Application Note
CMX991 and CMX992 Operation Below 100MHz

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Additional Resources	None

1 Introduction

The CMX991 RF Transceiver and CMX992 RF Receiver ICs are specified for radio systems operating between 100MHz and 1GHz. A frequent request asked by engineers is whether operation below 100MHz is possible with these ICs. This Application Note seeks to provide useful guidance on the use of the devices below 100MHz and contains details of how such operation can be demonstrated through component changes to the matching circuits on the EV9910B and EV9920B Evaluation Kits.

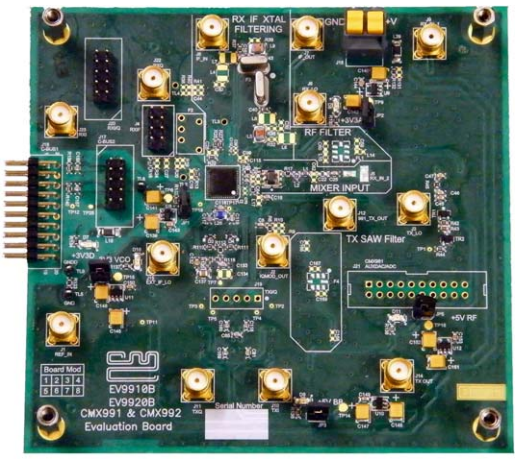

Figure 1 EV9910B CMX991 Evaluation Kit

The enclosed results for CMX991 transmitter operation show that it can be operated down to 5MHz by using a high IF and the transmit image-reject mixer as a down-converter.

The receiver 1st mixer has satisfactory performance between 100MHz and circa 50MHz, for operation below 50MHz, the CMX991 and CMX992 receiver mixer has matching losses that prohibit effective operation. The remaining sections of the CMX991 or CMX992 can still provide useful functions within a receiver, for example when used with an external 1st mixer.

2 History

Version	Changes	Date
1	Released	1-11-09

3 Contents

4 Overview

A common solution for operation in HF (3-30MHz) and low VHF (below 70MHz) communications systems that require a broad frequency coverage, is to use a superheterodyne architecture with a high 1st IF, typically 45MHz or greater. The scheme is equally applicable for both transmitter and receiver functions. In this technique, high-side mixing is used to either up or down convert to or from the IF. A simplified block diagram for the relevant transceiver functions is shown in Figure 2.

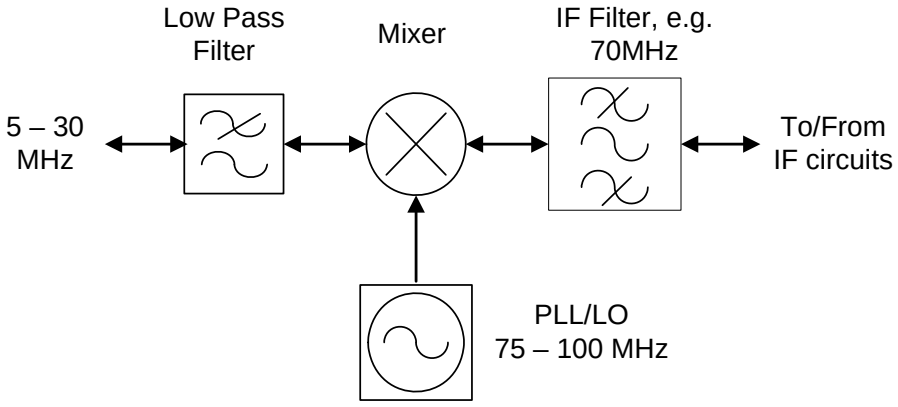

Figure 2 Simplified up/down convert architecture

Using this architecture has a number of advantages in terms of system design compared with using a lower IF in for example spurious mixing products on both transmit and receive, such as the image frequency, are more easily attenuated using the low pass filter, and the local oscillator only needs to cover a much lower tuning range (as a percentage of its operating frequency).

