Flexible Integrated RF Devices For Digital Wireless Markets

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Today we see a huge number of wireless systems in use, with two categories, in terms of numbers of RF devices, tending to dominate; both are high volume consumer markets. The first category is cellular technology - offering the amazingly complex technology of a system like W-CDMA or 3G-LTE is only possible because of the huge sales volumes justifying the investment in complex, leading edge, silicon integration. At the other end we have a range of low-cost and /or low-power technologies, often operating in license exempt frequencies. These include Bluetooth, and Wi-Fi, and low power devices such as wireless headsets, garage door openers and even car security systems. This second category includes complex systems, such as Wi-Fi down to the very simple ones such as door openers.

As shown in Figure 1, outside these two areas there are still many radio systems seeking technology solutions. These markets often feel pressure from the costs and form-factor achieved by the consumer technologies but because they are relatively specialist it is difficult to justify the same level of investment in silicon. Furthermore semiconductor companies have generally regarded this diverse marketplace as less interesting because of the large number of small players all with slightly different requirements.

CML Microcircuits is very familiar with this type of situation having PMR as one of its core markets for many years. Facing smaller volumes and specialized requirements the solution is to make generic products that are a ‘best fit’ for the needs of multiple requirements. Obviously this can mean compromises from time to time but the key is getting the important things right.

