A software modem approach to multi-standard TV & Radio reception on portable devices

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There is a growing trend for portable consumer electronics devices – such as cellular handsets, notebook computers, portable media players, handheld gaming consoles and portable navigation devices – to integrate an increasing number of wireless applications such as Wi-Fi, Bluetooth and GPS. A recent wireless application also vying for integration in portable devices is reception of broadcast radio and TV programmes.

In this article, the challenges of integrating global broadcast standards – TV in particular – on portable device platforms are outlined, and a solution is described for solving the multi-standard conundrum with a software modem approach.

Integrating multiple wireless technologies into a single device poses considerable challenges for silicon vendors and manufacturers alike, since such convergence aggregates all of the demanding technical requirements of each radio application into a single platform. In addition to the technical challenges, these converged devices must also adhere to the consumer electronics (CE) rules of keeping costs to a minimum, constraining the physical dimensions for ultimate portability, and minimizing the power consumption to extend the battery life.

Portable broadcast reception – historical limitations

Consumer demand for multimedia content on portable devices has grown rapidly in recent years, and *Broadcast* is a technology, together with *Cellular* and *IP-based* solutions, that can help to service this need. The enduring importance of Broadcast lies in the fact that it is the most efficient way to deliver media content to multiple consumers simultaneously. Additionally, Broadcast is well served globally by free-to-air content. By offering Broadcast reception – in conjunction with other content consumption mechanisms – CE device manufacturers can offer consumers the ability to enjoy live TV and radio content of their choice, and when and how they want it.

Whilst Broadcast radio has seen successful deployment in various portable devices, integration of TV reception has been less successful. This is due in large part to four reasons:

1) Analogue and digital terrestrial TV standards were never originally specified for good mobility performance, with low power consumption or a small form factor. As a result, early portable CE devices that integrated, for example, analogue PAL or digital DVB-T receivers, delivered a very

poor user experience. To address this matter, dedicated Broadcast Mobile Digital TV (MDTV) technologies – such as DVB-H, CMMB and MediaFLO – were developed, specifically targeting portability.

2) In spite of the advent of portable-friendly MDTV standards, these technologies require new transmission infrastructure and someone must pay for the deployment ... i.e. this is a commercial not a technical barrier. Traditional broadcasters do not want to launch MDTV services as there is no obvious means for them to generate sufficient additional revenue to cover the cost of service provision and infrastructure deployment. Some cellular operators did sense an early opportunity to generate additional ARPU by offering MDTV but, as in the case of the launch of DVB-H in Italy or DAB-IP in the UK, these operators made the crucial error of charging users high subscription rates for limited TV content, or content that they could already receive free or as part of an existing package while they were at home.

Japan and Korea are two geographical exceptions to this unsuccessful MDTV experience and it is rather telling that, in these countries, the governments mandated free-to-air mobile TV deployment which rapidly translated to a high MDTV attach-rate in cellular handsets. To recoup MDTV deployment costs, operators in these countries now have a loyal customer base and are offering paid-for TV content and data services such as traffic, weather and stock market updates.

3) TV uptake on portable devices has been muted because no global TV standard exists, either for terrestrial or mobile reception. This, together with differing regional spectrum allocations, has fragmented the total available market for manufacturers who prefer a single platform strategy that can be promoted worldwide to leverage economies of scale. Fragmentation ultimately leads to higher-cost CE devices and consumers typically do not want to pay a premium for one-of-many device features.

4) Additional costs. Today's single-standard broadcast receivers typically add around $8 to the bill of materials (BoM). Supporting multi-standard receivers is clearly unsustainable on cost-sensitive CE devices.

In the case of the first two barriers to successful TV deployment discussed above, some progress is now being made. Silicon vendors have made significant improvements in lowering the power consumption and increasing the mobility performance of terrestrial TV receivers. Today, notebook PCs and portable media players (PMPs) are available embedded with free-to-air TV reception, delivering an acceptable user experience, unlike previous historical attempts. Note that if ultimate mobility performance is required, portable terrestrial digital TV reception typically requires *diversity* – with its additional costs and size implications – and this is one case in which MDTV can excel technically.

In regard to the second commercial barrier to MDTV success, in Europe at least, cellular operator strategies and revenue models for MDTV are now being rationalized: lower subscription charges are being introduced and some free content is being made available to subscribers. In part, this capitulation is in response to savvy mobile virtual network operators (MVNOs) now offering their subscribers free-to-air terrestrial broadcast content via DVB-T, to win market share.