In practical high-performance implementations, banks of filters and oscillators covering narrower ranges (5-10M Hz) are often used, however the overall solution is still much less complex than that required for a lower IF (e.g. 9MHz or 10.7MHz) to achieve broadband, continuous coverage.

The CMX991/CMX992 may be used as part of an effective solution in up or down convert systems operating below 100MHz. Operation is shown by example using the EV9910B and EV9920B evaluation PCBs as shown in the following sections, 5.1 and 6.

5 Receiver Operation Below 100MHz

5.1 EV9910B and EV9920B Configuration Examples

The RF mixer input (J5) can be matched for the band of interest to the input of the balun transformer T1 using the suggested values in Table 1. Note that components fitted to location L2, which are inductors in higher frequency applications, are capacitors in these configurations. The values of other components (as shown in Figure 3) should be C25 = 0R, R49 = not fitted, C22 = 1nF and R17 = 0R for all the configurations shown in Table 1. The results for the three typical configurations are shown in Figure 4, Figure 5 and Figure 6.

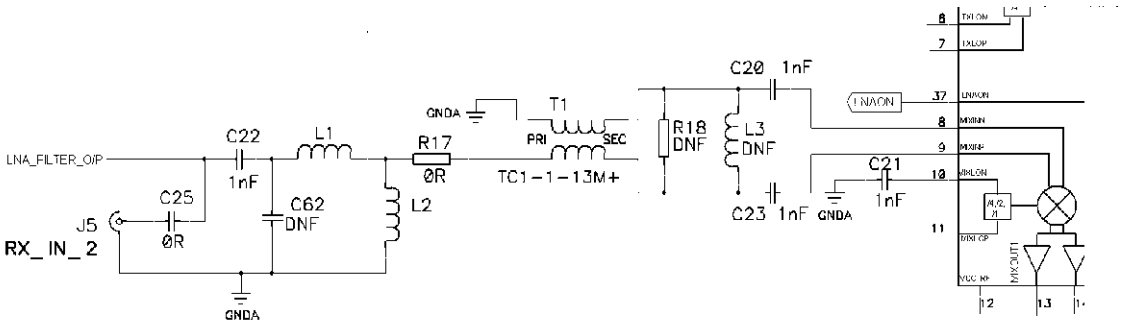

Figure 3 Extract from EV9910B/EV9920B schematic

Band (MHz)	C62	L1	L2
'Low Band' VHF (66-88 MHz) 75MHz Centre	24pF	330nH	6.8pF
35-41 MHz (39MHz centre)	NF	820nH	10pF
13-20 MHz (17MHz centre)	100pF	1.2uH (1008CS)	68pF // 330R