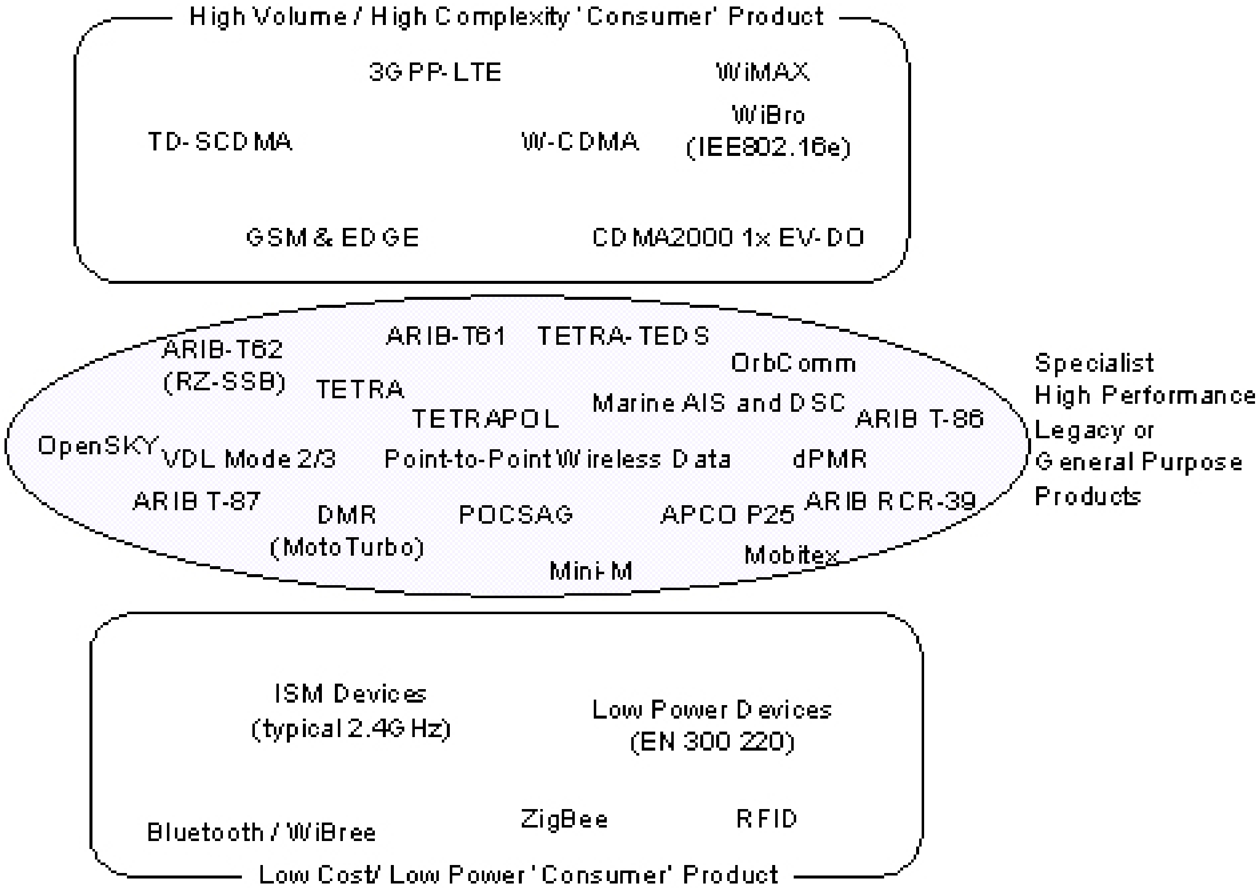

Figure 1 - Grouping of various radio system

Transmitter Solutions
2006 saw the launch of the CML's Cartesian Feedback Loop (CFBL) IC, the CMX998. This has proved popular in a range of radio products, across a diverse range of systems. The CMX998 addressed an emerging requirement for linearization of non-constant envelope modulations such as ?/4-DQPSK and QAM for the frequency range 30 MHz to 1 GHz.

For transmitter solutions that do not require the complexity of feedback linearization, but require the modulation precision of I/Q modulation, design options outside the common cellular bands around 900 MHz and 2 GHz have been historically limited. Some of the available products date back 15 years or more and even some of the newer parts only provide 5 V operation. CML's newly introduced CMX993, offers the benefits of a high-performance I/Q modulator with a 30 MHz to 1 GHz operating range, using a modern SiGe process and adds features such as gain control, flexible differential amplifiers and low voltage (3.3 V) operation.
Receiver Solutions

Receiver solutions for digital systems in high volume applications, adopted direct-conversation technology some years ago. Many other markets have continued to use the superheterodyne approach that has dominated radio architecture since the 1930s. The problem with generic receiver design is the diverse requirements of operating frequency, sensitivity, intermodulation, interference rejection etc. Each system has particular requirements and the variation between different system and regulatory standards is significant. This is demonstrated in Table 1, which shows the variation in the 'Third Order Intercept Point' (IP3) requirement for a range of common data radios. It will be seen that the Marine AIS system (used for collision avoidance and position tracking of large ships), requires a challenging +15 dBm, whereas Mobitex only mandates a rather relaxed –37 dBm! Using an IC designed to meet the marine AIS performance standard for a Mobitex design would result in excessive, uncompetitive, current consumption. In fact, this demonstrates aspects where the flexible design approach provides benefits. The marine AIS Class A requirement is so stringent, when compared to other systems, that it would be foolish to attempt to provide compliant performance in a general purpose IC. The use of the Superheterodyne architecture however, allows use of the integrated IF down-conversion stages, following an IF filter, even in the most demanding applications (Figure 2).

	IP3 Test Parameters				
	Interfering Signal /dBm	Wanted Signal /dBm	Co-channel (As specified) / dB	Sensitivity / dBm	IP3 /dBm
Marine AIS Class A	-27	-101	10	-107	15.5
Marine AIS Class B	-36	-101	10	-107	2
APCO P25 Class A Mobile	-41	-113	9	-116	0.4
APCO P25 Class A Portable	-46	-113	9	-116	-7.1
APCO P25 Class B Portable	-63	-110	9	-113	-34.1
EN 300 113 (12.5kHz)	-42	-107	12	-110	-2.6
EN 300 113 (25kHz)	-42	-107	8	-110	-4.6
EN300 220-1 (Rx Class 1)	-39	-104	10	-107	-0.6
EN301 166 (Portable, dPMR, 6.25kHz)	-42	-104	15	-107	-2.6
EN301 166 Mobile / Base	-42	-104	15	-107	-2.6
Mobitex	-67	-112	12	-115	-37.6
TETRA Mobile/Portable	-47	-109	10	-112	-10.1
EN 302 561 (Wideband PMR / TETRA TEDS)	-47	-106	12	-109	-10.6

Table 1 - Variation in receiver requirements for a range of common standards

Further complications for the designer are added when receivers are required to address multiple modes and/or systems within a single design. One common requirement is for products that provide multiple channel bandwidths. To facilitate this, the CMX991 and CMX992 ICs allow selectable first IF outputs so different IF filters can be applied depending on operating mode. For example, in a TETRA release 2 (TEDS) radios, ?/4-DQPSK 25 kHz channels must be supported for control information, but, 50 kHz data channels (multi-carrier QAM) will be used. In future TEDS radio 100 kHz and 150 kHz channels may also be required. It is anticipated that digital filtering will provide part of the solution, but analogue IF filtering will still be required to reduce the signal dynamic range in the presence of off-channel interferers (such as with blocking signals and intermodulation scenarios).

