PROVIDING MEDIA-RICH CONTENT USING DIGITAL RADIO

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INTRODUCTION

Since its inception, digital radio broadcast technology has held the promise of media-rich visual user experiences and multimedia data transport. Digital radio data services have the capability to deliver new revenue streams to broadcasters. By enhancing digital radio broadcasts with synchronized visual content and leveraging data and file transfer capabilities, it is possible to present media-rich content to the user while creating ubiquitous low cost transport mediums for advertising and information on personal devices as well as public displays through electronic signage. There are already some commercially available digital receivers capable of displaying graphics and video with many more under development. The author will discuss the principals, systems, protocols and applications required to present graphical content through enhanced broadcast transmission and receiver platforms.

BACKGROUND

Digital Radio Broadcasting (DRB) is the generic term for all digital radio systems. BRB has been in development since the mid-1980s as a more efficient digital replacement for traditional analog FM broadcasting. Instead of just one service per frequency, digital radio systems can provide multiple audio and data services on a single frequency.

Eureka 147 based Digital Audio Broadcast (DAB) and more recently DAB+ and Digital Multimedia Broadcast (DMB) systems have been developed as a replacement for traditional analog FM radio.

DAB can be transmitted on the FM band (88 MHz to 108 MHz), but the services that have been introduced in Europe, Canada and Australia are using Band III (174-230 MHz), formerly used for analog television signals. Others like Germany and Canada are using L-Band (1452-1492 MHz). DAB receivers currently on the market can receive both Band III and L-Band transmissions. DAB occupies approximately 1.5 MHz of bandwidth to provide around 1 Mb/second of data capacity. A goal of industry and these governments is to see all radio broadcasting moved out of the existing FM band which may then be auctioned to other potential users of the radio spectrum such as broadband and wireless telecommunications systems.

In the United States and other countries, the desire for a more gradual digital transition and the unavailability of Band III and L-Band has lead to the development of in-band on-channel (IBOC) digital radio technology. IBOC allows stations to transmit digital audio and data services within their allocated channel while maintaining the current analog signals in Band II with the intent of going all-digital sometime in the future. HD Radio™ is the trademark for IBOC technology developed by iBiquity Digital Corporation which was selected by the Federal Communications Commission (FCC) in 2002 as the digital audio broadcasting standard for the US. The HD Radio system occupies about 200 KHz providing up to 120 Kb/s of throughput. Panama, Mexico and Canada have also adopted HD Radio to some extent and it is being evaluated for adoption in more than a dozen countries including Brazil, Argentina and China.

Another IBOC technology standard currently under development for DRB is the Digital Radio Mondiale (DRM) developed in 2001 by a consortium of French broadcasters and manufacturers originally for Short and Medium Wave transmission. DRM+ developed in 2007 extended the DRM standard to the broadcasting bands between 30 and 174 MHz; primarily Band I (47 to 88 MHz) and Band II. DRM+ uses about 100 KHz of additional spectrum for the digital carriers and can provide up to four programs and multiple data service of up to 185 Kb/s.

All of the DRB systems use Orthogonal Frequency Division Multiplex (OFDM) modulation to produce the digital transmission and have the ability to subdivide the available digital bandwidth in separate functional data streams.

As this discussion is primarily intended for US audiences, we will focus the remainder of the discussion on the US and HD Radio.

COMMERCIAL CONSIDERATIONS

Multimedia enhanced radio services can provide direct revenue streams or may simply enhance the broadcaster's brand. The one-to-many nature, low cost per data unit, localized footprint, and ubiquitous penetration of radio places radio broadcasting in an enviable position as a data service provider. There are several business models worth considering.

Adding a multimedia dimension to radio broadcasts through album art, liner and programming notes, news, weather and sports enhances the value to the listener by providing a new and entertaining user experience. Revenue streams may be further enhanced by graphical advertising and product coupon offerings.

Providing useful multimedia subscription services such as location-based traffic and Journaline information services is already generating revenue for some broadcasters.