Table 1 Low frequency Rx mixer input matching components

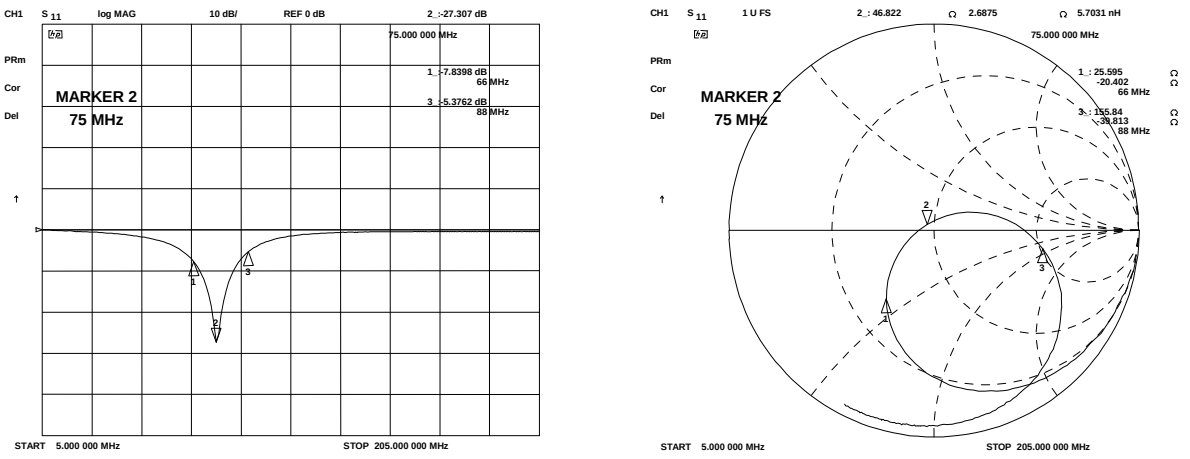

Figure 4 Mixer input matched to 75MHz

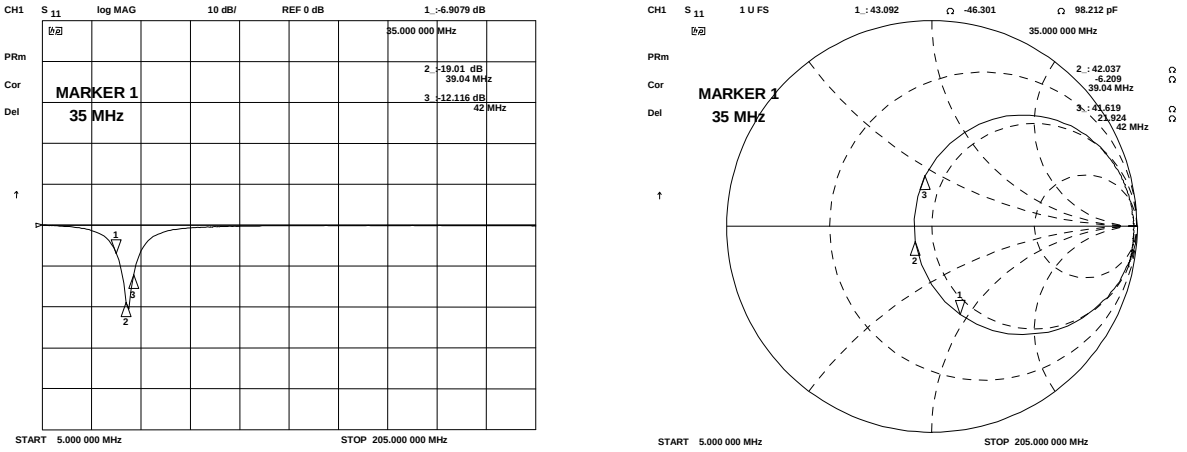

Figure 5 Mixer input matched to 39MHz

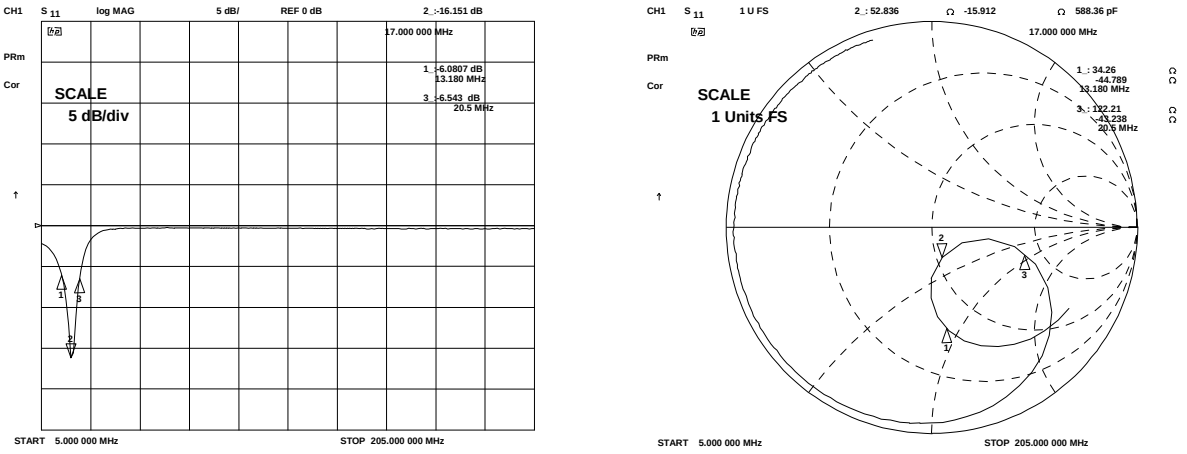

Figure 6 Mixer input matched to 17MHz

Tests on the mixer with a 90MHz IF and matched to 50Ω, without resistive matching for highest gain, gave the results presented in Table 2.

Band	LO MHz	Mixer gain dB	NF dB
75MHz	330	5	13.0
39MHz	258	0.7	14.7
17MHz	214	-11	27.5

Table 2 Rx mixer performance below 100MHz

5.2 Alternative Configuration Using 4:1 Centre-tap Balun

For lower frequency use, an alternative 4:1 input balun arrangement may be used. The balun transformer T1 can be replaced with a Coilcraft WBC4-1WL; this alteration should be performed carefully, as an additional ground connection is needed for the centre tap output winding. The effect of a 4:1 step-up has the advantage that lower Q networks are then required for matching to the high impedance mixer input. The values in table 3 are typical.

Band (MHz)	C62	L1	L2
'Low Band' VHF (66-88 MHz) 75MHz Centre	NF	120nH	2.2pF
50MHz	NF	220nH	10pF
35-41 MHz (39MHz centre)	NF	330nH	18pF
13-20 MHz (17MHz centre)	NF	820nH	82pF

Table 3 Low frequency Rx mixer input match components using 4:1 balun

The table below shows the performance using a 90MHz IF matched to 50 ohms without resistive matching. The RF mixer input is matched to the frequency of interest in each case. Note that whilst the match into the balun appears more wide-band in each case, the gain and noise figure performance is degraded compared with using the original balun transformer. The fundamental limitation of the internal coupling capacitance remains.

Band	LO MHz	Mixer gain dB	NF dB
75MHz	330	2.9	14.4
50MHz	280	0.8	16.3
39MHz	258	0.4	17.4
17MHz	214	-16.8	34.0