Another aspect of required flexibility is interfacing, where at least two approaches need to be supported. In many markets, such as TETRA, the I/Q system is almost universally adopted, however, there are significant applications and market areas where an IF sampling approach is preferred (such as APCO P25). The CMX991 and CMX992 have addressed this by allowing independent control of the I/Q paths, which can operate up to 1 MHz. This allows common IFs, such as 455 kHz / 450 kHz, to be supported and the output amplifiers can be used to add ceramic IF filters if required. For systems with multiple channel bandwidths, different ceramic filters can be used in each path as shown in Figure 2.

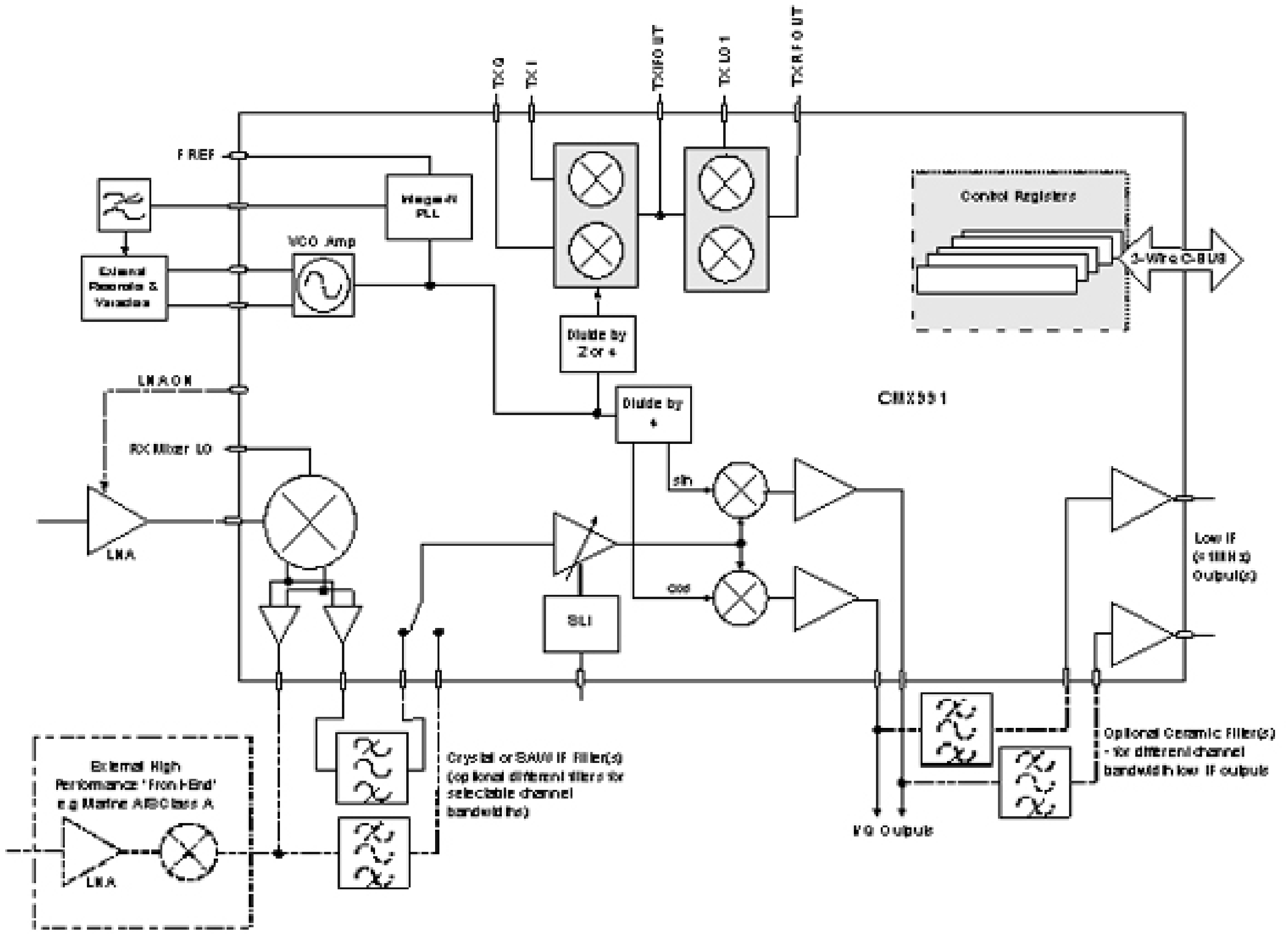

Figure 2 -CMX991 showing flexible configuration features such as the Low IF output(s) and optional high performance 'front-end'.

Transceivers

The pressure of reducing size in hand-portable products means that integration of transmitter and receiver sections into single-chip transceivers is desirable hence the CMX991 from CML Microcircuits. Receiver issues have been discussed above so lets now consider some transmitter issues.

A generic I/Q modulator can be used for modulation on final frequency or for modulation on an IF, in which case, it would need to be followed by a frequency conversion stage. In the former case it is essential to ensure excellent isolation between the modulated output and the local oscillator 'LO' to prevent 'pulling', which can severely degrade the signal. This isolation is often achieved by using an offset LO. As a result the two schemes are usually equivalent in complexity, thus the problem with both schemes is the size/cost of the filter needed, in order to remove spurious products after the mixer - this is where the ‘image-reject’ system helps a great deal, greatly simplifying the filtering requirements. The CMX991 provides the advanced of a image-reject up-converting I/Q modulator to complement the flexible receiver architecture from the CMX992.

The use of an integrated transceiver allows the re-use of local oscillator signals between transmit and receiver functions. This will often further save some circuit complexity as is achieved with the common IF VCO and PLL in the CMX991.

Local Oscillators
A particularly important area in generic radio transceiver design is the local oscillator (LO). The performance of the LO is often a key differentiator between low-cost / low power designs and high performance/‘professional’ systems. While it’s easy enough to make VCO’s on silicon IC’s today, it’s still very hard to achieve ‘professional’ performance levels.