Point-of-sale advertising and billboard models can provide additional revenue streams by leasing multimedia data capacity. Utilizing radio's data streams for multimedia transport, media content may be directed to over-the-air networks specifically designated receivers driving digital signage systems. This model is currently being explored using the Harris InfoCaster™ digital signage system as shown in Figure 1

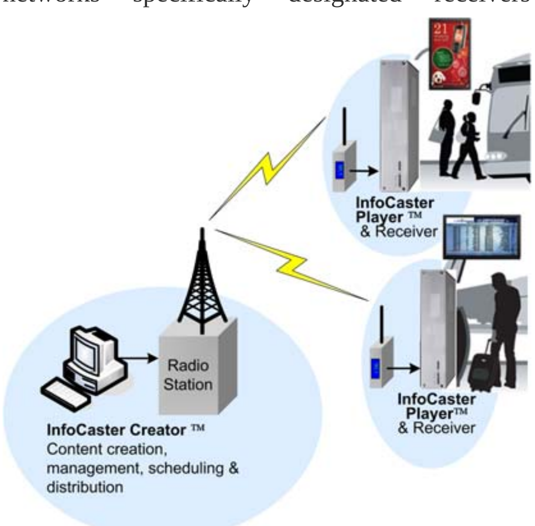

Figure 1 Harris InfoCaster™ over HD Radio

This model might also be used internally by broadcasters for promotional branding at station remotes and public events.

DIGITAL MULTIMEDIA FUNTIONALITY

While digital radio development has been focused on audio, data and multimedia capabilities have been designed into these systems from the beginning. DAB, has had well defined data and multimedia applications with a comprehensive set of open standards that have been implemented for some time in the UK and elsewhere. These standards lend themselves well to the other DRB systems. In the interest of compatibility and rapid deployment through judicious technology reuse iBiquity has developed the necessary Application Program Interfaces (APIs), within the HD Radio system transmission and receiver ecosystems to accommodate many of the capabilities already deployed for the DAB/DMB system.

Album Art is a derivation of the DMB Slideshow application which provides digital radio broadcasts with visuals using standard web image formats. The Album Art application provides the ability to deliver JPEG, GIF and PNG8 images synchronized with audio programming on HD Radio broadcasts. iBiquity is developing a Software Development Kit (SDK) for receiver partners to aid feature integration, which will be available in 2010.

TMC/TPEG Traffic (Traffic Message Channel/Transport Protocol Expert Group) application provides textual and graphic traffic and transportation system information in a standardized transmission protocol which can be displayed on enabled radio receivers or overlaid on GPS navigational systems equipped with a DRB receiver. TMC/TPEG is being used extensively by Clear Channel Radio's Total Traffic Network providing real-time traffic information to devices made by Garmin, TomTom, Mio-Mitac, Delphi, Kenwood, Clarion, Navigon, Cobra Electronics and Siemens VDO.

Journaline® is a relatively new data application developed for DAB and DRM that also is well suited for HD Radio. Journaline provides hierarchically structured textual information that the user can access on topics of interest in a magazine type format. Its core functionality resembles that of an electronic magazine or teletext on a TV. The listener can interactively access both program related and program independent textual information. Menus and text are encoded in JML (Journaline Markup Language) a binary representation of XML formatted content. Finally a compression scheme is applied to the plain textual information. Pages are restricted to a maximum size of 4 KB.

Journaline supports two ways to organize the transmission of objects within a single Journaline service: carousel mode and real-time transmission. Regular content is broadcast in form of a data carousel. As soon as a receiver starts decoding a Journaline service, it collects all received information objects and stores them in the cache for immediate future access by the user-until the objects are updated or removed from the carousel. An updated object can be re-transmitted immediately.

Information pages in form of ticker messages are updated regularly with changing content. This feature enables services like news tickers, dynamic program accompanying content (like song lyrics for Karaoke), or video subtitles in various languages.

Journaline Decoder implementations are available for licensing on Windows PC platforms, Linux PC platforms and Microcontroller platforms through Fraunhofer IIS making them easily adapted into the HD Radio receiver host processor.

Electronic Program Guide (EPG) offers users the ability to navigate, select, and discover content by time, title, channel and genre from an onscreen graphical program guide. EPG is well developed and widely in use for DAB throughout the UK. Digital radio broadcasting in the U.S. will benefit substantially by deploying an EPG system. iBiquity has developed an EPG data structure and client application specifically for HD Radio. Development and field trials of the overall EPG ecosystem for U.S. radio broadcasting is now underway with funding and management provided the NAB FASTROAD program.

