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Low/Medium Power Channel Selective Repeater Application

Using the RF2051 Wideband Synthesizer/PLL with Integrated Mixers

Overview

A cellular repeater is a system of duplex reception, amplification, and transmission used to enhance uplink (UL) and downlink (DL) signals in areas of low radio coverage. This enhancement expands the coverage of cellular network base transceiver stations (BTS) at low cost. The signals at the input and output ports of the two transceivers (TRX), each dedicated for the UL or DL direction of signal reception, amplification, and re-transmission, are multiplexed at a directional donor and local area antennas by means of diplexers in FDD systems such as GSM and WCDMA FDD.

For the DL path, assuming a fixed link with the BTS, a signal of relatively slow-varying power is amplified to a fixed level suitable for adequate radio coverage and QoS in the target local area. For the UL path, a signal of varying power due to slow-fading from user equipment within the local target area is received and amplified at a fixed power level before re-transmission to the BTS. Signal integrity on both the DL and UL paths should be maintained over the widest possible range of input levels in terms of modulation accuracy (EVM) and spectral content. In addition, the levels of in-repeater-band wideband noise and spurious emissions at the repeater output should comply with 3GPP requirements [1,2].

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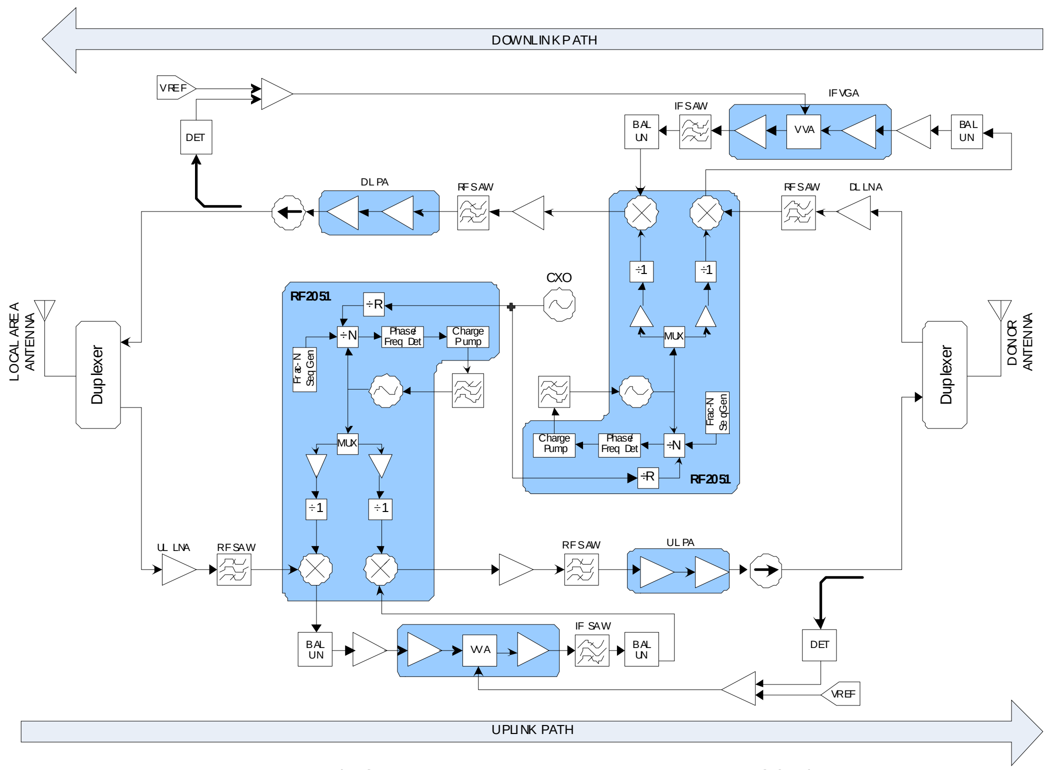

Figure 1. Generic repeater architecture with RF2051

Figure 1 shows a generic architecture of a channel-selective repeater. The corresponding operations of the UL and DL TRX subsystems are equivalent. An RF signal with power levels between S_{MIN} and S_{MAX} at the TRX input is amplified by an LNA stage, down-converted to IF, filtered and amplified by a VGA, up-converted back to RF and, finally, amplified by the power amplification stages at a nearly constant output power level P_0. The output power is dynamically maintained at the prescribed level for slowly varying input power via a closed loop power control scheme, which detects the average output power via a detector and log-amp, and compares it with a reference level voltage obtained from power calibration.

Down-conversion to IF provides certain advantages:

- Effective filtering of interfering signals outside the repeater pass band associated with the dedicated BTS and carrier frequency
- Wide dynamic range and robust power control design via the IF VGA
- Better isolation between the UL-TRX and DL-TRX paths

The selection of the IF, along with the specification of the front- and back-end RF filtering is critical in attenuating higher order mixer products to levels below the in- and out-of-repeater-band emission limits.