The reason for this comes from two factors, firstly the availability of varactor diodes on integrated circuits and secondly the Q factor possible from on-chip elements. Firstly very few silicon processes offer on-chip varactors and those that do are usually the more expensive ones. Various techniques exist to make some kind of voltage dependant capacitor on chip but all have a limited range of tuneable capacitance and usually offer relatively poor Q.

On chip inductors have progressed significantly in recent years but a Q of 30 is still considered ‘good’. With conventional inductors we could easily expect a Q of 50 for ‘ordinary’ parts and up to 150 when designing high-performance circuits. The pursuit of Q is vital in VCO design, as it has a strong influence on achieving good phase noise. The generic radio systems we are considering often have channel bandwidths of 25 kHz, 12.5 kHz or even 6.25 kHz, which means that the phase noise required at circa 10 kHz might be what a 200 kHz channelled cellular system would require at 100 kHz, thus the requirement in our case is 20 dB more stringent.

As a result on-chip VCOs are problematic for many ‘professional’ applications. Furthermore although something may be possible in specific cases, when seeking to produce generic and flexible devices there is little option but to make the local oscillators external to the IC solutions. This does have the benefit however of allowing the terminal designer total flexibility of performance, tuning range, power consumption and whether to seek a performance advantage by use the more costly fractional-N type synthesiser.

The Holy Grail – Direct Conversion
The direct conversion receiver has long been viewed as the ultimate RF solution due to is simplicity and hence low cost and small size but for many years it was the pretender to the crown held securely by the superheterodyne architecture. The growth of cellular with its intense cost and size pressures changed all that and for more than a decade direct conversion has been the solution of choice for integrated cellphone chipsets. The performance requirements and technical challenges of

direct conversion however meant that other radio systems did not quickly follow the trend and in fact ‘low-IF’ solutions gained considerable favour as an alternative. ‘Low-IF’ is still a Superheterodyne and if used in its simplest form the low IF solution suffers from the fatal floor of poor image rejection, making it unattractive for ‘professional’ level solutions. The landscape is changing however with the CMX994 direct conversion IC from CML Microcircuits (Figure 3). This IC has been developed to meet the technical challenges of direct conversion in ‘professional’ markets and is the first solution targeted at bringing the ultimate in low cost flexible RF architectures to the diverse radio market outside the mass consumer market.

