SOFTWARE DEFINED RADIO – PROGRAMMABLE TRANSCEIVERS FOR FEMTOCELLS

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ABSTRACT

The Home Base Station or Femtocell Market is a market segment that can be well served by programmable RF platforms. Many business cases describe the advantages of offloading both cellular voice and data traffic from the wide area network (WAN) onto the IP backbone via a residential broadband connection. This significantly reduces operator CapEx and OpEx. However, the long term success of this strategy may depend on identifying a suitable low cost architecture for the radio. Due to the relatively low initial volume in the Femtocell market (as compared to that of the mature handset market), integrated RF transceiver solutions which meet industry requirements for cost and performance have been slow to appear. Carriers need Femtocells which will directly support voice and data connectivity over multiple bands within the carrier's licensed spectrum and which will also enable channel sniffing. Existing design approaches quickly converge to architectures employing multiple RF transceivers to support both the Femtocell and channel sniffing functionality.

Programmable RF architectures can offer Femtocells designs reduced part count, and lower bill of material cost. They also provide a platform which can be quickly and inexpensively deployed for new bands of operation. The Softransceiver™ RFIC architecture in particular offers designers a single RFIC solution which can support both Femtocell traffic and channel sniffing. This solution immediately reduces the total cost of ownership. Sample bills of material and block diagrams are provided to illustrate the cost advantage and reduced part count possible with programmable RF transceivers in Femtocell applications.

1.0 INTRODUCTION

Penetration of mobile devices through the population has continued to increase around the globe. In the developed nations of the world (GDP per capita greater than $20,000), wireless devices exhibit greater penetration than wireline (Figure 1). Plunging prices have enabled handsets which cost less than $30. Given that the "last-mile" costs for copper are often as much as an order of magnitude higher than for an equivalent wireless solution[1], it's no surprise that wireless deployments are the primary source of new

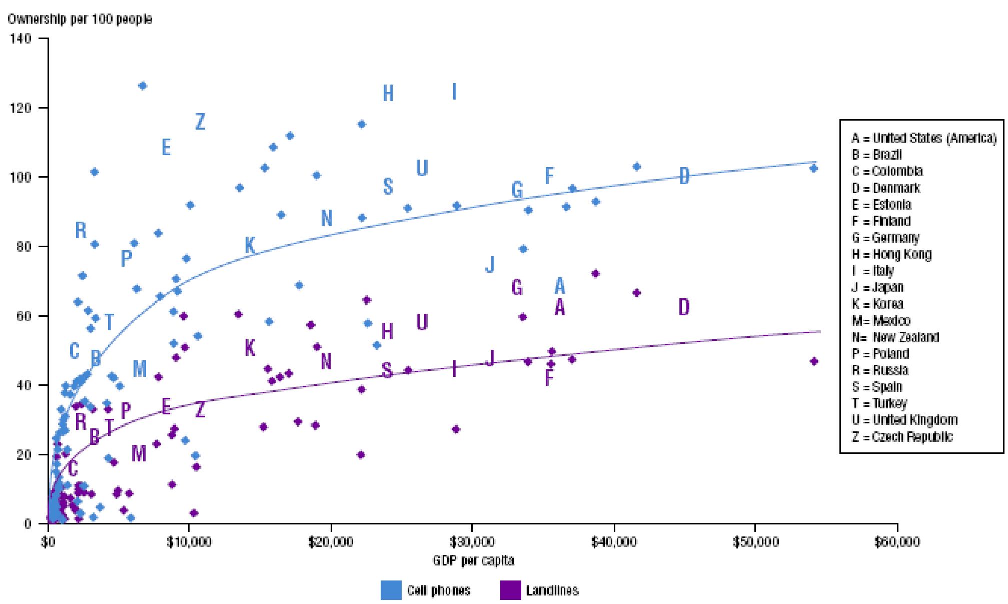

Figure 1 - Wireline vs. Wireless Penetration
Source: Federal Reserve Bank of Dallas, 2006 Annual Report, p. 19

connectivity around the globe. India, for example, is currently adding over 6 million new wireless lines per month[2].

Spectrum is controlled by each national regulatory agency. While there is a growing push to make more spectrum available (i.e. the US 700 MHz auction), the intersection of supply and demand means that new problems are created for the carriers who service those lines.

Dropped Calls - In dense coverage areas, users may suffer from dropped calls when too many users attempt to access the network. Capacity may be inadequate for the number of active users present in the area.

Poor Coverage (existing network)- Additionally, users may desire to use their voice and data services indoors and the additional loss involved in transmitting through walls and floors may also degrade the quality of service that they receive.

