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Broadcast Over Cellular

In last month's Hot Topic, (Adaptive Systems), we compared a number of digital broadcast 'scaleable OFDM' technologies including digital AM (Digital Radio Mondiale), DAB, and DVB.

In this month's Hot Topic, we look at digital broadcast receiver integration in cellular handsets. We review some of the present system and hardware constraints, identify a number of possible performance optimisation opportunities and highlight some practical (presently under appreciated) network deployment issues implicit in BOC (broadcast over cellular) network implementation.

Enabling technologies- a 50-year perspective.

Integrating broadcast receivers into small form factor hand held devices is not particularly new as a design concept. There is some dispute as to who produced the first 'pocket size' transistor radio. The picture (a Smithsonian Information Age exhibit) shows a product called the 'Regency' introduced in October 1954 which came to market in parallel with early Texas Instruments pocket radio receivers. This triggered a 'form factor' race with Sony producing the 'world's smallest radio'. (March 1957).

The 'Regency' Transistor Radio

Form factor and functionality is still directly dependent today on device geometry. Present device 'scalability roadmaps' suggest that present 95 nm devices will be replaced with 70 nm and 65 nm devices which will be replaced with 32 nm devices. Device geometry determines DSP, microcontroller and memory functionality which in turn determines what we can do in a small form factor power limited handset. This in turn enables us to realise system value, which in turn allows us to realise spectral bandwidth, which directly translates into system value, which directly translates into spectral value.

Spectral (radio) bandwidth allocations and spectral value

The present transition from analogue to digital broadcasting systems is generally considered by regulators as an opportunity to're-purpose' (and by implication re-value) existing spectrum.

The table below provides an overview of the **500 MHz** of broadcast (radio and TV) bandwidth available between long wave and 2 GHz and the associated digital broadcast radio system options.

Figure 1 Frequency allocations and digital broadcast system options

Radio Band	Frequency	System Options
Long Wave	3 kHz - 300 kHz	DRM (Digital AM)
Medium Wave	300 kHz - 3000 kHz (3 MHz)	DRM (Digital AM)
Short Wave	3 MHz - 30 MHz	DRM (Digital AM)
VHF (FM radio)	88 - 108 MHz	DAB/DMB
VHF Band 3	174 - 233 MHz	DAB/DMB (218-230 MHz)
UHF Band 4	470 - 490 MHz	DVB-H, ISDBT, Media Flo
UHF Band 5	790 - 862 MHz	DVB-H, ISDBT, Media Flo
L Band	1452 - 1492 MHz	DAB/DMB
	1670 - 1675 MHz	DVB-H

Broadcast spectrum has (always had) political value (Hitler, Mussolini, Churchill, Berlosconi), social value, evangelical value (Vatican radio) and economic value.

Economic value is a composite of license fee income (BBC in the UK), advertising revenue and (increasingly), participation bandwidth revenue. Participation revenues are a composite of text and voice value and (increasingly) image and video value (on line camera phone competitions).

The realisation of fiscal value from spectrum (measured in dollarherz or eurohertz or dollarbytes or eurobytes) is dependent on delivering robust radio systems with adequate link budgets that ensure consistent good quality reception of voice, audio and video content.

This in turn is dependent on realising good receive sensitivity in user devices. The devices have to be capable of working in low, medium and high mobility environments and need to have power budgets that deliver tolerable (downlink) TV and audio time and acceptable uplink talk and text time (**return channel** functionality).

Note how participation revenues (which in some countries like Finland now exceed advertising revenues) are closely dependent on the robustness and consistency of this return channel.

Participation **revenues**, in theory should increase as participation bandwidth increases. (This may **not** be true for participation margins where it will be hard to match the **margin** achievable on SMS voting and texting in terms of euros per hertz or euros per delivered megabyte).

Note also the blurring of definitions between audio and video and text in these broadcast radio systems - visual radio with text is essentially competing directly with wider bandwidth digital TV. Any /all of the broadcast options listed above are capable of triggering **uplink** bandwidth value.

System Comparisons
So we are interested in the performance of the receiver in terms of sensitivity, application bandwidth and power efficiency and the performance of the receiver in the presence of locally generated transmit power (the return channel).

We should also remember that we can also deliver radio and TV channels over existing cellular radio bandwidth.

This means that our choice of broadcast receivers could include existing analogue AM or FM radio, digital AM (DRM or equivalent), DAB/DMB, DVB-H, ISDBT, proprietary systems such as Qualcomm's MediaFlo (integrated with 1XEV) and /or EDGE or HSDPA.