The ultimate success of MDTV in cellular handsets will be determined by operators and broadcasters working together to devise business models that attract many users, whilst still enabling them to recoup their infrastructure deployment costs or to offset their lost voice-based telephony revenues. The Japanese and Korean MDTV experience suggests that, with careful thought, this may be possible.

The remaining major barriers to successful portable broadcast reception therefore lie in cost-effectively addressing the fragmentation caused by the multiplicity of technical standards around the globe.

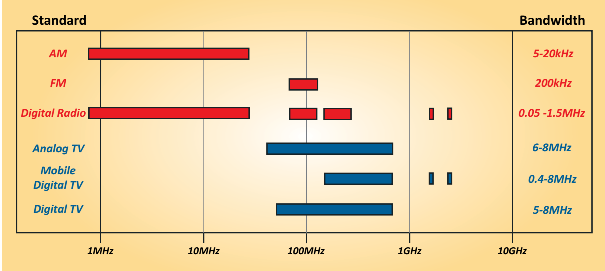

Figure 1
Spectrum allocation (on a logarithmic scale) and channel bandwidths for various Broadcast TV and radio standards

Global standards

Fig. 1 shows the spectrum allocations and bandwidth requirements for various broadcast radio and

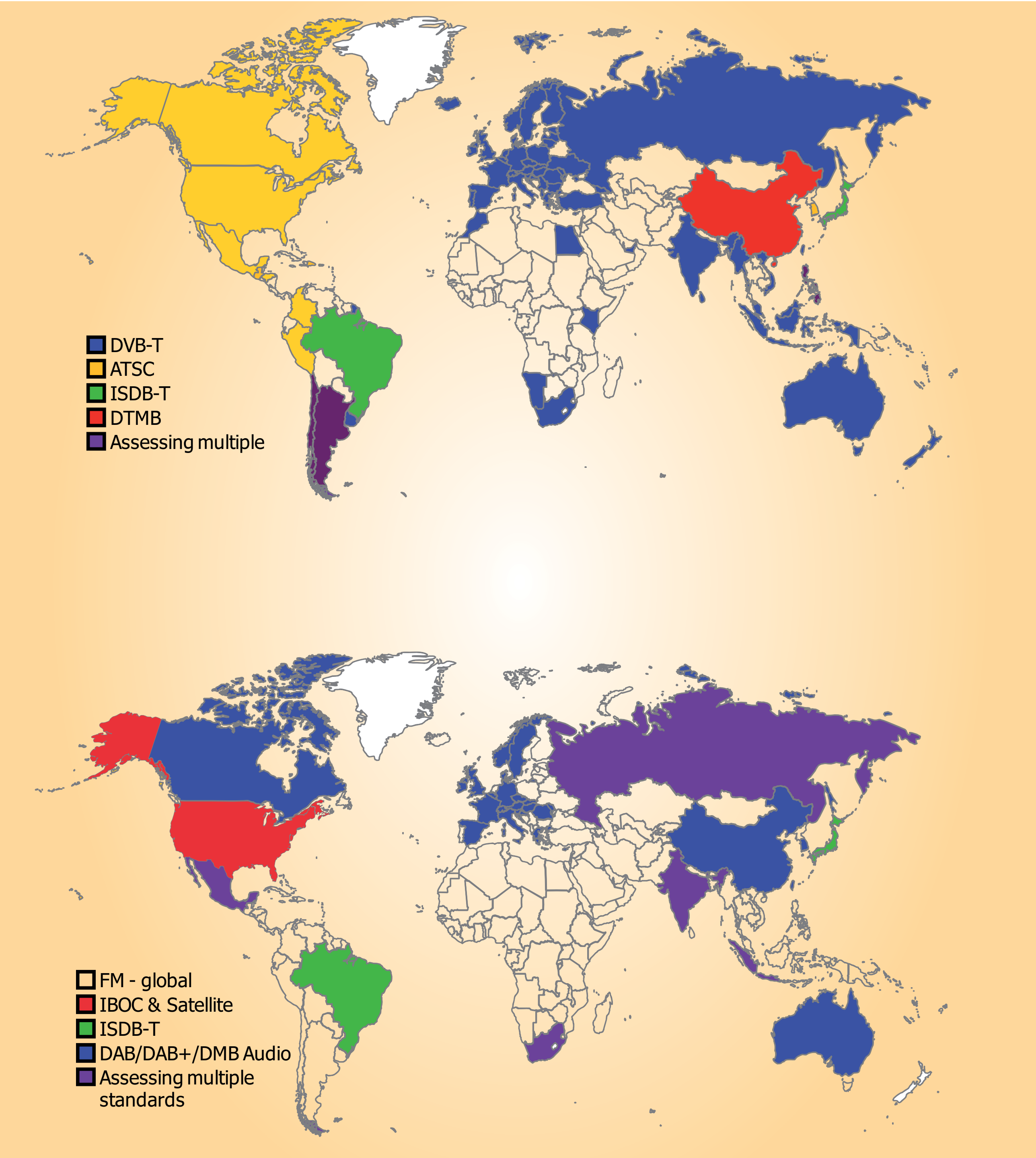

Figure 2
Global standards for *(upper)* digital TV and *(lower)* radio

TV standards, while *Fig. 2*, in combination with *Table 1*, highlights the geographical distribution of Broadcast TV and radio standards worldwide.

Table 1
Summary of global TV and radio standards

Broadcast standard	Primary geographies
Analogue TV	
PAL	Europe, Asia, Africa
NTSC	Americas, Japan, S. Korea
SECAM	France, Africa
Digital TV	
DVB-T	Europe, Asia
ATSC	North America
ISDB-T (Full-Seg)	Japan, Brazil
DTMB	China
Mobile digital TV	
T-DMB	S. Korea
DVB-H	Europe
CMMB	China
MediaFLO	USA
ISDB-T (One-Seg)	Japan
Analogue radio	
AM (LW/MW/SW)	Global
FM	Global
Digital radio	
Digital Audio Broadcasting	Europe, China, Australia
HD Radio	USA
Satellite radio	USA, Canada
Digital Radio Mondiale	Global

The global fragmentation of standards is readily apparent.

Note also that the problem of multiple standards is further compounded by the fact that a particular given standard may be deployed with significant regional variances. As an example, DVB-T in the UK – due to spectral co-existence limitations with analogue TV – is transmitted at relatively low power compared to