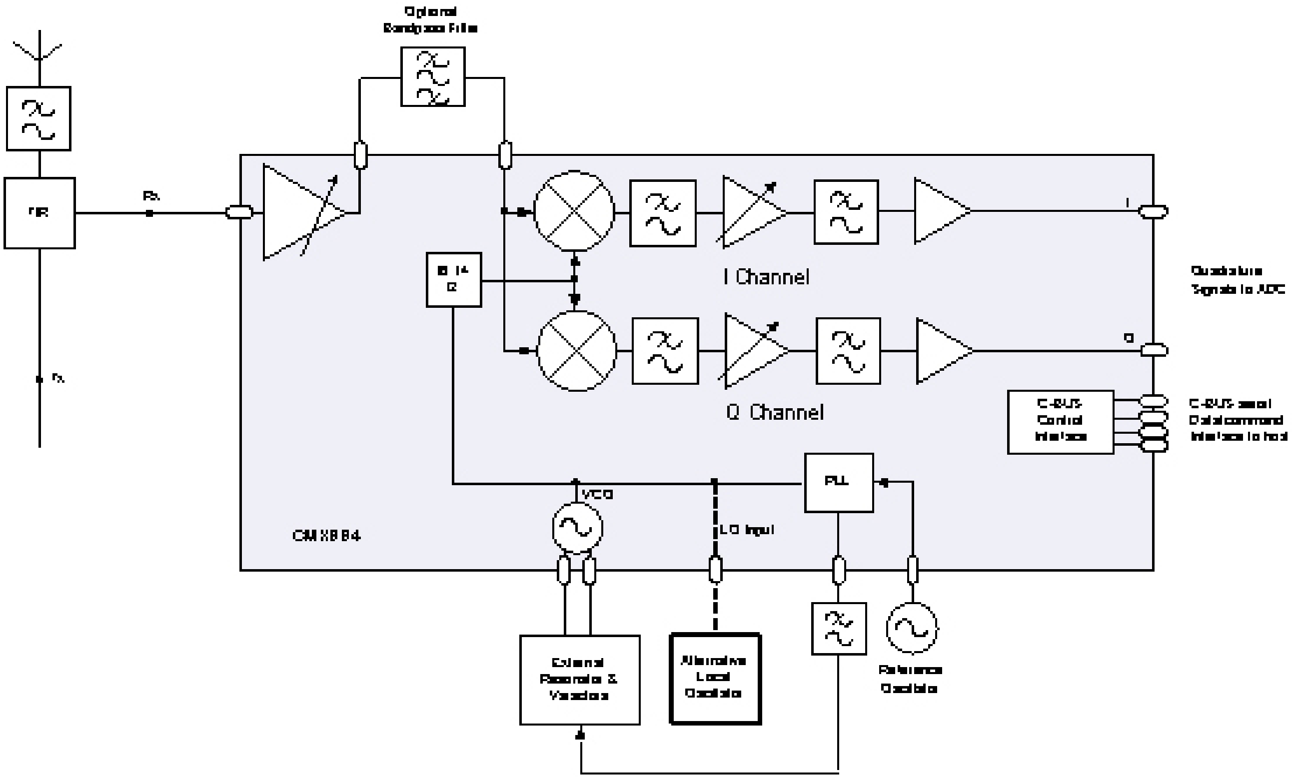

Figure 3 - CMX994 Direct Conversion Technology

When combined with a multi-mode modem solution, such as the CML CMX7164, this technology represents the state-of the art in flexible RF solutions. A typical solution implementing a range of QAM modulation and 4-FSK / 2-FSK is shown in Figure 4.