Figure 2 Broadcast Receivers

Broadcast receivers	**Functionality**
Analogue AM	Voice and low bandwidth audio
Analogue FM	Voice, stereo radio, text and images (visual radio)
DRM	Voice, audio, text , data, images
DAB	Voice, audio, text, data ,images, video
DVB-H	Voice, audio, text, data, images ,video
ISDBT	Voice, audio, text, data, images ,video
Media Flo (integrated with 1XEV)	Voice, audio, text, data, images ,video
EDGE (Dual transfer mode).	Voice, audio, text, data, images ,video
HSDPA	Voice, audio, text, data, images ,video

There are a number of phones that include integrated FM tuners. They work as well as most FM tuners when used in mobile applications ie quite well some times but not consistently well in weak signal or high mobility conditions.

There is nothing wrong in principle in adding digital sub carriers to existing analogue bandwidth and using these carriers for data and image transmission - an analogue and digital multiplex. This has provided a perfectly adequate basis for' first generation 'visual radio' systems (for example in Finland).

In practice, over the longer term, it should be possible to get better bandwidth and power efficiency and a more consistent user experience from a digital broadcast receiver. The same applies for analogue AM systems.

All of the digital broadcast systems should in theory and generally in practice provide a performance benefit in terms of quality, consistency and bandwidth and power efficiency.

DRM is (relatively) easy to integrate into present cellular handset form factors, works well under a wide range of operating conditions and is power efficient. It is however bandwidth limited and (at present levels of compression) incompatible with any existing TV content standards. There is a wide range of global programming available (Vatican Radio is one example). The picture shows a present DRM product offering from Coding Technologies.
www.codingtechnologies.com.

DRM Broadcast Receiver

DAB/DMB is potentially useable across three radio bands - the VHF FM band, band 3 and L band. It is MPEG2 TS and MPEG4 Part 10 compliant and supports some useful features like Multi Media Object Transfer so it's definitely not now just an audio delivery system. Presently however, there are few really well developed DAB networks other than in the UK.

DVB-H is potentially deployable into Band 3 VHF, Band 4 or Band 5 UHF. Crown Castle have purchased a 5 MHz bandwidth allocation in the US between 1670 and 1675 MHz and this is presently being used for a DVB H trial in Pittsburgh.

DVB-H increases the power efficiency of the receiver by time slicing. If multiplexed with a DVB T signal for example, a 2 M/bit burst would be taken out of the DVB T 15 Mbps stream and sent in a 146 millisecond burst. The receiver then powers down for just over 6 seconds then powers up for the next burst. The 2m/bit burst is read into and out of a buffer at a constant 350 kbps. While this optimises the receiver power budget, it saves less power than might seem immediately apparent (the baseband processor still has to work pretty hard) and there has to be careful (and fast) synchronisation with the continuous and scattered pilots modulated on to the OFDM signal. Extended receiver power down is however a well understood technique and has been used in paging systems for at least 30 years so it should be possible to make this work satisfactorily. The time slicing also allows for neighbour measurements and mobile initiated handover in multi frequency networks. This would allow a high density DVB H network to be overlaid on to an existing cellular network.

There are however some practical issues when implementing a DVB H receiver in to a cellular handset (which you would need to do in order to take advantage of this type of 'co-operative' network deployment). Producing a DVB H front end capable of accessing low band VHF, UHF (and L band) would be /will be challenging in terms of antenna design (and will result typically in negative antenna gain of the order of between 5 and 10 dBi.

Probably more problematic is the issue of GSM (or equivalent cellular) transmit power and wideband noise from the TX PA desensitising the DVB H receiver. This suggests either a careful choice of DVB H channel allocation and/or some carefully designed (and potentially expensive and lossy) filtering.

There are various ways in which DVB H receiver sensitivity can be improved, for example by using antenna diversity or additional time diversity (using the optional MPE FEC encoder) but this will not overcome the problem of locally generated interference within the handset. Diversity gains within present handset form factors would also be marginal though spatial diversity receivers might be more appropriate in (for example) automotive applications.

ISDBT will have similar problems to overcome. ISDBT, specified originally for the Japanese market, is arguably the most scalable of the present digital broadcast OFDM systems. It divides a 6 MHz channel into sub channel segments each of just over 400 kHz each segment has a variable OFDM multiplex, variable modulation (QPSK, 16 QAM, 64 QAM) and variable levels of convolutional coding. The table below summarises these capabilities.

Table 3 ISDBT

Mode	Mode 1	Mode 2	Mode 3
Number of segments	One or three		
Bandwidth	432.5 kHz (one segment) 1.289 MHz (three segment)	430.5 kHz (one segment) 1.287 MHz (three segment)	429.5 kHz (one segment) 1.286 MHz (three segment)
Carrier Spacing	3.968 kHz	1.984 kHz	0.992 kHz
Number of carriers	109 (one segment) 325 (three segment)	217(one segment) 649(three segment)	433 (one segment) 1297 (three segment)
Modulation	QPSK, 16QAM, 64 QAM, DQPSK		
Number of symbols per frame	204		
Effective symbol duration	252 microseconds	504 microseconds	1.008 milliseconds
Guard interval	1 /4 1/8 1/16 1 / 32		
Inner code	Convolutional 1 /2 2/3 3 /4 5/6 7/8		
Outer code	RS (204,188)		
Information bit rate	One segment 280.85 kbps to 1.7873 Mbps		

	Three segment 0.842 Mbps to 5.361 Mbps

Although the system promises substantial deployment flexibility, performance (as with DVB H) will be dependent on achieving successful (RF) integration into existing and future cellular transceivers.