Surround Sound provides 5.1 stereo surround broadcasts via discreet, spatial coding or matrix processing for receivers equipped with the appropriate decoder. Fraunhofer IIS licenses their MPEG Surround® Spatial Audio application and DTS/Neural Audio Corporation licenses the Neural-THX® upmix/downmix matrix applications for transmission and receiver application development. These applications are already incorporated into many 5.1 home theater systems.

Conditional Access, while not a multimedia technology, allows controlled access to digital radio services. Conditional Access provides pay-for-play as well as other restricted access services. The conditional access architecture for HD Radio is well conceived and easily integrates into the HD Radio system. The conditional access unit at the station scrambles the data streams and entitles specific radio receiver by addressing the receiver's unique electronic serial number (ESN).

DATA TRANSMISSION ARCHITECTURE

The HD Radio stream is organized into services which are logical components of the broadcast stream that the user can select. Service mime types and port numbers are organized and configured in the Importer's Administrator to identify the service to receiver applications. This information is aggregated for all services to generate the Service Information Guide (SIG) as a separate, dedicated data service. The SIG data service provides information to the receiver as to the services available, port number and applications required to deliver them. Figure 2 shows the basic HD Radio system transmission architecture.

The HD Radio architecture is composed of three basic components. These are the Importer, Exporter and the Exgine (a subsystem of the Exciter). The Importer is responsible for multiplexing all of the Advanced Applications Services (AAS) supplemental audio (HD2, HD3 etc) and data services. Audio and PSD are presented to the Importer API by audio client applications, while separate data client applications supply the data services. Audio is encoded and compressed by the HD Codec (HDC). All data, including the audio associated data (PSD), is encoded separately from the audio stream via the Radio Linking Subsystem (RLS) and are asynchronous with the audio. These separately encoded data streams are multiplexed into a single Importer to Exporter I2E IP stream for transport to the Exporter.

The Exporter requests and receives data synchronously from the Importer via the I2E data link where the multiplexed AAS data from the Importer is then multiplexed with the encoded Main Program Service (MPS) (HD1) audio and PSD data. The HD Radio stream is sent asynchronously from the Exporter to the Exgine as the E2X IP transport stream for low level modem processing onto the OFDM waveforms, ready for up-conversion to the final on-channel frequency by the rest transmission system.

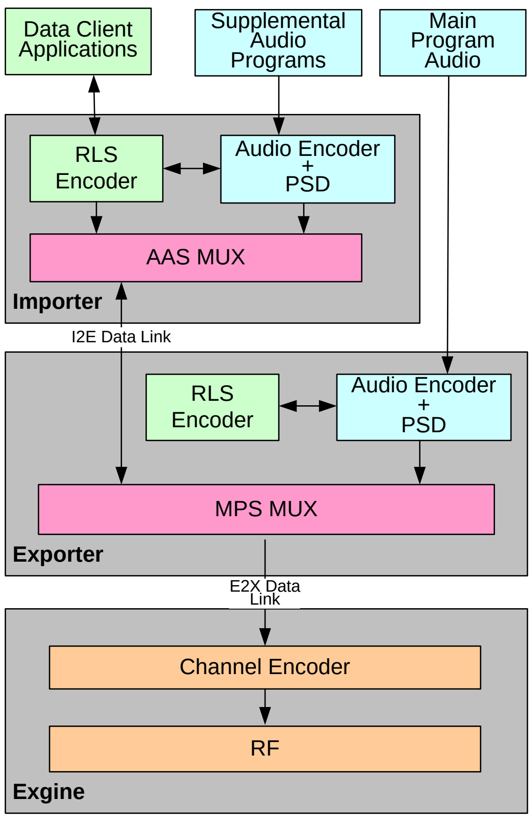

Figure 2 Basic HD Radio Data Transmission Architecture

Data Bandwidth Allocation

The HD Radio stream can carry four streams of digital audio. Theoretically the number of data streams is only limited by the available bandwidth. In practice, the number of simultaneous data streams is highly variable, dependant on what remains available after audio allocations, the data protocol used and the logical channel employed.