other European countries. In addition, 2k FFT and 64-QAM modulation schemes are used on some multiplexes which, in combination with low transmission power, leads to probably the most challenging DVB-T reception environment in the world. If manufacturers wish to develop DVB-T products to leverage economies of scale, their devices must therefore be designed for worst-case deployments.

Functional integration

The multiple broadcast standards listed above create a huge problem for manufacturers who ideally want to build platform products. From both the manufacturer's and silicon vendor's perspective, a multi-standard receiver must still be cost-effective compared to a single-standard or regional product if the CE criteria of low cost and power are to be met, allowing economies of scale to be realized.

Efficient system partitioning is a key design consideration in CE devices featuring converged wireless functionality. The key radio technologies can be *functionally* categorized as:

- **Cellular:** GSM, CDMA2000, UMTS, LTE, etc.
- **Connectivity:** WLAN, Bluetooth, Ultra-wideband (UWB), Near-field communication (NFC), WiMax, etc.
- **Broadcast:** TV, Radio, GPS.

Although typical CE devices are unlikely to feature *all* of the listed cellular, broadcast and connectivity wireless radios, it should be noted that today's cellular handsets already typically integrate one radio from each of the stated three functional categories, and manufacturers are striving to absorb further functions to meet consumer demand. Increasingly, notebook computers, mobile internet devices (MIDs) and other similar CE devices are also following this integration trend.

Since there is a practical size limit and cost consideration to the number of individual integrated circuits (ICs) that can be physically accommodated onto a single-device platform, chipsets are now available that integrate radio functions typically *within* one of the three functional categories defined above. This can be referred to as "horizontal" functional integration and is illustrated in *Fig. 3*.