Poor Coverage (data throughput) – Data services typically require higher order modulations. This magnifies the effects of poor or limited coverage for data users.

Capacity – With the continued push to increase revenue from data services, carriers are allocating an ever-increasing slice of the available capacity (spectrum) to data thus compounding the effects of increasing demand.

Costs - Building and maintaining new cellular macro basestations is increasing due to regulatory, environmental, real estate and raw material costs.

There is a solution to these problems on the horizon: Femtocells. The Femtocell is a small, low power version of a macrocellular basestation. Macrocells are typically found beneath a cluster of antennas and processors on a hilltop tower or top of a tall office building. A Femtocell on the other hand is designed like a WiFi Access Point. The Femtocell is typically designed to support between 1 and 4 users and to provide data coverage within a house or apartment. Key differences between a Femtocell and Base Station lies in the transmit power (low), the location of the antenna (within the four walls of your home) and the method of backhaul (over your broadband internet connection).

2.0 EXISTING ARCHITECTURES

Current Femtocells are just beginning to see deployments in networks around the globe. Although Femtocells are much anticipated and offer many key benefits to both users and carriers, it remains difficult to predict the timing of the volume ramp. Current forecasts already show 30 – 43 million units shipped by the year 2012.

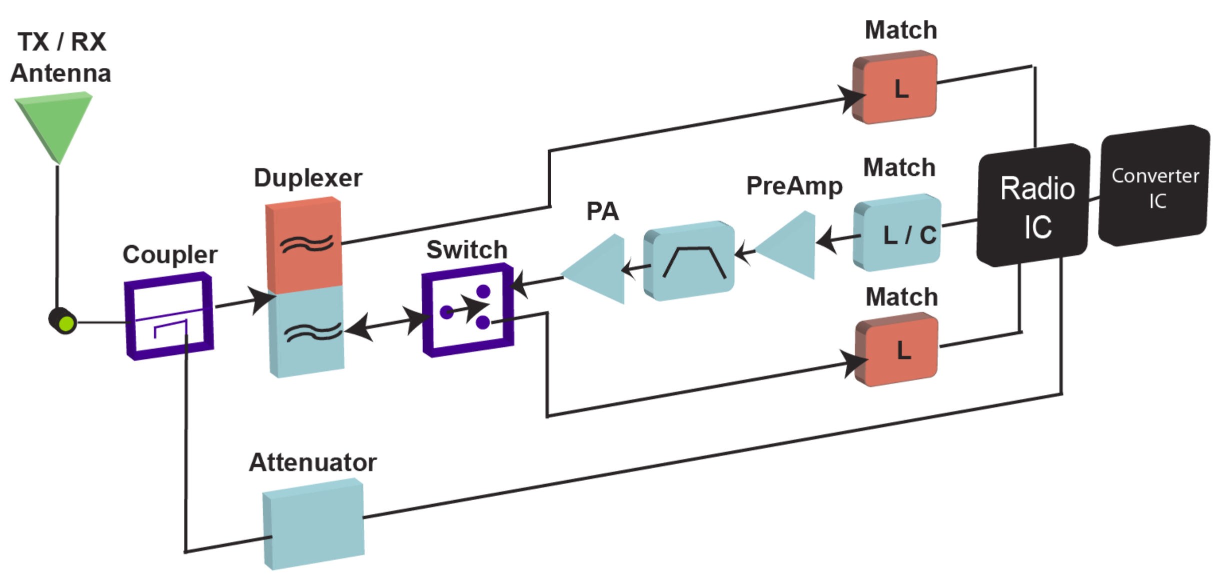

Figure 2 - Single Band Femtocell with Downlink Scanning (Chipset Solution)

