Criss-Cross RFAL Cancels the IMD Distortion in Amplifiers.

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This article provides a new design configuration that uses the basic concept of the RFAL distortion cancellation technique.

The basic RFAL technique uses the behavior of a transistor when driven into its non-linear operating region. At the high drive level the input reflects not only the fundamental components of the input signal but also the non-linear distortion components appearing at the output of the transistor. The level of the distortion products at the input is sufficiently proportional to the output such that it can be used and processed as a correction or error signal to cancel the output distortion of the transistor amplifier.

Block diagrams, circuit schematic and performance data are included in the article.

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The Criss-Cross RFAL Amplifier is new amplifier configuration that uses the basic techniques of the RFAL (Reflect Forward Adaptive Linearizer) amplifier. The new RFAL version is more suitable for lower power Class A and Class AB amplifiers with low VSWR and can provide a high level of cancellation of the intermodulation (IMD) products with high power efficiency.

The basic RFAL technique uses the behavior of a transistor when driven into its non-linear operating region. At the high drive level the gate input reflects not only the fundamental components of the input signal but also the non-linear distortion components appearing at the output of the transistor. The level of the distortion products at the input is sufficiently proportional to the output such that it can be used and processed as a correction or error signal to cancel the output distortion of the transistor amplifier. Previously published articles describe the RFAL technique in detail. See listed references

The Criss-Cross RFAL shown in Figure 1 samples the input reflected signal from both Main amplifiers. The reflected signal from the input of each Main amplifier is independently amplified, phased, and combined with the input signal of the opposite main amplifier to produce cancellation of IMD products at the output of each of the Main amplifiers.

The Criss-Cross RFAL shown in Figure 1b is similar to Figure 1 but the signal is returned to the output of the opposite main amplifier after the main delay line. This configuration provides a wider frequency operation with added complexity and lower efficiency.

To maintain the overall IMD cancellation efficiency of the Criss-Cross RFAL it is important to achieve a high level of input match from both main amplifiers. A low input VSWR keeps the reflected fundamental signals close to the input intermod product levels and allows use of low level amplifiers in each of the error paths to correct the distortion of the main amplifiers.

The circuit symmetry of the Criss-Cross RFAL design in Fig 1 eliminates the use of lengthy and lossy output delay lines to cancel the IMD products in a smaller circuit area. The downside is that it works over a narrower frequency band. The Fig 1b configuration on the other hand operates over a wider bandwidth but requires the use of a main delay line, and higher level amplification of the error signal and results in lower power efficiency.
The Noise Figure increases when the correction circuit is on versus when it is off. To eliminate this effect level detectors can be used to drive a switch that turns the loop amplifiers on or off depending on input signal level. This will maintain the basic noise figure of the main amplifiers at low input levels. The overall power efficiency of the system is also improved by limiting the operating range of the cancellation system. The RF response time of the controlling network must be properly designed for the particular application.

A prototype breadboard was constructed and tested to show the described technique.
The main amplifiers use ATF-25735 GaAs FET transistors. The parallel combined pair of FET transistors provides a gain of 10 dB with a 3rd order intercept level IP3 of +28 dBm at 880 MHz up to a +13 dBm composite output signal. With the IMD correction circuit turned on, the gain is around 10 dB and the IP3 level increases to +37.8 dBm. Figure 3 shows the level of improvement of the IMD corrected versus the uncorrected Criss-Cross RFAL amplifier at the +13 dBm composite Pout level. See the attached figures.

The circuit of Fig 2 provides significant IMD cancellation for a bandwidth of 10 MHz around the 880 MHz center frequency. (15 dB improvement from ON to OFF condition). The IMD cancellation versus frequency can be improved if the circuit uses matched transistors, in-phase splitter/combiner such as Anaren's Zinger 4D1304, Soshin's couplers GSC301, GSC302, GSC362, and by controlling the phase of the loops more precisely.

Band-Pass filtering at the input of the amplifier is desirable to prevent operation where the Main amplifier's VSWR is above 2:1. Filtering prevents the IMD correction Loop from saturating and feeding distortion into the Main amplifier's circuitry.

The assembly and components used for this work were selected from available components at hand. Use of MMIC devices instead of discrete devices connected to Soshin couplers can make the circuit small and power efficient. The VVA can be replaced with a fix value temp-comp type attenuator and a narrow dB range voltage attenuator to achieve the high level of cancellation over temperature.

The Criss-Cross RFAL allows the use of smaller geometry transistors to achieve a given level of IP3 increasing the overall operation efficiency of the final amplifier. This technique provides another alternative for achieving significant level of distortion cancellation for Class-A and Class-AB single stage parallel combined amplifiers.