Although cross-functional integration is possible, and indeed will be needed to support converged wireless content delivery (e.g. between broadcast and connectivity functions), this integration will be unlikely to cross the cellular boundary. This is because, in CE devices featuring cellular capability, device integrators typically develop multiple product generations, based upon the same cellular

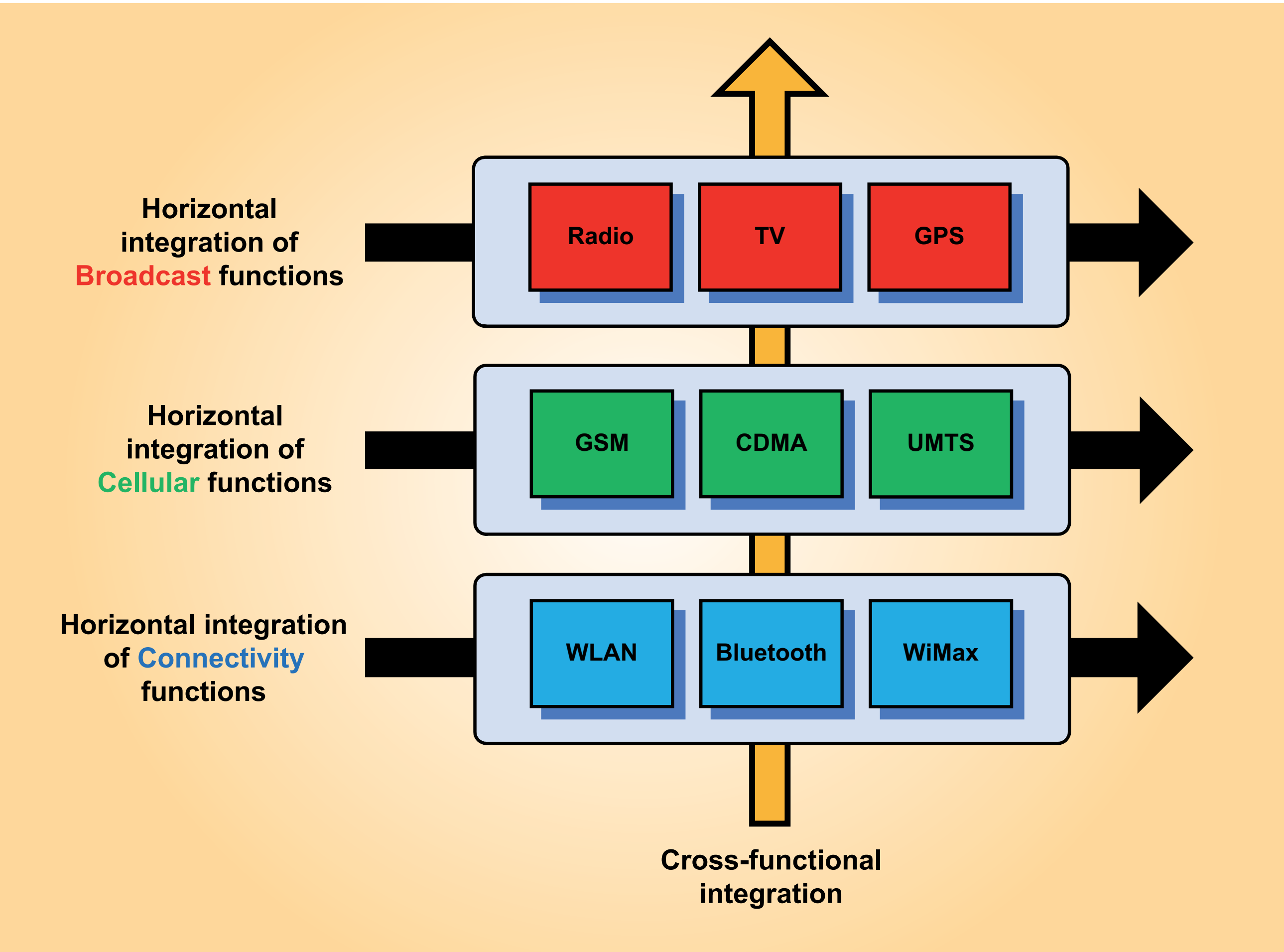

Figure 3
Radio integration architectures for consumer electronics devices

Abbreviations

64-QAM	64-state Quadrature Amplitude Modulation
AAC	Advanced Audio Coding
ADC	Analogue-to-Digital Converter
CE	Consumer Electronics
CMMB	China Multimedia Mobile Broadcasting
DAB	Digital Audio Broadcasting (Eureka-147) http://www.worlddab.org/
DAB+	DAB using the AAC codec
DAB-IP	DAB - Internet Protocol
DMB	Digital Multimedia Broadcasting http://www.t-dmb.org/
DSP	Digital Signal Processor / Processing
DTMB	Digital Terrestrial Multimedia Broadcasting
DVB	Digital Video Broadcasting http://www.dvb.org/
DVB-H	DVB - Handheld
DVB-T	DVB - Terrestrial
FFT	Fast Fourier Transform
GPS	Global Positioning System
I/Q	In-phase/Quadrature
IBOC	In-Band On-Channel
ISDB	Integrated Services Digital Broadcasting
ISDB-T	ISDB – Terrestrial
MDTV	Mobile Digital TeleVision
MID	Mobile Internet Device
MVNO	Mobile Virtual Network Operator
OFDM	Orthogonal Frequency Division Multiplex
PMP	Portable Multimedia Player
PND	Portable Navigation Device
SiP	System-in-Package
SoC	System-on-Chip

