Architectures of Highly Integrated RFICs for 900 MHz US Digital Cordless Systems

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Abstract:

Cordless phone systems operating at 900 MHz in the United States have gained popularity over the older 49 MHz analog systems. The driver that has made these 900 MHz systems popular, is performance at the right price for consumer applications. This paper reviews architectures and shows examples of highly integrated RFICs applicable for this market.

Introduction:

Since the first introduction of US 900 MHz cordless systems seven years ago, these consumer products have gained significant popularity in the market due to the voice quality and range that they provide over and beyond the 49 MHz analog systems. The key that has made these systems successful has been the ability to achieve price points that make these systems competitive with the lower cost 49 MHz products. In 1991 these systems were retailed for $300 while today in 1998, you can find them for as low as $60. These systems operate in the FFC Part-15 band from 902 to 928 MHz. The FFC requirements for this ISM band are to control emissions but not to restrict the protocol and architectures of systems used in this frequency band. Interoperability is not a requirement and thus several architectures and systems have been made practical and available to consumers in this band. Both digital and analog 900 MHz systems are currently on the market. While analog systems are less expensive, they are more susceptible to eaves-dropping and interference.

Architecture requirements:

The major architecture driver is the ability to produce a system that maintains voice quality and range at the lowest possible price. In this extremely price sensitive market, one has to be careful and make sure that integration and technology costs are commensurate with the market needs. The largest competitor to integrated systems is the ability to build something less expensive with discrete components. Unlike the cellular market, size and weight of the handset is not one of the primary technology drivers, in cordless, price is a distant first. Also, unlike cellular, cordless needs to have wireline voice quality and reliability. The key of successful cost reduction lies in architecting a system that absorbs most of the radio costs into an RFIC while keeping the external component cost to a minimum.

Architecting around filters:

Filters are of significant cost and contribute heavily to the radio bill of materials. The key goal is to eliminate them altogether and place all the filtering in the analog/digital domain. Today's technology does not allow us to achieve this noble goal. In order to achieve the required selectivity and provide immunity

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to out of band interferers, some filtering is required in most of these systems. For out of band interferers, filters at 900 MHz are required in the receiver section to protect from signals in the cellular, mobile radio and paging bands. This is usually achieved using a low cost two pole dielectric filter. Channel selectivity is usually achieved using low cost 10.7 MHz ceramic filters that are popular due to FM radio. Although 10.7 MHz is not an ideal IF frequency for systems that can operate over a 26 MHz bandwidth, these low cost ceramic filters make most architectures converge and adopt this 10.7 MHz IF frequency.

Choice of Division Duplex and its Impact on the Architecture:

Several types of digital radio protocols have been successfully implemented, all of which have their advantages and disadvantages. Analog systems, as well as some earlier digital systems, are restricted to Frequency Division Duplex (FDD) and they operate by separating two chunks of band approximately 2 MHz wide at the distant edges of the 902 - 928 bands. This usually requires a frequency duplexer to separate the transmitted and received signals since they are present simultaneously. Some systems also require a 900 MHz SAW filter for interference immunity from the paging bands. More advanced digital systems operate in Time Division Duplex (TDD). Most systems transmit and receive in alternating frames but do not share the time slots between channels. This is due to the wide data bandwidth required to achieve wireline voice quality and the need to achieve long range since the FCC regulates the instantaneous transmitted power rather than the average transmitted power for a given channel. To save cost and take advantage of the 10.7 MHz IF frequency, some digital comparisons of these systems is very difficult, since the environment is not quantifiable and is systems do both FDD and TDD simultaneously. The advantage of TDD is that it allows you to integrate the transmitter and the receiver on the same RFIC since you are not transmitting and receiving simultaneously, thus isolation from the transmitter to the receiver is not important.

Digital Narrowband vs. Spread Spectrum Protocols:

The FCC regulations allow for three major categories of architectures, namely a) narrowband transmission with radiated power close to 1 mW, b) direct frequency spread spectrum with 10 dB processing gain with 1W maximum radiated power, and c) slow frequency hopping spread spectrum with 50 channels and 1W maximum radiated power. In order to save battery power and control emissions most spread spectrum systems only transmit 100 mW even thought they are allowed by the FCC to transmit as much as 1W. For narrowband transmission, all related emissions have to be -50dB down from the total transmitted power while the spread spectrum related emissions need to be better than -20dB. The advantage of the spread protocols over the narrowband systems is range, since they are allowed to transmit more power. In a line-of-sight open field environment, the range of the analog 49 MHz systems is about 100m, the range for 900 MHz narrowband is about 250m, while the range for a 900 MHz spread spectrum system transmitting 100 mW is 750m. However, in-building propagation is better at 49 MHz but usually 900 MHz narrowband still has about twice the range of 49 MHz analog. On the other hand, in-building the spread spectrum systems with 100 mW transmitted power usually only provide about 50% more range than the narrowband counterparts. In building a variable; thus most systems are usually compared using open field line-of-sight range numbers although most consumers use the product indoors.