MP1 mode provides only the P1 logical channel partition which provides 96 kilobits/sec. of bandwidth. The Main Program Service (MPS) is the digital simulcast of the analog program. The MPS is required to have a minimum bandwidth allocation of 32 kilobits/sec. That leaves 64 kilobits/sec for additional audio or data services in MP1 mode. MP3 mode provides an additional 24 kilobit/sec data on the P3 channel partition that may be used for supplemental audio channels or data services. It must be noted that these partitions cannot be used contiguously. Each configured service must be assigned to, and fit within the assigned P1 or P3 partition. A typical example might to be to configure a 46 Kb/s HD1 (MPS) and a 46 Kb/s HD2 service and four 1 Kb/s data services configured to provide two streams of album art (one for each audio service), a traffic service and an EPG service. For example; if there are ten files of 10 kilobytes each that need to be delivered on a single stream, (that’s 800 kilobits, 10 kilobytes x 10 files * 8 bits/byte), it will require 800 seconds or about 13 minutes to deliver all of the files to the receiver at a 1 kilobit/second rate. If faster delivery and/or larger file sizes are needed, more data bandwidth can be allocated to the data services at the expense of audio service bandwidth. Bandwidth management for audio and data is handled by the Importer’s bandwidth manager and is configured in the Importer Administrator.

Data Transport Methods and Protocols

In the HD Radio system all data services share a common protocol: Radio Linking Subsystem (RLS). The data is typically bound for various receivers with a variety of possible rendering applications, which may or may not exist on a particular radio. RLS uses a dynamic port numbering method to distinguish the various services sharing the station’s bandwidth.

There are four underlying transport protocols used to encode the data received from a data client prior to application into the RLS transmission stream:

- Standard Packet
- Flex Packet
- Byte Streaming
- Large Object Transfer

Standard Packet encoding encapsulates a predetermined set of bytes received from the client as an individual “Packet” This frees the application from performing any segmentation and reassembly. These packets are maintained throughout the transmission and receiver decoding processes. In theory, the packets received from a data client can be any size, independent of the allocated bandwidth. However, in practice the packet size cannot exceed 8192 bytes due to receiver limitations. The bandwidth manager assures that each data client receives the allocated bandwidth. This means that the bandwidth allocation is statistical in nature and that there is no guarantee of bandwidth for each frame and no guaranteed arrival time.

Using Standard Packet delivery, the data client is limited to a packet size no greater than the capacity of the Program Data Unit (PDU) in which it is to be carried. This means that a data client must be cognizant not only of the allocated bandwidth but also of the transmission rate of the logical channel being used to carry the data. As described in Figure 3, the HD Radio system has two logical channels: the P1 channel and the P3 channel. The P1 channel PDU rate is ~1.486 seconds while the P3 channel PDU rate is ~0.186 seconds. A data client with a bandwidth allocation of 1 kbps is limited to a packet size of: (1000 bits/sec) x (1 byte/8 bits) x (1.486 sec/PDU) equaling ~185 bytes on the P1 channel. Whereas on the P3 channel the same service is limited to a packet size of: (1000 bits/sec) x (1 byte/8 bits) x (0.186 sec/PDU) equaling ~23 bytes.

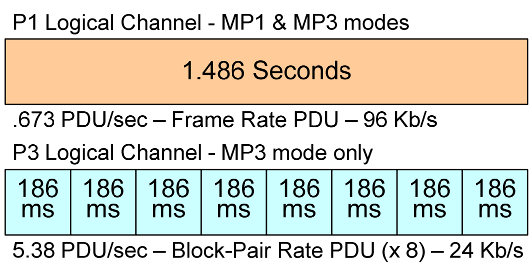

Figure 3 - P1 & P3 Logical Channel PDU Rates

The advantage of the Standard Packet method is that packets are guaranteed to be delivered to the receiver in every PDU. If a service can adjust its native packet size to match the allocated bandwidth and logical channel's rate, Standard Packet can utilize the native encapsulation to limit the processing required on the receiver. The Standard Packet transport is best suited for non-real-time applications and file transfers where the file sizes are know and packet encapsulation is fixed by the originating application.

Flex Packet encoding lifts the packet size restriction and allows packet sizes independent of allocated bandwidth or PDU capacity. This means that the bandwidth allocation is statistical in nature and applications may incur substantial delay in the delivery of the data packets. The advantage of the Flex Packet method is that services can allocate very little bandwidth and maintain their native packet structure independent of logical channel. The disadvantage is that services (using large packet structures but with very little bandwidth allocate) may affect the delivery time of all other data services that are using the Flex Packet delivery method. When the large Flex Packet file is being delivered, all other Flex Packet services on that logical channel must wait until the entire file has been delivered. This can render file delivery unpredictable. When transferring images, the difference between the packet delivery methods can dictate how far in advance of the associated audio the image must be sent to insure it is available for display when the associated audio arrives. The Flex Packet delivery method is best suited for non-real time applications.