baseband platform to achieve the maximum return on their large software development effort for a given cellular baseband: by absorbing new radio functions that are peripheral to the cellular functionality, this would involve software re-engineering and repeating the cellular "type approval" process, thereby leading to a "latency" in the deployment of new radio technologies in handsets.

There are also significant technical barriers to integrating – or not – the differing radio technologies. These reasons encompass fundamental considerations such as:

- Modulation scheme – many modern digital TV and radio technologies use OFDM modulation;
- Antenna limitations – the inability to share an antenna due to bandwidth constraints, or the need for simultaneous operation; and
- Co-existence of interference problems – a sensitive GPS receiver may effectively be blocked if it were integrated with a cellular transceiver due to harmonic or spurious signals occurring in the same band.

Therefore, even if cross-functional integration is not attempted, integration of multiple broadcast applications poses significant implementation challenges to silicon receiver designers.

Multi-standard receiver challenges

A conventional broadcast receiver comprises an RF tuner and a demodulator (the output of which is decoded for audio-video playback). These silicon blocks may either be separate or integrated into a system-on-chip (SoC) or a system-in-package (SiP). This generic approach is shown in *Fig. 4*.

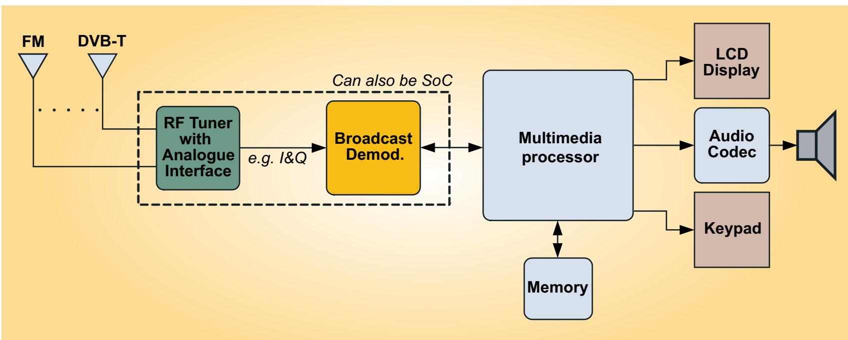

Figure 4
A generic broadcast receiver approach based on hardware demodulation

While this receiver architecture is well proven, it is typically limited to single-standard operation, since to enable multi-standard TV and radio reception, multiple receiver ICs would be required, leading to increased cost, battery power dissipation and device size – an unacceptable compromise for consumers. However, by employing innovative reconfigurable circuit techniques in the tuner and demodulator, it *is* possible to develop a multi-standard receiver, though the technical challenges are considerable.

Consider the case – applicable to much of Europe – of a multi-standard RF tuner designed to receive digital TV (DVB-T), digital radio (DAB) and analogue radio (FM). The synthesizer in the tuner must cover a whole decade in frequency from 88MHz to over 800MHz, it must support frequency step sizes down to single-digit kilohertz, deliver low integrated phase noise to support 64-QAM modulation and also feature low single-side-band noise to mitigate blocking effects. Additionally, the RF input stage must support a large dynamic range to allow for reception of signal levels from as low as –105dBm to as high as 0dBm, often in the presence of interferers, whilst the baseband section must support channel bandwidths from 200kHz to 8MHz. Additionally, robust performance in the presence of unwanted interferers is vital to ensure a good user experience in the "real world".

In the case of this tri-standard broadcast receiver example, typical sources of on-channel interference include high-power FM signals, whose second harmonics may fall into the wanted DAB signal band, or harmonics of DAB signals falling into the wanted DVB-T channel. Note also that higher-order mixing products of the interfering signal and oscillator may also fall in-band. Other interference scenarios that can result in blocking of the wanted signal include the presence of strong adjacent channels, or reciprocal mixing of wideband interfering signals due to inadequate phase noise suppression. A careful choice of down-conversion architecture (heterodyne versus homodyne), the use of harmonic rejection mixing, and on-chip filtering, can help to alleviate these problems.