Examples of Highly Integrated RFICs for Digital Cordless Applications:

An example of a highly integrated RFIC that addresses the digital narrowband 900 MHz cordless market is given in Figure 1. This architecture uses both FDD and TDD to reduce system complexity while maintaining excellent performance. The receiver has an image reject 900 MHz front end to eliminate the need of a SAW filter and uses a limiting IF with a frequency discriminator and a data slicer to provide data to the baseband chip. The system thus uses one, two pole 900 MHz dielectric filter, and two 10.7 MHz filters for interference immunity and selectivity. The chip has a synthesizer and a VCO for generating the LO for both transmit and receive. The VCO is differential and uses an external resonator. The transmitter uses direct modulation of the VCO to generate the modulated transmitting frequency directly from the base band signals thus requiring no intermediate frequency and no RF filtering. The whole chip is biased from an internal current reference, while the VCO is on a separate regulated supply that uses an external discrete PNP. A picture of the IC is given in Figure 3. This RFIC is built in a 12 GHz Ft bipolar process and is packaged in a 48 lead TQFP package.

An example of a highly integrated RFIC that addresses the 900 MHz direct sequence spread spectrum cordless market, is given in Figure 2. This architecture also uses both FDD and TDD to reduce system complexity while maintaining low emissions. The receiver also has an image reject 900 MHz front end followed by a 10.7 MHz despreading mixer and a filtered/limiting IF that is demodulated in the baseband chip. The transmitter uses an IQ modulator to generate the modulated and spread transmitting frequency directly from the base band signals, thus requiring no intermediate frequency and no RF filtering. Carrier frequency generation and chip biasing is similar to the narrowband chip in Figure 1. The picture of the IC is similar to the one given in Figure 3.

Conclusion:

This paper reviews architectures used for US 900 MHz cordless phones and points out the engineering tradeoffs that drive it. Examples of two state-of-the-art RFICs for narrowband and direct sequence spread spectrum systems are also given.

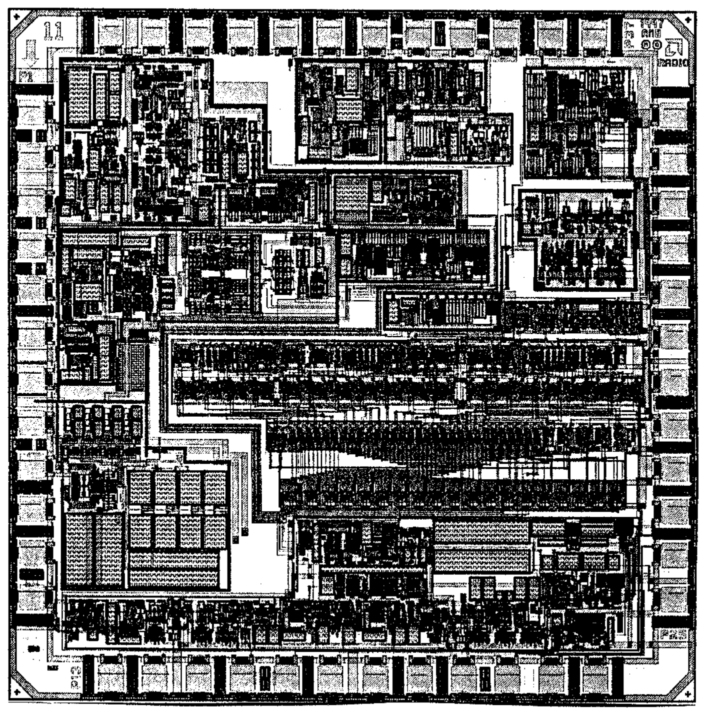

Figure 3. Chip micrograph of a US 900 MHz narrow band digital cordless phone.