References:

- US Patent 6,573,793 "Reflect Forward Adaptive Linearizer" June 3, 2003.
- The RFAL Technique for Cancellation of Distortion in Power Amplifiers. High Frequency Electronics, June 2004
- High Efficiency Linearized LDMOS Amplifiers Utilize the RFAL Architecture. High Frequency Electronics, February 2006.

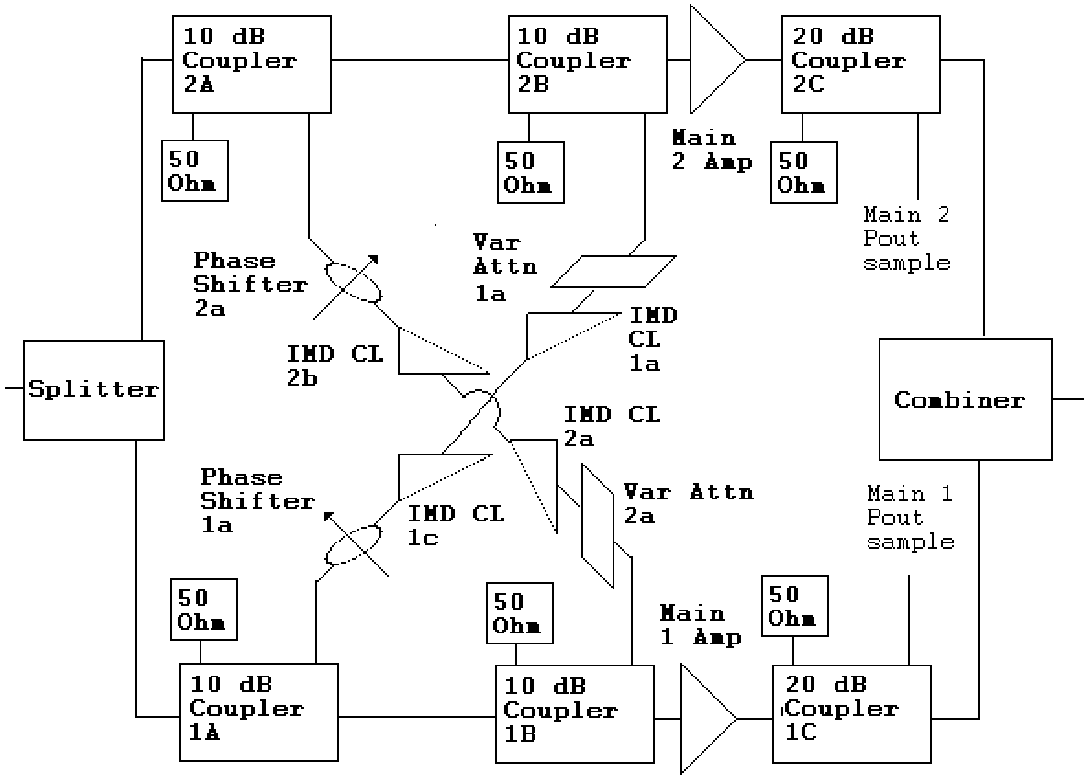

Figure 1. Criss-Cross RFAL Block Diagram

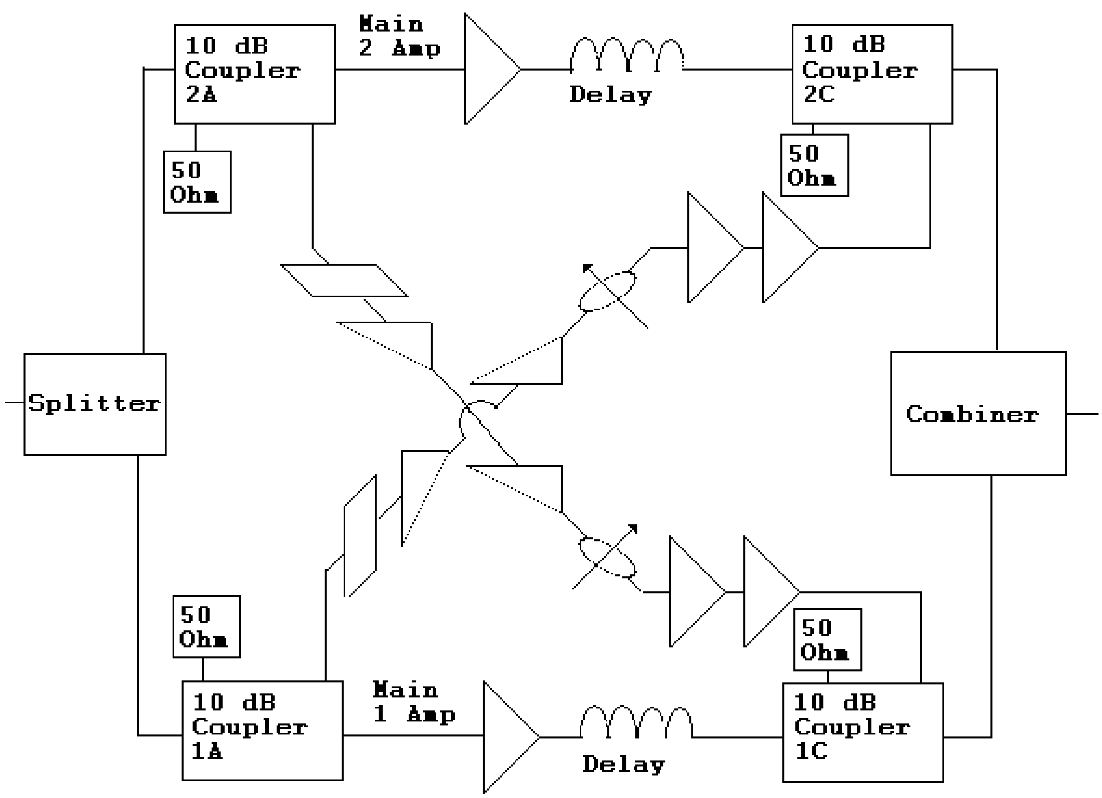

Figure 1b. Criss-Cross RFAL Block Diagram

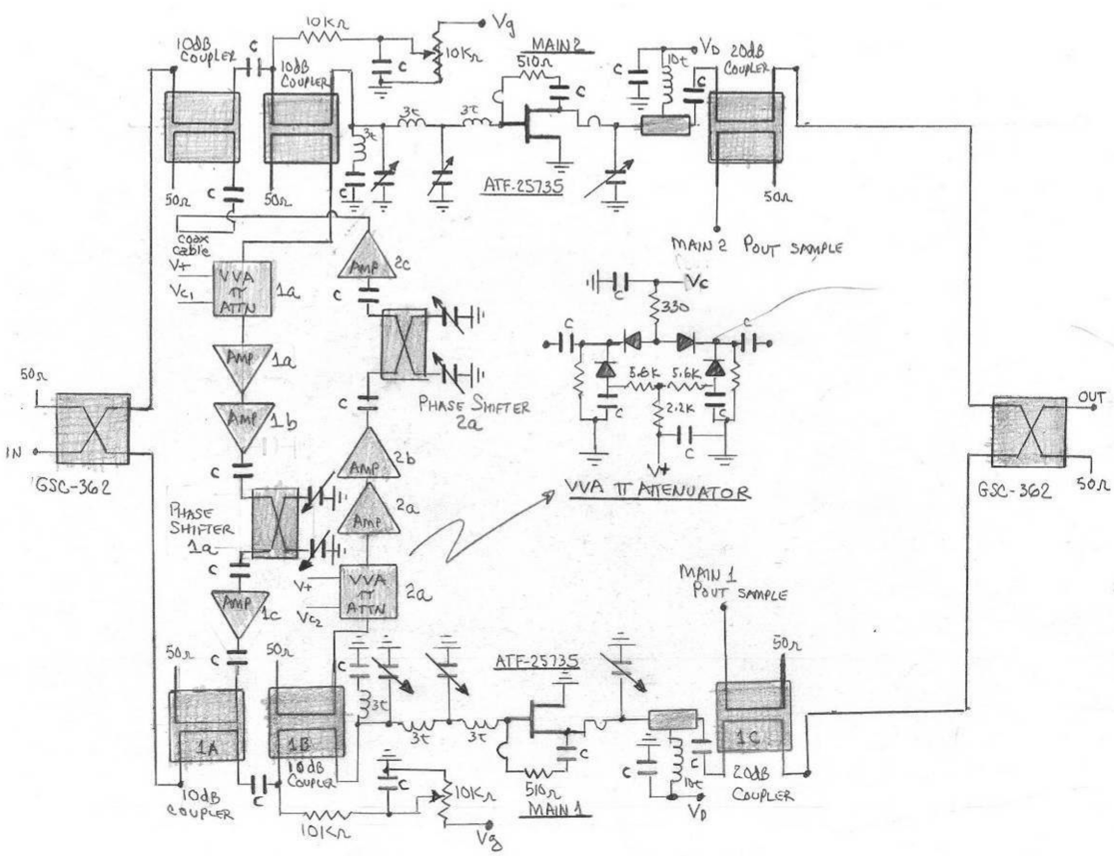

Figure 2. Circuit Diagram of Actual Prototype Circuit.