Table 4 Rx Mixer performance below 100MHz using 4:1 balun

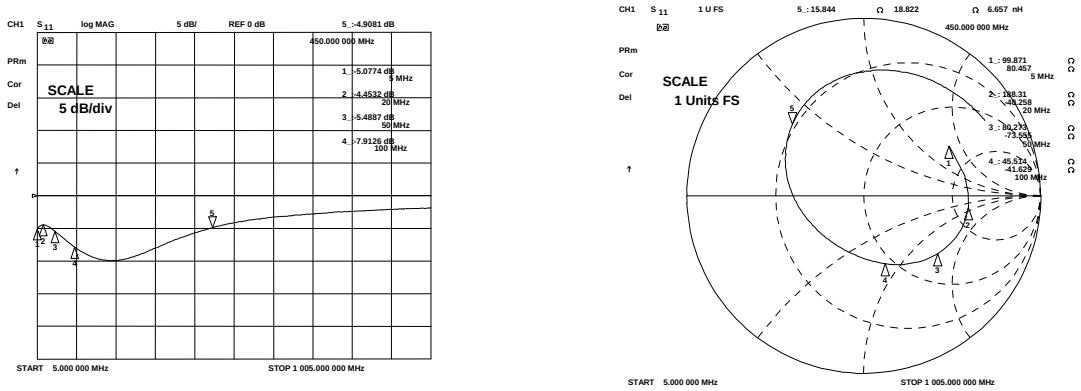

Figure 7 RX mixer input via Coilcraft WBC4-1WL 4:1 balun

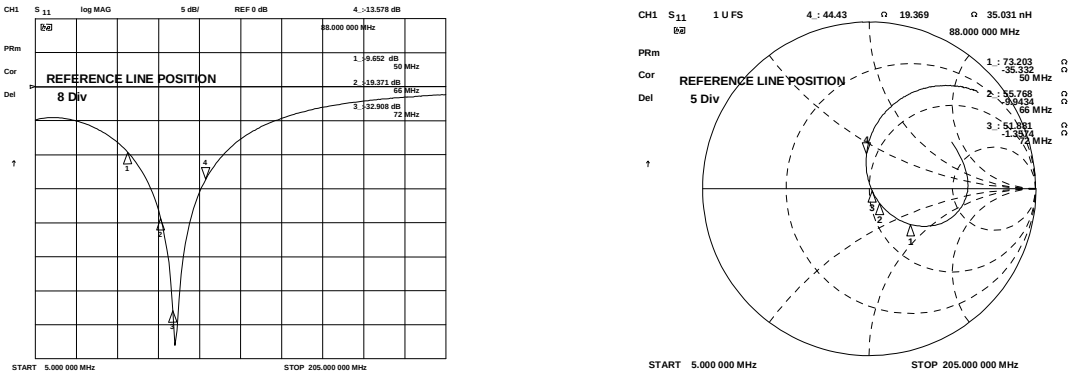

Figure 8 Mixer input matched to 75MHz using 4:1 balun

Note the wider bandwidth compared with Figure 4

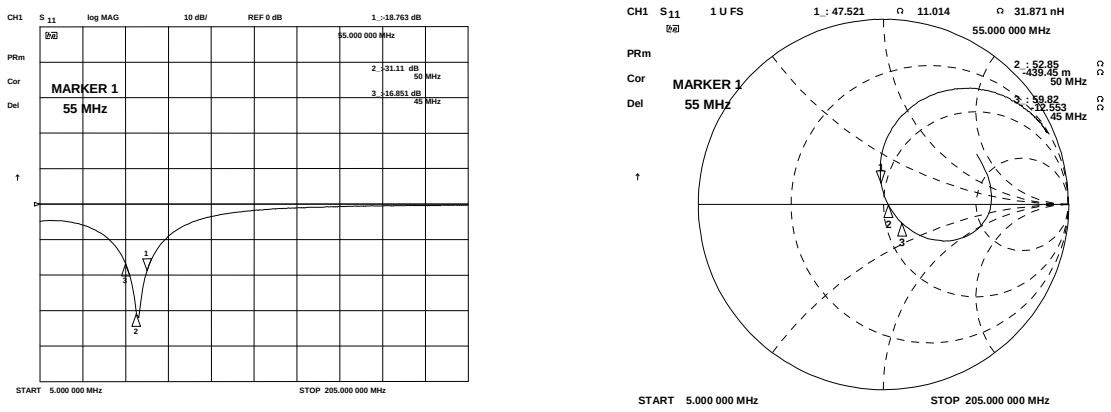

Figure 9 Mixer input matched to 50MHz using 4:1 balun

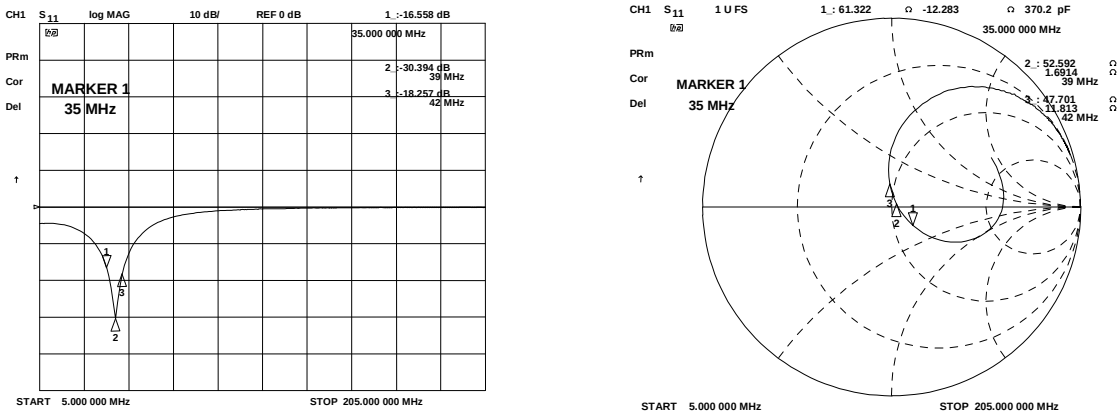

Figure 10 Mixer input matched to 39MHz using 4:1 balun

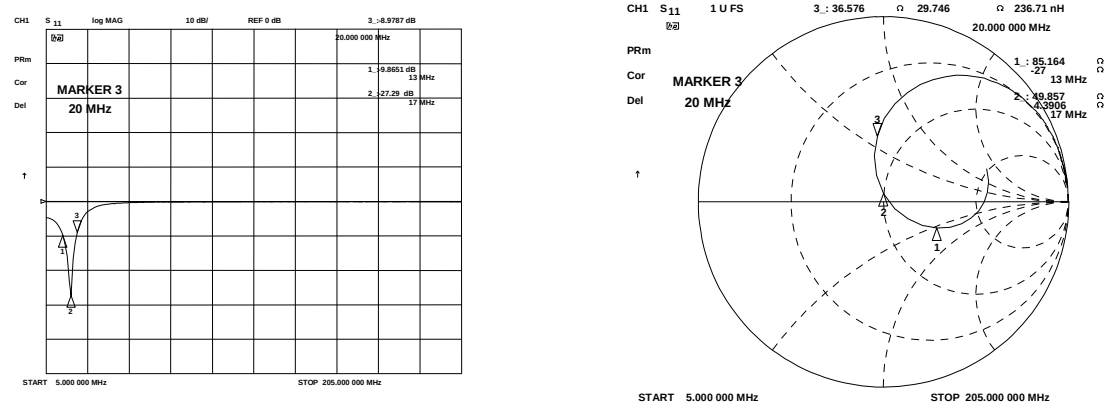

Figure 11 Mixer input matched to 17MHz using 4:1 balun

5.3 Operation Below 50MHz and Multi-Band Configuration

Whilst the mixer can be matched to lower frequencies (<50MHz), the high input impedance of the IC, in particular the low value of the internal coupling capacitance (approximately 300R across the pins with 8pF to each input), causes higher circuit losses and increased noise figure. Also, as a consequence of the high impedance, the match bandwidth also becomes increasingly narrow without

resistive loading. Use of CMX991 and CMX992 1st mixer below around 50MHz is therefore not recommended; an external mixer is likely to be a better solution.

The rest of the CMX991 and CMX992 receiver circuitry however remains highly useful as building blocks within a lower frequency receiver system. One possible configuration for multi-band operation (Figure 12) is using an external 1st mixer connected to one of the IF inputs of the CMX991 and CMX992 for HF operation, with the other IF input used with the on-chip mixer for VHF operation. The C-BUS LNA control signal is available for both modes. The 1st receive mixer of the CMX991 and CMX992 can be disabled to reduce power consumption if required.