Antenna integration must also be considered in any multi-standard system. Antenna multiplexing techniques can be used to reduce the physical number of antennas that must be integrated into a CE device, although the wideband antenna frequency response and multiplexing insertion loss must be considered.

The tuner design must also consider the power dissipation and size trade-offs involved in optimal partitioning of the signal processing *between* the RF tuner and the digital demodulator. Analogue filtering provides a good example of this: if an RF front-end provides too much analogue channel selectivity, there is an unwelcome impact on tuner die size; conversely if insufficient analogue selectivity is delivered, the analogue-to-digital converter (ADC) in the demodulator faces unreasonable dynamic range requirements. Careful analysis and balancing of these system trade-offs must be therefore be considered.

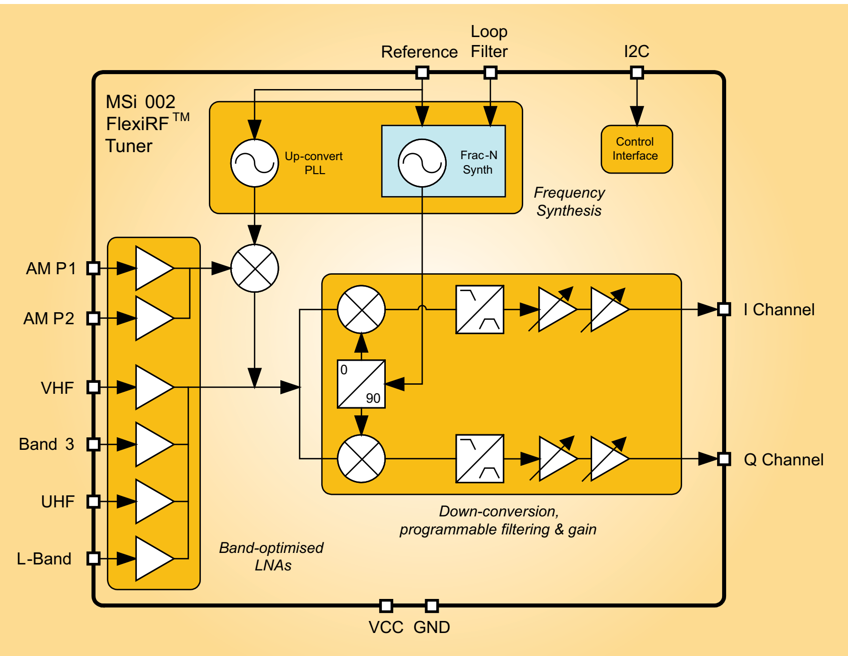

Figure 5
Mirics reconfigurable multi-standard FlexiRF^{TM} tuner

Shown in *Fig. 5*, FlexiRF™ from Mirics is a global tuner solution for portable broadcast TV and radio reception, and can receive many of the TV and radio standards detailed in *Table 1*, including CMMB, DAB, DRM, DVB-T, FM, ISDB-T, PAL and T-DMB. The tuner employs reconfigurable circuit techniques, to deliver flexibility whilst maintaining a competitive die size. The tuner achieves multi-standard flexibility by multiplexing bandoptimized front-end amplifiers into a common RF down-conversion block, and a programmable synthesizer, together with programmable baseband gain and filter blocks, enabling tuner customization to individual standards without incurring a multi-standard "penalty".

Of course delivering a multi-standard tuner is only one half of the multi-standard receiver equation – the demodulator must also be considered. The main challenge for implementing a cost-effective multi-standard demodulator is the fact that – unlike RF tuners – the silicon hardware required for the demodulation of the various analogue and digital broadcast signals can be vastly dissimilar, with little scope for circuit re-use through reconfigurability. Multi-standard capability in a demodulator can therefore lead to a considerable increase in die area and hence cost.

This problem is further exacerbated if an MDTV standard such as DVB-H must be supported, due to the requirement of additional error-correction memory that would not be required for other standards. The multi-standard penalty is mitigated to some degree in some newer demodulators that embed DSP to deliver reconfigurability and hence multi-standard functionality. However, while DSP-based demodulation may resolve many of the technical aspects of multi-standard broadcast reception, this hardware approach will not ultimately deliver the *lowest* cost solution.