RF2051, with its integrated PLL and two mixers, augmented by suitable LNA, IF VGA, and driver/PA subsystems, is ideally suited to perform the down- and up-conversion functions of the architecture shown in Figure 1 in a compact and efficient manner. It provides a high spurious free dynamic range, with low noise and low spurious content TRX paths.

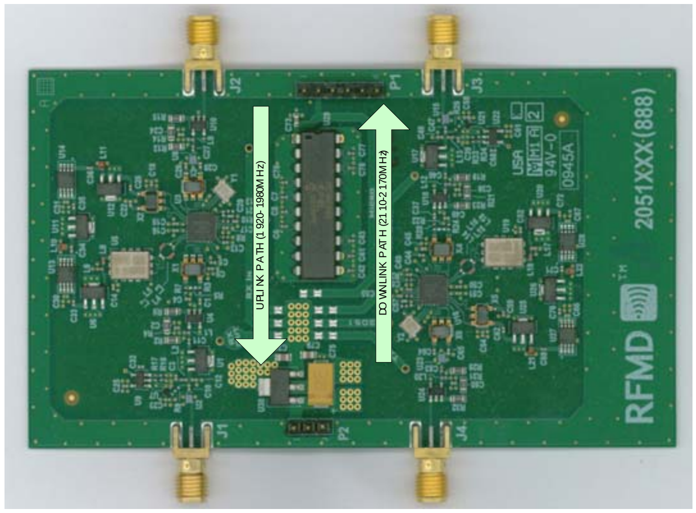

Figure 2. Experimental prototype of the repeater implementation with RF2051

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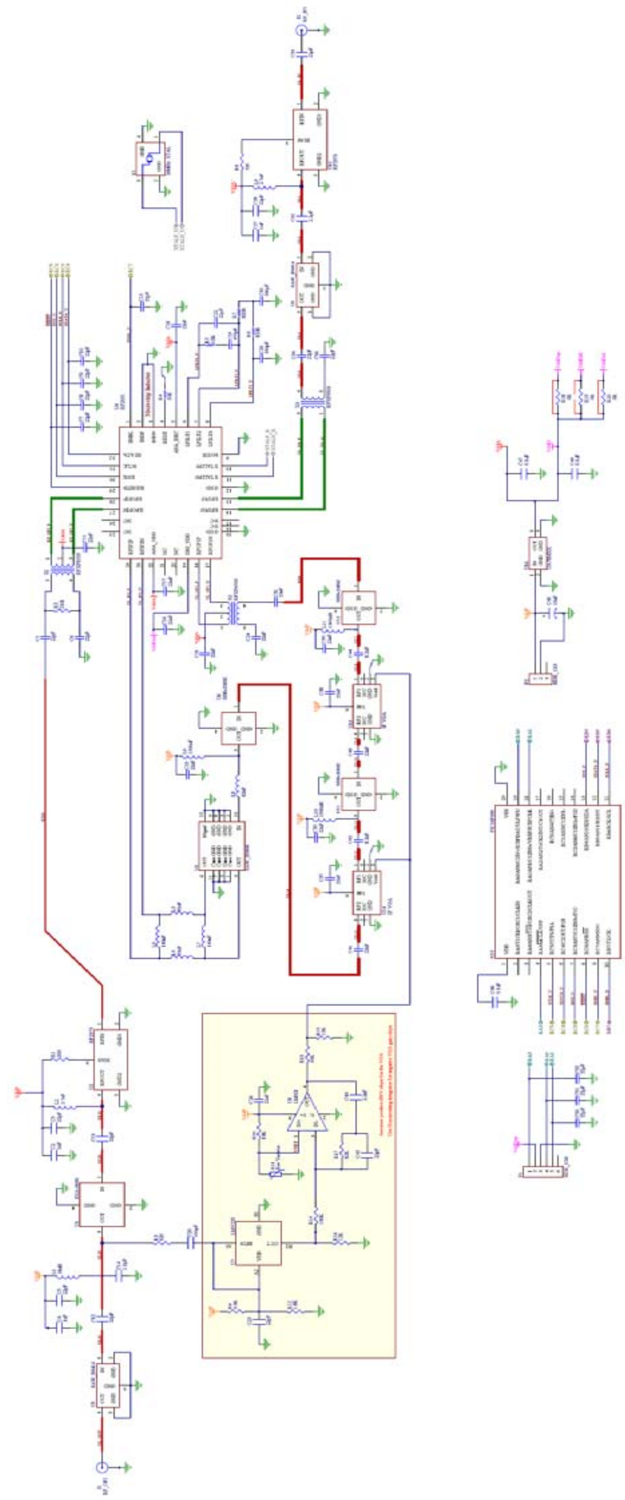