Media Flo is Qualcomm's proprietary offering for broadcast receivers. It shares some common techniques with DVB H in that it uses a time division multiplex, with one or more traffic packets being transmitted within a reserved slot to all users in the service area. Users receive the same packets from multiple cells. An OFDM multiplex is used to slow down the symbol rate and the symbols are soft combined to improve down link performance.

Media Flo is to be used in Channel 55 in the UHF band (Channel 55 in the US was recently acquired by Qualcomm). It has the (probably significant) merit of being intrinsically compatible with existing and future 1X EV DO networks.

As with EDGE and HSDPA, there are a number of advanced receiver diversity and equalisation techniques that can potentially improve receiver performance and/or help to deliver the additional downlink radio capacity needed to support broadcast applications. Similar techniques based on pilot interference cancellation can be deployed in the (1XEV) base station to improve back channel performance.

Similarly it would be feasible (though not necessarily economically attractive) to use **EDGE** as a broadcast radio bearer. Dual transfer mode would support some 'ring fenced' broadcast bandwidth within the present slot structure. There are already broadcast packet channels for signalling bandwidth so it is not so great a leap to deploy broadcast packet channels for broadcast content and there are a number of receiver optimisation techniques such as joint detection (Single Antenna Interference Cancellation) that could be used to improve receiver performance.

Joint detection uses the mid amble in the wanted signal and unwanted interferers to cancel out unwanted signal energy. The technique however is computationally expensive when used with 8PSK and needs a synchronised network to deliver useful performance gain. (Few GSM networks with the exception of US and Latin American networks deploying Compact EDGE are presently synchronous).

HSDPA is probably a more persuasive candidate. Release 7 will be likely to include specific work items on receiver optimisation using advanced diversity and equalisation techniques. (The pilot symbols on the channel can be used in a similar way to present OFDM based broadcasting to provide active channel characterisation). The HSDPA MAC (2 millisecond based admission control) is also more IP friendly than the Rel99 MAC (and probably more power efficient for broadcast reception).

BOC (Broadcast over Cellular) Network Issues

Press To Talk Over Cellular (POC) has been difficult to deploy because cellular networks were and are not designed to support Press to Talk (end to end latency sensitive) applications.

Similarly there are a number of deployment issues that arise from the inescapable fact that cellular networks were not and are not designed to support broadcasting applications.

Traditionally (in the 1980's and 1990's), cellular networks were radio engineered to provide a balanced link budget. Given that handsets had less power available than base stations, it was usual to provide some additional link budget gain on the uplink. A typical cell site might provide for example 17dB gain on the uplink using diversity and/or dual polarisation antennas and 9 dB of gain on the (sectored) downlink.

Similarly in the access network, the A bis and Gb interface was designed to support symmetric bi-directional (largely duplex voice based) traffic.

In contrast, digital broadcast networks used (and still use) ATM to deliver a one way traffic multiplex which is (completely) asymmetric and highly asynchronous (variable rate).

The Rel 99 air interface addressed this issue by introducing an ATM based radio layer (10 millisecond frame based admission control) and an ATM based radio access and core network.

The present debate is now beginning to focus on the present and future role of IP in broadcast networks. DVB-H for example is explicitly being positioned as an IP based broadcast system solution. This means that the IP subsystem at the transport layer has to behave at least as predictably as an ATM based transport layer, or in other words, the IP sub system has to replicate ATM end to end functionality. (The ability to control a complex multiplex in the time domain). This is not something that IP networks were ever designed to do.

The integration of flexible network bandwidth provisioning and QoS based broadcasting will be particularly challenging and will need to encompass transport and network design, server architectures and performance and content management systems.

Summary

Broadcast content can be delivered to cellular phones either over existing cellular networks or over dedicated broadcast networks or over a combination of both.

Either option is implicitly expensive and involves the provisioning of substantial amounts of server bandwidth, network bandwidth, radio bandwidth and user handset clock cycles.

A fiscal return on this cost is dependent on the availability of a robust return channel. A robust return channel desensitises the broadcast receiver.

Receive sensitivity can be addressed by implementing advanced receiver architectures and using techniques such as diversity reception and advanced equalisation but these imply substantial additional processing overheads which are problematic to accommodate within existing handset power budget constraints.

The successful deployment of BOC (broadcast over cellular) solutions will be critically dependent on the integration of a wide range of RF and baseband handset design skills and hardware and software optimisation.

At network level, there are substantial QoS issues still to be addressed and network delivery costs are likely to be substantially higher than presently expected.

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RTT, the Shosteck Group and The Mobile World are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

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