Based on the limitations of current demodulator architectures, a rethinking of the integration model is therefore required for portable devices such as ultra low-cost netbook PCs and MIDs in which multiple wireless modems must be accommodated.

Software demodulation

Today's personal computers (PCs) are multimedia entertainment platforms, featuring multi-core CPUs, plenty of system memory, and built-in advanced A/V capabilities such as MP3 and H.264 playback. Some desktop and notebook platforms are beginning to feature embedded broadcast TV, but the uptake so far has been slow. Manufacturers have cited that the key barriers to mass-market TV adoption on PCs – and notebook form-factors in particular – are the lack of availability of a global receiver solution, and the need to achieve a bill of materials of less than $5.

As previously noted, some commercially-available hardware broadcast demodulators already feature limited functional flexibility through the use of on-chip DSP combined with hardware acceleration. If the use of DSP is extended to its logical extreme, by leveraging the existing system processing and memory resources in today's PCs, the entire demodulator function can conceivably be implemented in *software* running on the host processor. If such a software demodulator is then combined with a multi-standard RF tuner, it is possible to then implement a true global-standards broadcast receiver.

This approach – effectively a software modem – is highly cost-effective due to the elimination of a hardware demodulator. It also enables ultimate flexibility and future-proofing against emerging broadcast standards – or new variants of existing standards – due to the inherent reconfigurability of the software. With such a software approach, manufacturers can implement a platform strategy, with its associated benefits of simplified manufacturing logistics and substantial economies of scale, whilst simultaneously fulfilling consumer demand for the consumption of live content on portable devices.

In the case of a generic software-based broadcast receiver, a multi-standard RF tuner must interface directly to the host processor via a digital interface, such as USB 2.0, PCIe or SDIO. This approach is shown in *Fig. 6*.

The Mirics FlexiTV^{TM} broadcast receiver solution shown in *Fig. 7* is a commercial implementation of the software-based demodulation concept, and targets x86-based PC processor platforms. By combining the FlexiRF multi-standard tuner with highly-efficient demodulation algorithms running on a host processor, a global PCTV solution is made possible for less than the cost of conventional hardware-based single-standard solutions. Note that the digital interfacing between the FlexiRF tuner and the PC host processor is implemented by a "bridge" interface IC, which takes the analogue output of the tuner (base-band I/Q), digitizes it via on-chip ADCs, and then translates this sampled signal to USB 2.0 for host interfacing.

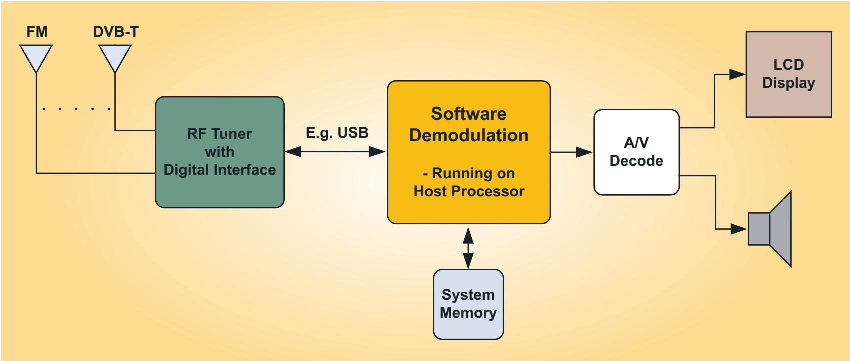

Figure 6
A generic broadcast receiver approach based on software demodulation

A key concern for a software-based broadcast receiver running on a portable device is power consumption, which must be comparable with hardware solutions to ensure a positive user experience. In typical notebook PC platforms, the power consumption is dominated by the host processor and the LCD screen. What makes software-based demodulation so compelling is the fact that the processing power of modern PC processors is constantly increasing over time, and where a dual-core processor architecture may have been state-of-the-art twelve months ago, today it is mainstream. Software-based demodulation therefore expends a smaller proportion of total processor load – and so consumes less power – as processors evolve ... to the extent that, today, the LCD screen and software-based video decoding of a high-definition H.264 broadcast transmission, will become the dominant power drains in the notebook. Note also that processor load is a function of the broadcast standard being received: for example, radio reception or reception of MDTV standards requires a much smaller proportion of processor load than terrestrial TV.