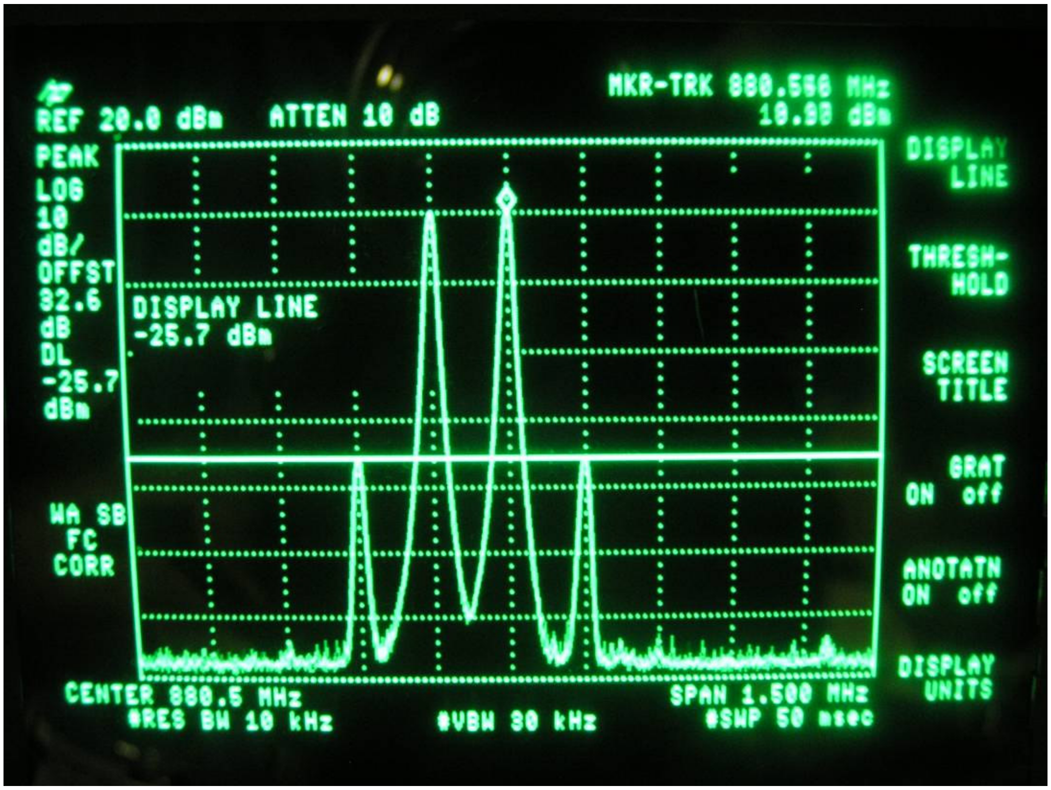

Fig 3a Criss-Cross RFAL Output with IMD Cancellation Loops OFF

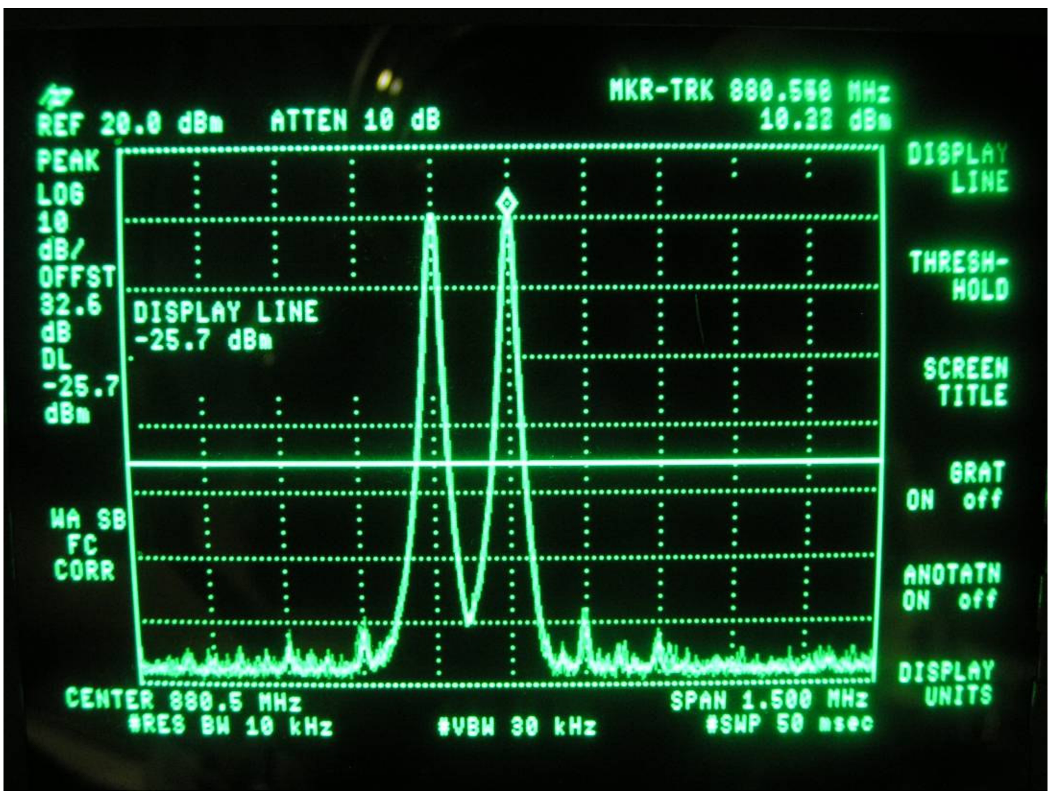

Fig 3b Criss-Cross RFAL Output with IMD Cancellation Loops ON

