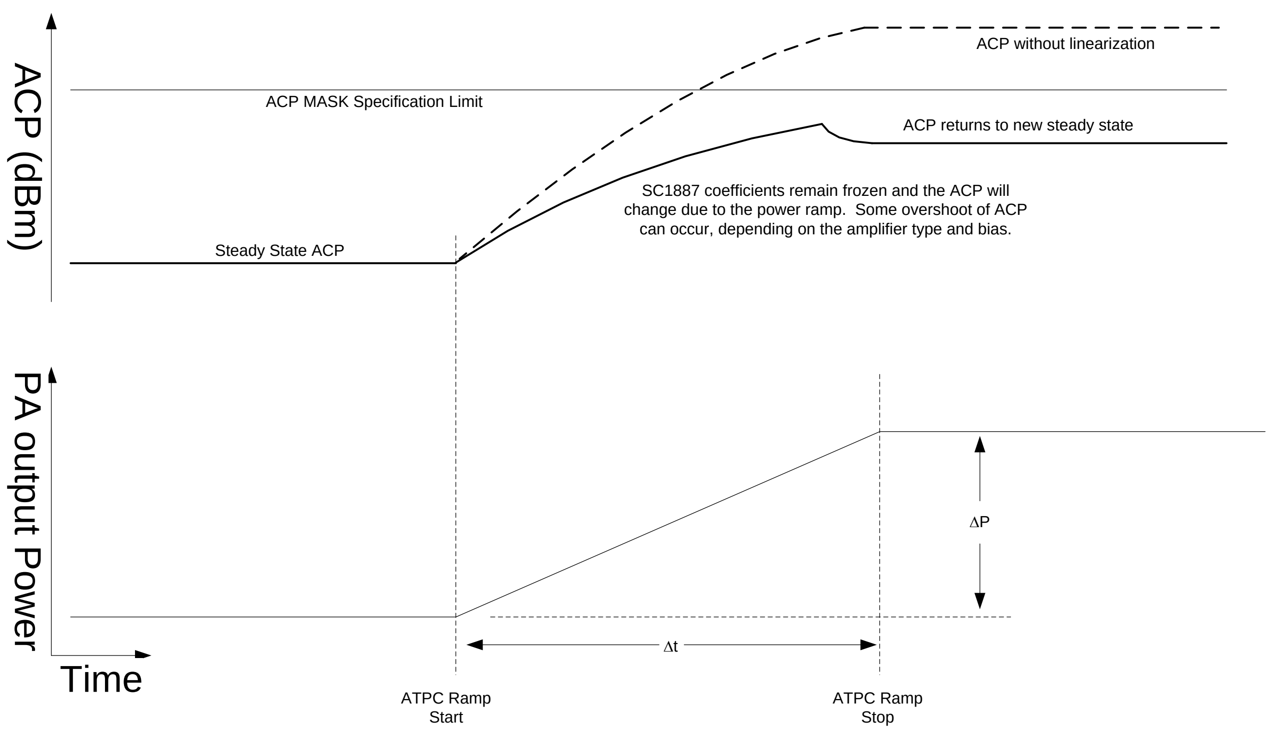

Figure 3. Power Ramp Sequence when SC1887 correction is frozen at max power

5. Appendix

Reference Information from ETSI 302 217-1 V1.3.1 (2010-01) regarding Automatic Transmit Power Control (ATPC)

Reference Information from ETSI 302 217-2-2 V1.4.1 (2010-07) pages 85 and 85.

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Document 101A • Issued: August 2011