Figure 3. Schematic of the prototype

General Repeater Characteristics

Of particular interest, especially in the UL path, is the dynamic range of the TRX subsystem. This range is the difference between the maximum and minimum input signal that the TRX system can accommodate for a fixed output power level P0. In general, the maximum allowable input signal S_{MAX} is constrained by the minimum available gain of the receiver, the compression point of the TRX system, and regulatory limits of ACPR, spectrum emissions, and in-repeater-band intermodulation products for a multi-carrier input scenario. On the other hand, the minimum possible input signal S_{MIN} is a function of the maximum available gain G_O, along with the desirable output power level P_O, and the in-repeater-band wideband noise. In RF2051, G_O is approximately 70dB, while there is sufficient attenuation control range in the IF VGA to support a high level input before a saturation of any of the stages occur. Ultimately, the DR of the repeater will be constrained by its wideband noise and linearity performance.

The cascaded NF, along with total gain, will determine the thermal noise floor at the output of the TRX. For large values of gain required for low input signal levels, the cascaded NF mainly depends on the front end and 1st mixer NF while the output noise power increases monotonically with system gain. The level of the thermal noise at the output of the TRX as a function of the effective system noise BW (3.84MHz for WCDMA) will be given by

$$N_{MAX}(dBm) = -173.9(dBm/Hz) + \log 10_{10} BW + NF(dB) + P_O - S_{MIN} \quad (1)$$

Given the maximum allowable adjacent channel noise to signal power ratio

$$ACPR = N_{MAX} - P_O \quad (2)$$

at the output, the minimum input signal level S_{MIN} can be obtained from equations (1) and (2).

On the other hand, the P1dB and IP3 points of the two mixers define the cascaded linearity parameters of the TRX paths. For WCDMA, the ACPR is approximately related with the OIP3 of the system via

$$ACPR \approx -20.7 + 1.6 \cdot PAR + 2 \cdot (S_{MAX} - IIP3) \quad (3)$$

where the UL PAR is less than 5dB. The maximum acceptable ACPR for the given channel output power P_O will determine the cascaded required IP3 and P1dB points, as well as the maximum input signal level S_{MAX}. A summary level diagram of a 10dBm WCDMA repeater with the RF2051 is shown in Table 1.

LEVEL DIAGRAM		RF Input	RF Filter		LNA		2051 MIX1		IF VGA		IF SAW		2051 MIX2		Driver		Amplifier		RF Filter	
Level & Gain			dB	dBm	dB	dBm	dB	dBm	dB	dBm	dB	dBm	dB	dBm	dB	dBm	dB	dBm	dB	dBm
Maximum RF Inp	dBm	-21.5	-2.5	-24.0	17.5	-6.5	-6.0	-12.5	17.0	4.5	-12.0	-7.5	-11.0	-18.5	17.0	-1.5	13.0	11.5	-1.5	**10.0**
Minimum RF Inp	dBm	-59.5	-2.5	-62.0	17.5	-44.5	-6.0	-50.5	55.0	4.5	-12.0	-7.5	-11.0	-18.5	17.0	-1.5	13.0	11.5	-1.5	**10.0**
Cascaded Gmin	dB			-2.5		15.0		9.0		26.0		14.0		3.0		20.0		33.0	-1.5	**31.5**
Cascaded Gmax	dB			-2.5		15.0		9.0		64.0		52.0		41.0		58.0		71.0	-1.5	**69.5**
Noise Figure	dB		2.5		1.3		12.0		3.3				12.0		1.5		8.0			
Cumulative NF (Gmin)	dB			2.5		3.8		4.6		5.6				6.4		6.6		6.7		**6.7**
Cumulative NF (Gmax)	dB			2.5		3.8		4.6		4.8				4.8		4.8		4.8		**4.8**
OP1dB	dBm			100.0		13.9		6.0		21.0		100.0	12.0	1.0		14.0		25.0		23.5
Cascaded P1dB (Gmin)	dBm			100.0		13.9		3.8		11.2		-0.8		-12.1		4.4		16.7		**15.2**
Cascaded P1dB (Gmax)	dBm			100.0		13.9		3.8		17.4		-5.4		-6.5		8.9		20.2		**18.7**
OIP3	dBm			100.0		25.5		12.0		43.0		100.0	18.0	7.0		25.0		38.0		36.5
Cascaded IP3 (Gmin)	dBm			100.0		25.5		11.3		26.5		25.9		1.9		17.9		30.1		**28.6**
Cascaded IP3 (Gmax)	dBm			100.0		25.5		11.3		39.9		27.9		6.6		21.2		32.7		**31.2**