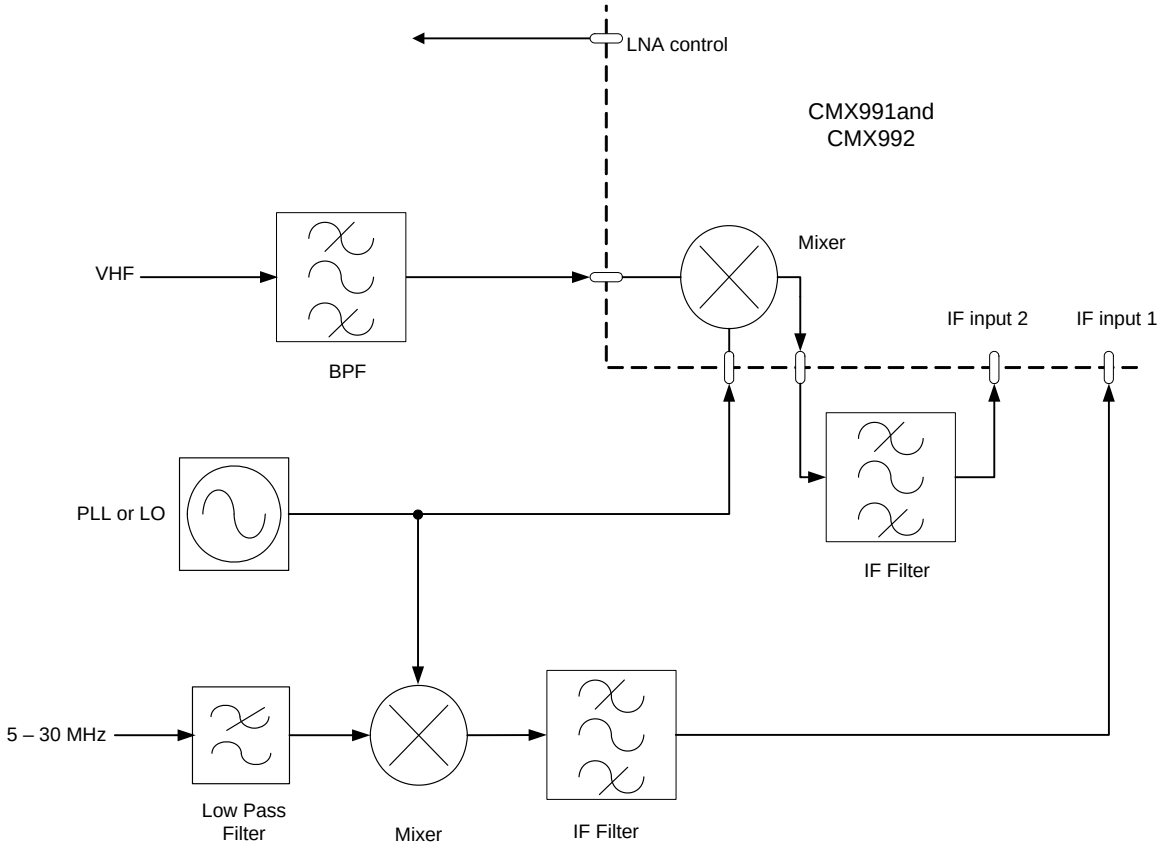

Figure 12 Typical multi-band receiver architecture

6 EV9910B Transmitter Operation Below 100MHz

6.1 EV9910B Configuration Examples

To achieve low frequency operation with the CMX991 transmitter, the image-reject converter stage can be operated as a down-converter. Operation can be demonstrated with the EV9910B evaluation card.

The default EV9910B Tx output configuration uses a 4:1 balun transformer T3 (Mini-Circuits TC4-14M+), which is rated for operation between 200-1400MHz, although performance at 100MHz is still acceptable. For operation at lower frequencies the transformer should be changed, a Coilcraft WBC4-1WL is recommended. The WBC4-1WL is rated for operation between 0.5-1000 MHz.

To demonstrate operation a 90MHz IF can be used with the transmit output taken from J12 and with C76 and L27 fitted as 0R. The output should be configured for $F_{rf} = F_{lo} – F_{if}$ operation[1] and in this example the LO was operated in divide-by-2 mode[2].

Operation close to sub-harmonics and mixing products of the IF and Tx LO's should be avoided to reduce spurious to a level that they can be easily removed by filtering. For example, operation at 15MHz output with a 45MHz IF would be potentially problematic due to the third harmonic relationship between the two frequencies. Users adopting this architecture will need to consider their choice of IF to avoided such spurious based on their specific frequency coverage requirements.

With a single tone output, generated with quadrature sine waves on I and Q channels, typical output power as a function of frequency is shown in Table 5.