Byte Streaming protocol accepts bytes from the client as they arrive. As the bytes flow into the RLS they are buffered and the transmission system decides how best to break them up into frames based on the allocated bandwidth. Packet encapsulation is lost, but each stream is guaranteed bandwidth and time-of-arrival for each frame. Streaming protocol is most appropriate for applications requiring near-real-time performance. Streaming protocol is the most efficient method of data transfer and should be considered for custom application development that can provide message management. There are currently no applications utilizing streaming protocol.

A Standard Data Client application is included as part of the Importer product suite and accommodates Standard Packet, Byte Streaming and Flex Packet protocols. The Data Client API Software Development Kit (SDK) allows the developer to incorporate LOT into custom applications and is available under license from iBiquity Digital Corporation.

Large Object Transfer (LOT) is an iBiquity proprietary protocol similar in function to the DAB Media Object Transfer (MOT) protocol LOT is an Application Programming Interface (API) that allows a station or Service Provider to transfer large data objects of any type through the HD Radio transmission system to a receiver equipped with a LOT decoder. Files are passed from the serving application via IP to the LOT application which invokes the Importer's

LOT API functions to generate data messages suitable for the HD Radio broadcast transmission systems. LOT builds upon the packet delivery methods of RLS by breaking the large objects into multiple packets containing fragments of the original object. The messages are transported using either the Packet or Flex Packet methods with a nominal packet size of 256 bytes. Reassembly of LOT objects is performed by the LOT decoder in the baseband processor of the receiver for presentation to the appropriate receiver application. The LOT application can manage lists of files to be transferred and the protocol offers other features such as multiple transfers, discard times, content identification, and error protection. LOT is the recommended method for broadcasting images.

The LOT API is available under license from iBiquity as a standalone application and as an API Software Development Kit (SDK) allowing developers to incorporate LOT into a variety of custom applications.

Synchronization of Media with Audio

There is no provision for synchronization of the program audio services with the data services inherent in the HD Radio system. All data, including audio associated data, is encoded via a separate protocol (RLS) and is completely asynchronous with the audio transport. Some of the data transport protocols have inherent non-guaranteed time of delivery and may also be dependant on the behavior of other clients. When transferring images, the difference between the packet delivery methods can dictate how far in advance of the associated audio the image must be sent to insure it is available for display when the associated audio arrives. Also, data delivery can incur substantial broadcast delays due to encoding, buffering and transport latencies. In the receiver, there are separate data and audio processing and decoding chains as well as wide variabilities in host processors. This makes synchronization of audio and graphics quite unpredictable without some tools and methods of synchronization.

System Timing - While the broadcast system delays may vary from installation to installation, within any one particular installation the various delays are constant and known by the broadcast system components. The delays can be expressed in terms of Absolute Layer 1 Frame Reference (ALFN) deltas among the various components. ALFN is a calculated time stamp reference to the number of frames that have occurred since the epoch date of 12:00AM, January 1, 1980. The Importer delivers the number of bytes/PDU the client has allocated for its service and the PDU rate in frames/sec. By applying the ALFN deltas along with the bytes/PDU and PDU rate, a bps value can be calculated as to when the data client application needs to start transmission of a particular image for on-time arrival. While this method cannot provide precise synchronization of audio and images, it can provide a level of assurance of in-time or just-in-time data delivery

Binding Audio and Data Services – Binding of the audio and data services is accomplished by the registration of the services in the Importer, transmitting that binding information to the receiver via the SIG channel and identification of the intended application within the receiver through MIME types. Within the data client applications, an association can be made between the data service and the desired audio channel's Service ID. It should be noted that a single data client may be associated with multiple audio services.

Triggering - The presentation time of each image is controlled by the broadcaster or service provider. This is accomplished by including a custom ID3 tag that is transported along with the other Program Service Data (PSD) information (the song title, album, artist information), in a special "XHDR" ID3 tag. The XHDR tag frame contains the LOT ID which identifies the file to display, the size of the file and one of three commands; DISPLAY a specified file on the device, BLANK the device's display or FLUSH the device's memory. Upon receiving the XHDR tag, the receiver executes the appropriate command to provide an acceptable degree of synchronization with the audio content.