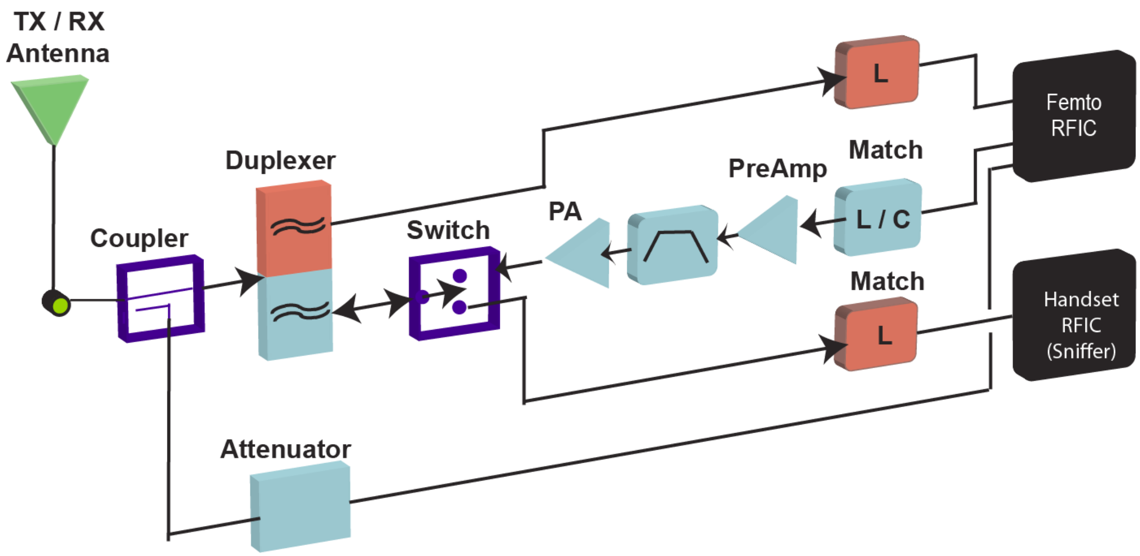

Figure 3 - Single Band Femtocell with Downlink Scanning (Multi-RFIC Solution)

Existing Femtocell designs are either comprised of discrete RF components or are based on multi-band chipsets. Given the short supply of femtocell RF transceiver vendors, the frequency bands which can be supported by the limited product families are minimal. Block diagrams for single band Femtocells architectures are provided in figures 2 and 3. Existing architectures don't offer a clear path to reduced total cost of ownership that a programmable architecture would provide since each carrier-specific solution would require different chips or chipset(s).

Typical RF transceivers currently available are a necessary starting point. However, each band combination required by an individual carrier may require multiple unique RFICs to support both the femtocell in its primary bands of operation s as well as support the necessary channel sniffing. Femtocell vendors will be forced to compete on price and although this may be good for carriers in the short run, doesn't provide a long term incentive for femtocell vendors to develop the technology or provide a path to a low cost platform that can trigger mass deployment by operators.

3.0 PROGRAMMABLE TRANSCEIVER BENEFITS

Programmable RF architectures for Femtocells offer both a solution to the current challenges faced by Femtocell manufacturers as well as a path to quickly creating new applications and functionality.

Reconfigurable architectures offer many benefits through the complete wireless value chain. Users seek devices that offer more applications in a single device than ever before. Reconfigurable devices can also provide adaptive performance and modify their operating characteristics (such as sensitivity and power) to suit the RF environment which currently surrounds them. Reconfigurable radio has something to offer all members of the wireless value chain.

Lower BOM – More functionality in one chip therefore the Femtocell requires fewer chips. Fewer chips means lower cost.

Flexibility in Deployment - Femtocell manufacturers will be able to deploy one platform into many carrier programs and simplify their supply chain since a single solution may support more bands and protocols. Inventory costs can be driven down

Future-proofing - Carriers will be able to provide software upgrades to Femtocell RF performance and device functionality

Turnkey Radio Solution – Programmable RF transceivers offer the tools to quickly program the device to work with any combination of baseband modems and front end module. The ability to develop new solutions from the same hardware platform enables significant reductions in time to market.

4.0 EXAMPLE ARCHITECTURES

Programmable solutions for Femtocells offer clear advantages over discrete radio designs as well as the fixed function transceivers currently being used. Figure 4 shows a Femtocell block diagram of a single protocol design (Femtocell with channel sniffing). The discrete components