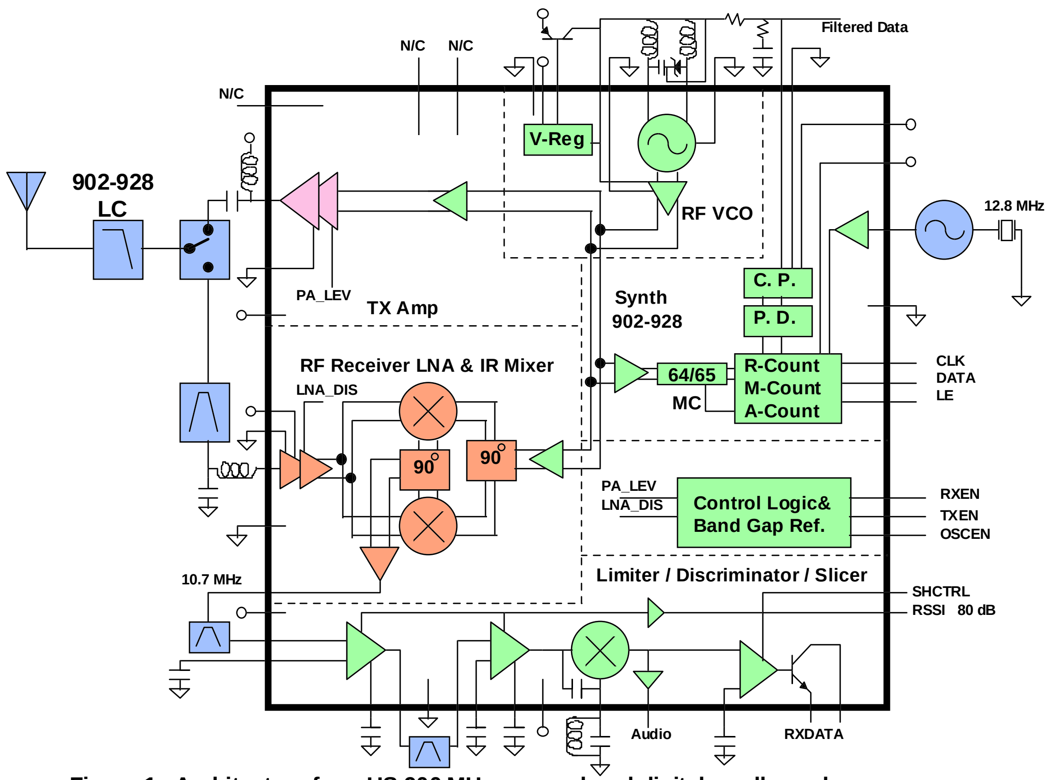

Figure 1. Architecture for a US 900 MHz narrow band digital cordless phone.

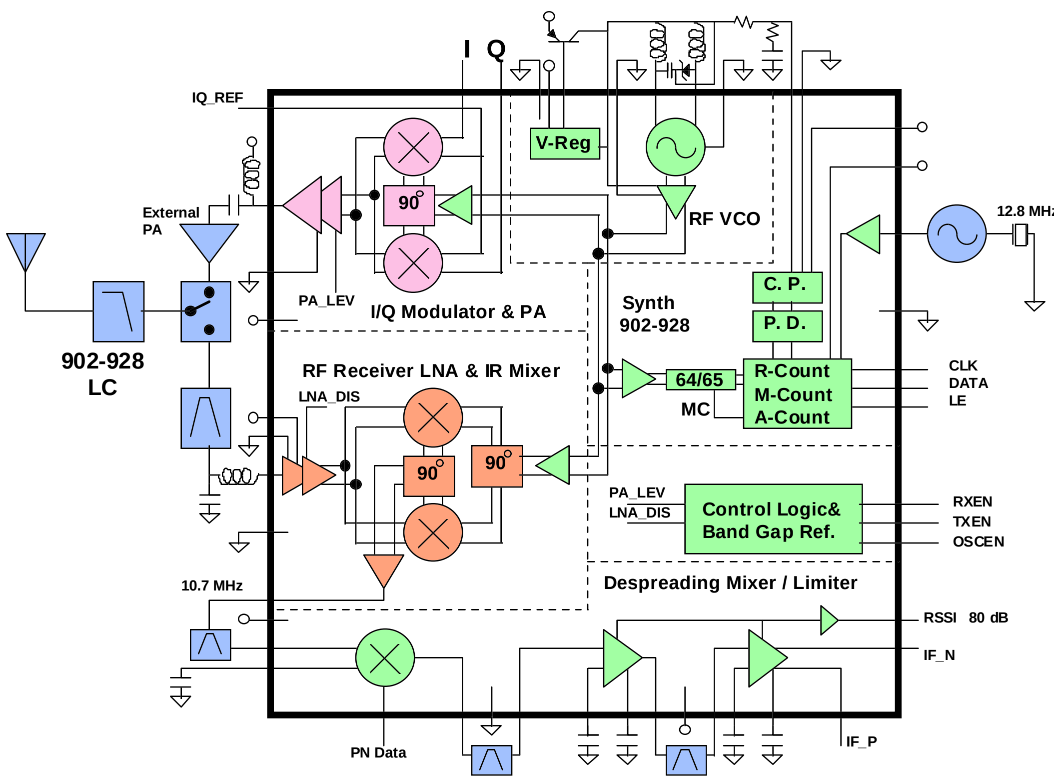

Figure 2. Architecture for a US 900 MHz direct sequence spread spectrum cordless phone.