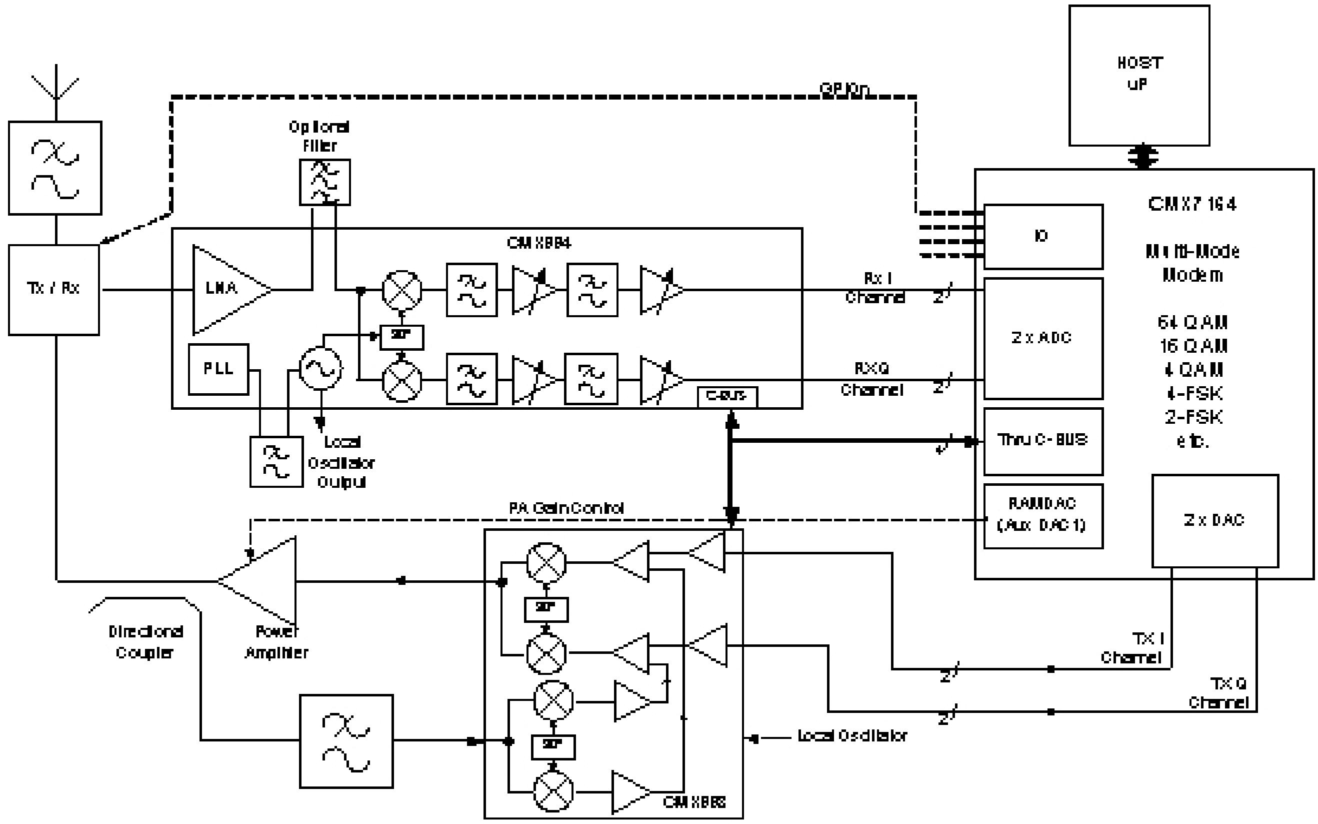

Figure 4 - Flexible Multi-Mode Radio Solution

Mix and Match co-ordination
CML's approach is to optimise silicon designs to provide attractive system solutions. For example all of the devices use the same supply rails, and have a common approach to configurable interface levels for control. This allows direct connection to low voltage micro-controllers or DSPs (transmitter and receiver devices can also use common 3-wire control interfaces as the internal registers are designed not to overlap).

A further helpful feature for handset designers is the ability to separate analogue and digital power supplies. This gives the analogue circuits optimum isolation from digital noise. Also, analogue sections can have power removed while the digital sections can be kept alive, thus retaining programming data for minimum leakage current.

Looking to the future
CML is committed to continuing this approach to RF design, providing new generations of improvements to RF systems. Each new generation will follow the same design principals outlined here offering the customer timely upgrades and improvements.

Further Information
CML products cited throughout this article:
CMX991 RF quadrature / IF transceiver
CMX992 RF quadrature / IF receiver

CMX993 / CMX993W Quadrature modulator
CMX994 Direct Conversion Receiver
CMX998 Cartesian feedback loop (CFBL) transmitter
CMX7163 QAM Modem
CMX7164 Multi-Mode Modem
Further information, datasheets and evaluation kits are available:
www.cmlmicro.com [1]

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