Efficient demodulation algorithms and software coding, written with a close understanding of the complete receiver system, are key to delivering maximum battery life. In the case of Mirics' FlexiTV,

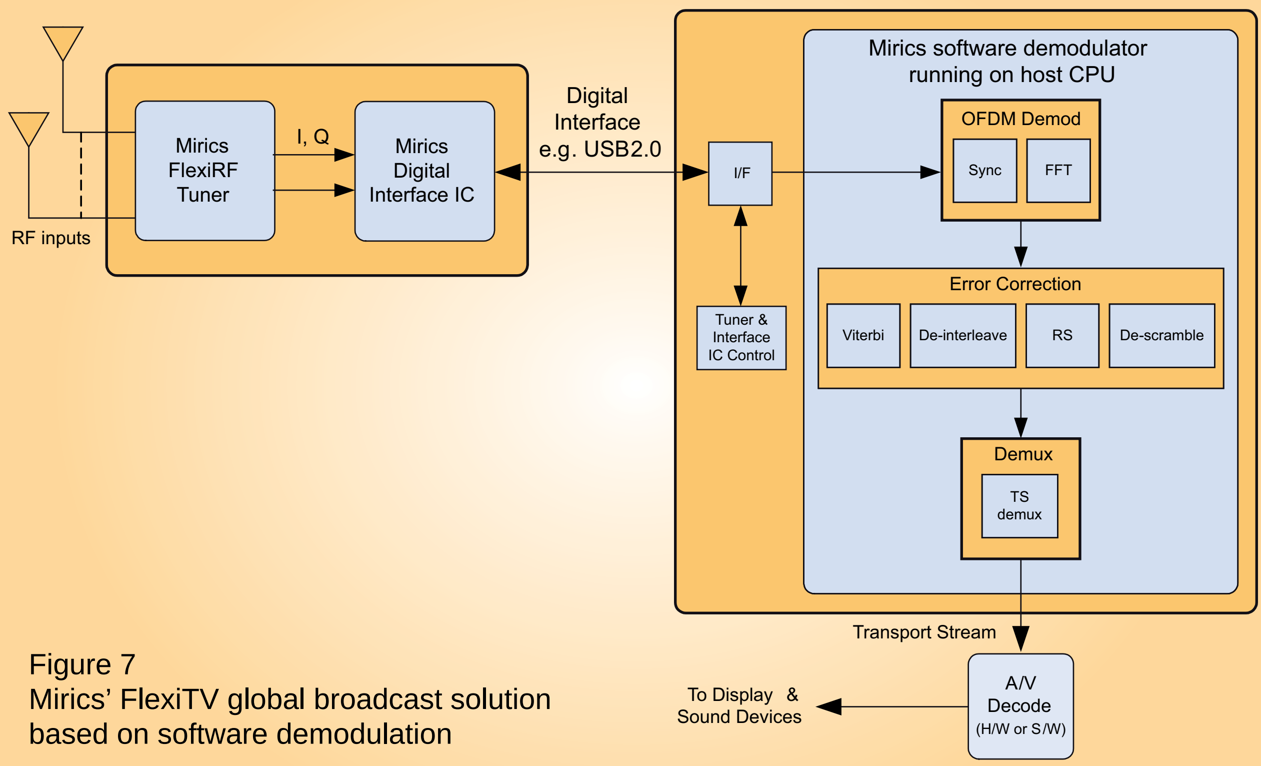

Figure 7
Mirics' FlexiTV global broadcast solution based on software demodulation

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the software-based DVB-T demodulation – running on a typical mainstream dual-core notebook processor – has been field-proven to consume less than 30% of the CPU load, and so delivers comparable battery life to commercially-available hardware-based DVB-T solutions. Note also that even netbook PCs, which typically feature more modest processors, can benefit from the cost savings delivered by software demodulation – by leveraging the distributed processing that is enabled by the co-existence of graphics processing units (GPUs).

Conclusions

Consumers are demanding increased multimedia content on portable CE devices, but do not want to pay a premium for this functionality. Broadcast TV and radio reception is one content-delivery mechanism that can address this user requirement but, to deliver manufacturing economies of scale through a platform strategy, multi-standard receivers are required. Hardware-demodulator-based receivers cannot cost-effectively address this challenge and, instead, software-based demodulation architectures must be considered.

As the processing power and distributed processing in modern portable devices increases to meet consumer needs, the software modem approach discussed in this article will become ubiquitous in processor-based CE devices, encompassing other wireless content-delivery methods. Software modems – previously a concept confined to academia and military research – are finally coming of commercial age.