RECEIVERS

HD Radio allows the reception of both digital audio and data services using the same receiver. In order to present multimedia data to the user, special application software is needed on the receiver side to decode and present a specific type of data. Standards are defined as to how the data is structured and transported and how it is to be decoded and presented by applications within the host processor. These specific applications reside on the receiver's host processor. The basic architecture of the HD Radio data receiver is shown in

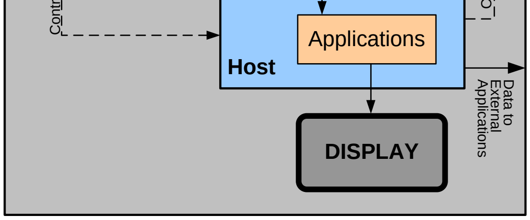

Figure 4

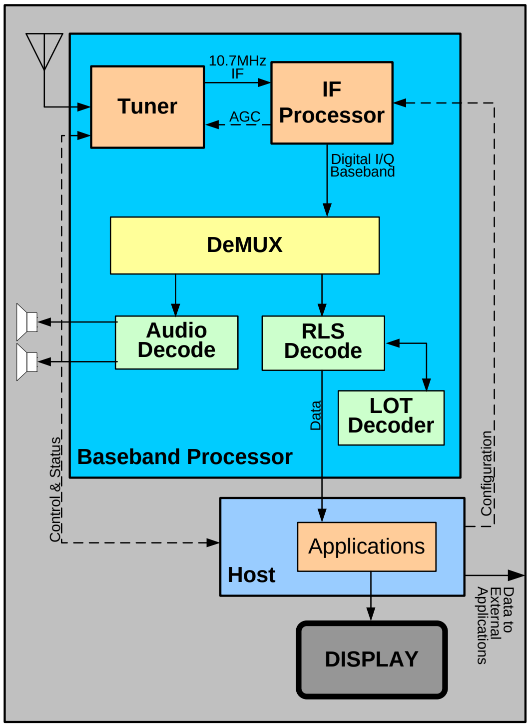

Figure 4 - Basic HD Radio Data Receiver Architecture

There are two primary components in an HD radio receiver; The Baseband processor and the Host Processor. RF signals are received by a tuner which provides a 10.7 MHz IF signal to the IF processor where it is demodulated into digital I and Q baseband signals. The digital I/Q are de-multiplexed into audio and data streams. Audio is sent to the audio decoder for conversion to an audio output for amplification. All data is sent separately to the RLS Decoder. The LOT decoder reformats any LOT formatted data received into the RLS decoder. The RLS decoder reformats the data back into the original structure. The data is sent to the Host Micro Processor. The Host uP contains the application software to initiate the necessary interaction with the various applications.

The host processors are not generally standard and can vary considerably in their ability to process and present the various data streams. Many baseband processors on receivers severely limit the memory allocated to LOT processing but should have sufficient memory to decode images files size up to 50 KB and have a minimum of 50 KB available to the host processor for the storage of images. Album art images are specified to be between 75x75 to 300x300 pixels which would equate to JPEG images of between 5 to 15KB each. When a new image arrives and there is not enough buffer space, images with the closest discard time are flushed, so it would behoove manufacturers to provide more on the order of 200 KB of memory in order to store a sufficient number of individual images to cover transport times.

The multimedia receivers currently being built leverage architecture and hardware borrowed from DAB/DMB. For receiver application development, iBiquity offers an Advanced HD Radio Receiver Development Platform and software development kit consisting of a tuner/baseband processor integrated into a Windows® CE based single board computer and a color display. This is an invaluable tool for the next generation of HD Radio application developers.

CONCLUSIONS

This has been an overview of some of the systems, applications and techniques available to transmit and receive images and data over digital radio broadcast systems. This discussion is not intended to be an exhaustive description or “how to” manual but rather, an opening dialog to spur ideas and development.

The concepts and technology for providing media-rich content over Digital Radio Broadcasting is in its adolescence but all of the pieces are there. As with any promising but unruly adolescent, it will require nurturing, development, discipline and patience to create a mature medium.

Many pieces still need to come together in terms of business, technology and receiver penetration but with all of these challenges, digital media over radio creates a new, exciting frontier for creativity and innovation. The stakes have never been higher for the radio broadcast industry and I believe we are up to the challenge.

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