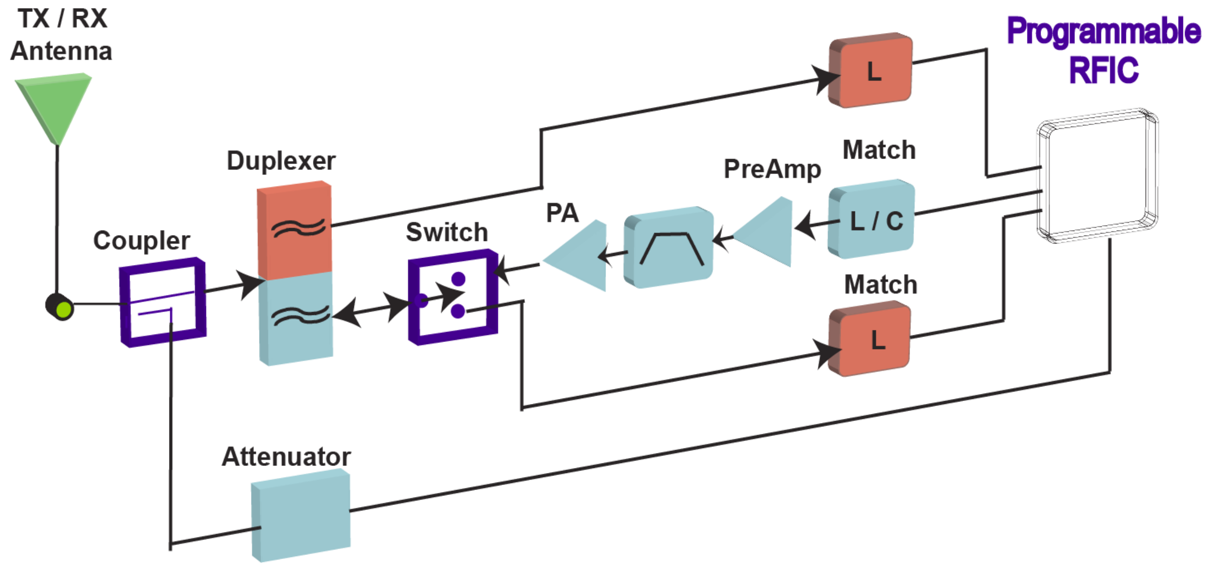

Figure 4 - Single Band Femtocell with Downlink Scanning (Programmable RFIC)

used in Figures 2, 3 and 4 are almost identical and the costsavings created through the use of a programmable architecture is therefore found in the elimination of the additional RFICs or Converter ICs used in current designs.

In the case of BitWave's Softransceiver RFIC, the ADC and DAC are included in the System-On-Chip (SoC) enabling elimination of the converter IC shown in figure 2. If we consider other architectures which utilize a second transceiver for channel sniffing (Figure 3), the programmable transceiver eliminates the need for that second transceiver since it can be reprogrammed to provide the functionality of the Femtocell transceiver as well as that