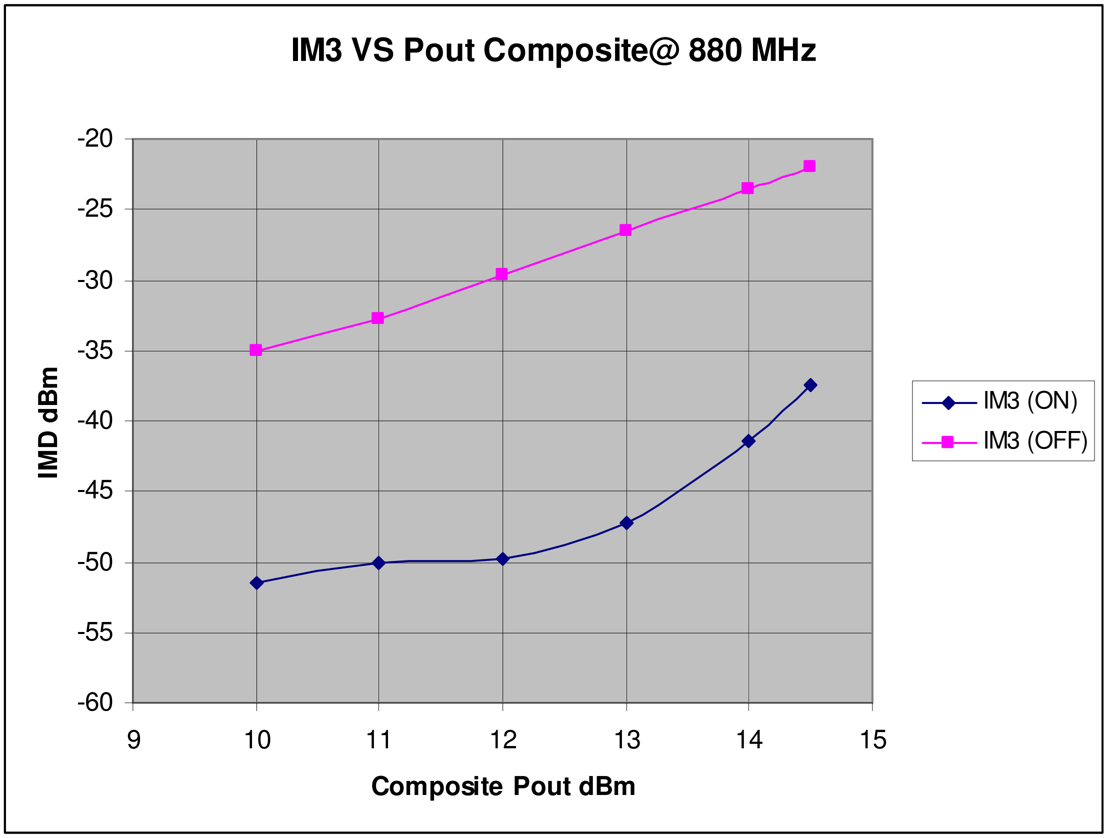

Figure 6. Two Tone IM3 VS Pout Composite at 880 MHz.
f1=879.85 MHz f2=880 MHz

IM3 (ON) shows performance with both IMD correction loops ON
IM3 (OFF) shows performance with both IMD correction loops OFF