LO Frequency (MHz)	RF Output (MHz)	Output Level (dBm)
580	200	-9.4
480	150	-9.6
380	100	-9.6
320	70	-9.6
280	50	-9.65
240	30	-9.45
220	20	-9.4
200	10	-9.55
190	5	-9.61

Table 5 Tx converter output level at <200MHz using a 90MHz IF

An example of the spectrum produced with a two-tone input and operated at an example PEP of -6dBm is shown in Figure 13. The graph is for 20MHz operation and it will be observed that IMD3 products are below -40dBc. Very similar results are observed for outputs down to 5MHz.

[1] Tx Mode Register b2='0'

[2] Tx Mode Register b1='0'

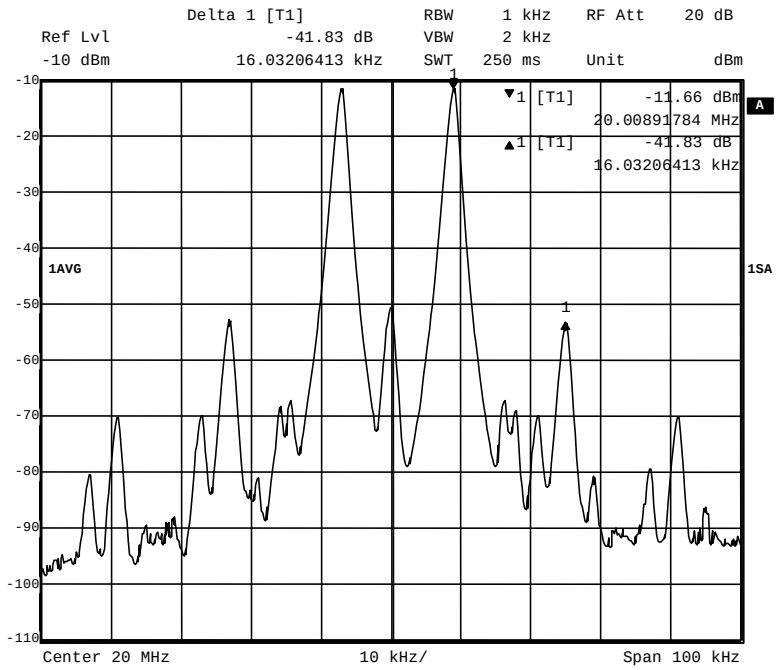

Figure 13 CMX991 with -6dBm PEP output at 20MHz, IMD3 at approx. -42dBc

6.2 IF Output

A further option for low frequency operation of the CMX991 is the IF output mode[3] (TXIFOUT pin) which operates between 100MHz and 10MHz.

[3] Tx Control Register b0='1'

7 Glossary and Definitions

7.1 Glossary of Terms

IF	Intermediate Frequency
IMD3	Third Order Intermodulation Products
LO	Local Oscillator
PEP	Peak Envelope Power

8 References

The following information is available from www.cmlmicro.com:

[1] CMX991/CMX992 datasheet.
[2] EV9910B/EV9920B schematics
[3] EV9910B/EV9920B user manual

CML Microcircuits (UK) Ltd COMMUNICATION SEMICONDUCTORS	CML Microcircuits (USA) Inc. COMMUNICATION SEMICONDUCTORS	CML Microcircuits (Singapore) Pte Ltd COMMUNICATION SEMICONDUCTORS
Tel: +44 (0)1621 875500 **Fax:** +44 (0)1621 875600 **Sales:** sales@cmlmicro.com **Tech Support:** techsupport@cmlmicro.com	**Tel:** +1 336 744 5050 800 638 5577 **Fax:** +1 336 744 5054 **Sales:** us.sales@cmlmicro.com **Tech Support:** us.techsupport@cmlmicro.com	**Tel:** +65 67450426 **Fax:** +65 67452917 **Sales:** sg.sales@cmlmicro.com **Tech Support:** sg.techsupport@cmlmicro.com
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