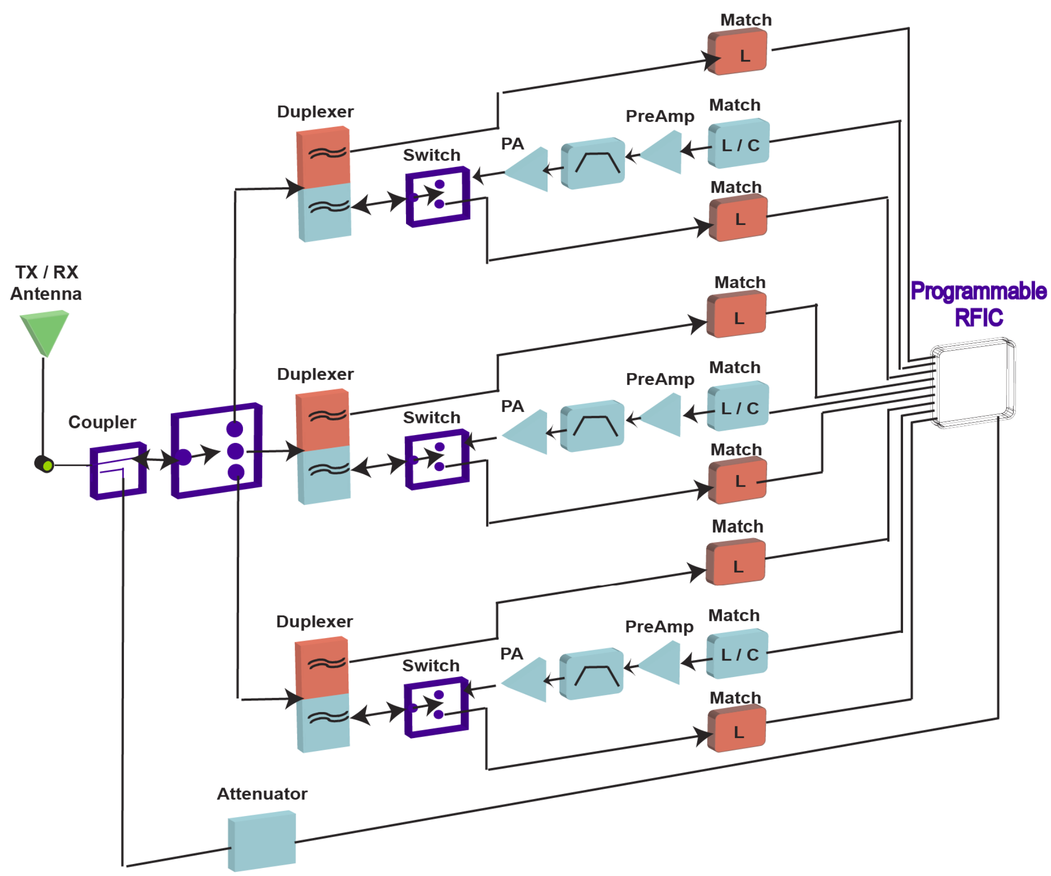

Figure 5 - Tri-Band Femtocell with Downlink Scanning and Programmable TXCVR

of the channel sniffer. Channel sniffing (to confirm Femtocell location and identify surrounding macrocells) does not need to be done simultaneously while in a call, it only needs to be completed periodically as determined by the wireless carrier. However regardless of frequency of the check, the Femtocell must include that full channel sniffing functionality in its transceiver solution and the Femtocell will therefore become more expensive. While the block diagram is figure 4 is very similar to the existing architectures shown in Figures 2 and 3, it is readily apparent that a programmable transceiver can be used to replace the two fixed function transceivers in Figure 2 or 3 with a single programmable transceiver capable of supporting multiple modes and operating frequency bands. The near term value to the Femtocell is in the cost difference between the two solutions as well as in the supply chain overhead reduction that comes with reduced part count in a design.

Carriers continue to acquire more spectrum licenses in order to meet their customer demands for more capacity. The new spectrum often results in fragmented frequency bands of operation. Customers expect seamless coverage and carriers will always looks to integrate coverage for all their bands of operation into each Femtocell they deploy. The design simplification obtained with a programmable transceiver becomes more compelling as carriers target more operating frequency bands. Shown in figure 5 is a block diagram for a tri-band Femtocell using a programmable transceiver. The transmit and receive paths in the front end are of the same basic architecture seen in the single band design (figures 2 and 3); they are simply repeated for each unique frequency band required by the application. Size will therefore scale with the application complexity but at a much lower rate than if new RF transceiver ICs were required to support the additional bands. Furthermore, a programmable RF transceiver also reduces the total part count in the design. Taking BitWave's BW1102 Softransceiver as an example, an estimate of the necessary bill of material to implement the RFFE in figure 4 for WCDMA projects a reduction in total part count and cost . The cost per frequency band of operation is estimated at $6. This cost includes the front end components between the RF transceiver and the antenna. If we consider that a single RFIC could cost at least $6, that at least 50% of the cost of the total RFFE is in the transceiver and that the cost to the manufacturer will be highly dependent on the number of RFICs. Solutions which require fewer ICs will therefore have a significant advantage.

- ***PA***
- ***Pre-driver***
- ***SAW filter***
- ***Duplexer***
- ***Coupler/detector/converter***
- ***1:2 Switch***
- ***TX match(2 inductors,1 capacitor, 1 resistor)***
- ***RX match(1 inductor)***
- ***Other passives (33 decoupling & loop filter components)***

Approximate RFFE cost (excluding TXCVR) ~ $6

Table 6 – Estimated Baseline BOM for WCDMA w/ WCDMA sniff

5.0 SUMMARY

For Femtocells to become as ubiquitous in homes and businesses as cellphones themselves, Femtocell vendors need to design and manufacture platforms which are high performance, low cost and adaptable to different frequency bands of operation and wireless protocols For Femtocells, the challenge to lower cost, provide flexibility in deployment, future proof designs, as well as offer turnkey solutions can be met with programmable RF architectures. In the simple examples described earlier, it's clear that a single programmable RF architecture can meet the needs of multiple Femtocells designs while lowering bill of material cost and part count. Supplying carriers with common platforms which can be reprogrammed with software to support multiple bands and protocols offers carriers an opportunity to streamline their supply chain and simplify their customer offering. This all leads to reduced CapEx and OpEx.

By lowering the Femtocell total cost of ownership (TCO) early in the lifecycle of Femtocell deployments, wireless carriers will be able to quickly scale to volume. Lower TCO offers better effective margins for the carrier, the Femtocell manufacturer and RF transceiver supplier yet still allows the carrier to meet consumer price expectations. Healthy margins support continued innovation and enables the cycle to start anew.

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[1] Cherry, S.M. "The wireless last mile" IEEE Spectrum. September 2003: 18-22

[2] "Indian GSM operators add 5.95 million subscribers in August (India)", www.wirelessfederation.com/news/category/reliance-telecom/, September 18th, 2007