Table 1: Level Diagram for 10dBm Repeater

Repeater Demonstrator

The characteristics and performance of a low power (10 dBm), channel-selective WCDMA repeater are demonstrated employing a prototype system built around two RF2051 ICs, along with LNAs (RF2374), drivers (RF2374), PAs (SXA-389B), and IF VGA stages (SBB-2089 and third party VGA). Figure 2 and Figure 3 show the repeater demonstrator board and the schematic diagram of its UL path, while the schematic diagram of the DL is similar. The LNA stages are specified with a nominal gain of 16.5 dB, an IIP3 of 9 dBm, and an NF of 1.2 dB, while the driver and PA stages have a nominal linear gain of 30 dB and an output P1dB of 25 dBm. An IF SAW filter with a 5 MHz nominal bandwidth is centered at the selected IF of 172.8 MHz.

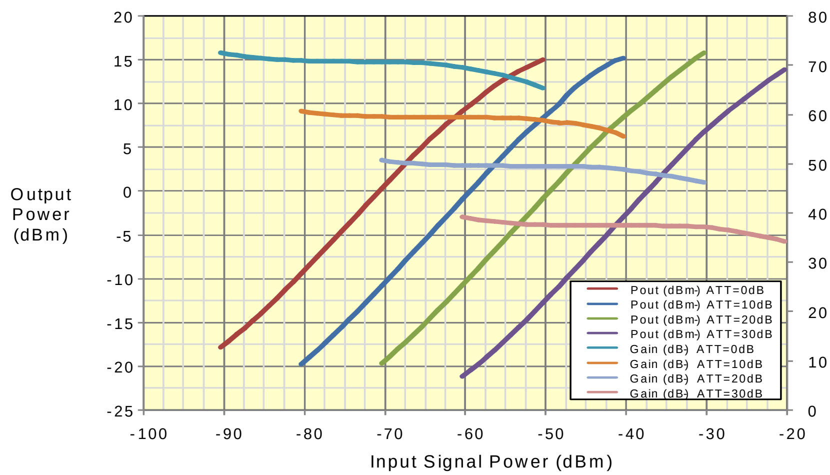

Figure 4. Output Power and Gain Performance

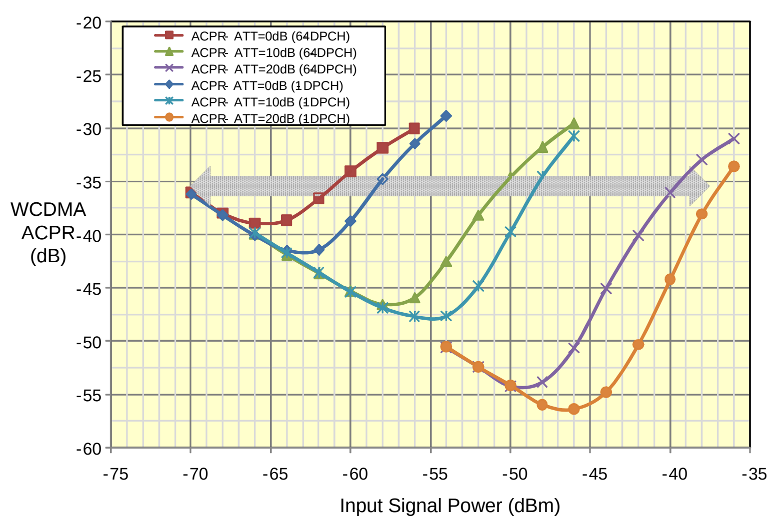

Figure 5. ACPR versus Input Signal Power: WCDMA 64-DPCH-1C(TM1) and 1-DPCH

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Figure 4 and Figure 5 summarize the performance of the repeater, in terms of its power and gain, as well as the dynamic range constraints due to wideband noise and intermodulation. Figure 5 illustrates the effect of the wideband noise for low input signals and correspondingly high gain settings, while the maximum input signal is limited by the intermodulation performance and the maximum acceptable adjacent channel power ratio. It is worth pointing out that the ACPR, on the left of the of its minimum point in Figure 5, increases linearly with decreasing signal level or increasing gain, whereas on the right of this point it increases approximately 2dB per every 1dB increase in signal input level. In this case, an input signal range from -60dBm up to -30dBm can be accommodated while maintaining an ACPR level below 35dB and meeting the spectrum emissions requirements[1] with adequate margin. This 30dB dynamic range and output power can be extended by higher gain and an IP3 power amplifier.

References

[1] 3GPP TS 25.106, UTRA Repeater Radio Transmission and Reception (Release 8), V8.0.2, 2008-03.

[2] 3GPP TR 45.050, Background for Radio Frequency (RF) Requirements, Annex E: Repeater Scenarios, V8.10.0, 2008.

[3] RFMD, RF2051 High Performance Wideband RF Synthesizer/VCO with Integrated RF Mixers, DS080513.

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