

DOCKET FILE COPY ORIGINAL

Before the  
FEDERAL COMMUNICATIONS COMMISSION  
Washington, DC 20554

In the Matter of	)	MM Docket No. 99-25
	)	
Creation of a Low	)	RM-9208
Power Radio Service	)	RM-9242

RECEIVED

AUG 2 1999

FEDERAL COMMUNICATIONS COMMISSION  
OFFICE OF THE SECRETARY

**COMMENTS OF  
LUCENT TECHNOLOGIES INC.**

Diane Law Hsu  
Corporate Counsel  
Lucent Technologies Inc.  
1825 I Street, N.W.  
Washington, D.C. 20006  
(202) 756-7092

David R. Siddall  
Verner, Liipfert, Bernhard,  
McPherson and Hand, Ch.  
901 15th Street, N.W.  
Washington, D.C. 20005  
(202) 371-6326

Philip L. Verveer  
Willkie Farr & Gallagher  
1155 21st Street, N.W.  
Washington, D.C. 20036  
(202) 429-4740

August 2, 1999

No. of Copies rec'd 0+9  
List ABCDE

## TABLE OF CONTENTS

	<u>Page</u>
<b>Executive Summary</b> .....	<b>i</b>
<b>Introduction</b> .....	<b>1</b>
<b>Digital is Broadcast Radio’s Future</b> .....	<b>3</b>
<b>The Proposed Rules Changes Have the Potential to Impair Transitioning to Digital by Potentially Diminishing Analog and IBOC Digital Coverage Areas</b> .....	<b>5</b>
<b>Existing Receiver Analog-to-Analog &amp; Digital-to-Analog Interference</b> .....	<b>7</b>
<b>Dual-Mode Hybrid Receivers, Analog-to-Analog Interference</b> .....	<b>8</b>
<b>Dual-Mode Hybrid Receivers, Digital-to-Analog Interference</b> .....	<b>9</b>
<b>Dual-Mode Hybrid Receivers, Analog-to Digital Interference</b> .....	<b>9</b>
<b>Conclusion</b> .....	<b>10</b>
<b>Appendix A</b>	
<b>Appendix B</b>	
Lucent Digital Radio and Broadcast Electronics Announce Joint Testing Agreement for Digital Audio Broadcast System	
Lucent Digital Radio and Electronics Research Inc. Announce Agreement to Develop Digital Radio Broadcast Equipment	
Lucent Digital Radio Announces Successful Over-The-Air Test of Digital Audio Broadcast System with 90.5 WBJB-FM	
Lucent Digital Radio and Nautel Limited Will Jointly Test Lucent’s In-Band On-Channel Digital AM Broadcasting System	
Lucent Digital Radio Announces New Product Line Based on the Lucent Perceptual Audio Coder (PAC™)	
Lucent Digital Radio Announces Digital Audio Broadcast System Testing with Nassau Broadcasting Partners	

Lucent Digital Radio Announces Tests of its Digital Audio Broadcast System with 90.5, WBJB-FM, an NPR® Member Station

Lucent Digital Radio Announces Significant Technical Advance; Reaffirms Royalty-Free License Offer to Radio Broadcasters

Lucent Digital Radio Announces Licensing Agreement with Audio Video Communications in Australia

## Executive Summary

Maintaining the capability for broadcasters to implement in-band on-channel (IBOC) digital broadcasting without disrupting current listeners should be the Commission's paramount goal. The Commission is addressing details of an appropriate digital transmission system and related transition methodologies in a separate proceeding, and has announced its intention to launch a rulemaking this summer. Active participation by its staff in industry forums analyzing the digital proposals would assist the Commission in considering the complex issues presented both in this proceeding and the digital proceeding.

Lucent approaches the technical issues related to low power FM solely from the perspective that the effect of any changes to the Commission's technical rules governing the FM service must not preclude the ability of broadcasters to initiate digital broadcasting in a consumer-friendly manner. Whatever the outcome of the Commission's proposals in this docket, it is an essential element of the public interest that free, over-the-air broadcasting be able to join the digital revolution and continue to be available to all members of the public. The Commission must adhere to earlier commitments that radio broadcasters will have a meaningful opportunity to implement new digital transmission systems.

The analysis that we have conducted to date, while not complete, leads us to be pessimistic about the effects of permitting low power FM stations on adjacent channels. Our analysis suggests that it will be difficult for additional low power analog and new digital IBOC signals to co-exist and serve their intended service areas. The Commission's proposals generally either will constrain the capability of an IBOC system to replicate each station's analog service area with a digital audio signal during a transition period, or the digital signal will cause interference to the analog LPFM signal in a portion of that station's service area.

For existing receivers, the potential for analog-to-analog and digital-to-analog interference depends upon their technical characteristics. Lucent defers judgment to the Commission's technical engineering experts on the extent and probability of interference. The Commission should take into account the characteristics of existing analog receivers as set forth in studies that are expected to be submitted, as well as its own receiver evaluations. The expert opinions of the Consumer Electronics Manufacturers Association (CEMA), the National Association of Broadcasters (NAB), the Society of Broadcast Engineers (SBE), and possibly other similar expert entities should be carefully considered.

For the dual-mode receivers that will be introduced during the transition to digital, three types of potential interference must be assessed: analog-to-analog, digital-to-analog, and analog to digital. Receiver designs and technical characteristics are determined by cost/performance trade-offs that manufacturers make based on multiple factors. Performance of these receivers for analog-to-analog interference could be designed to be equal to or better than that of existing analog receivers. The potential for digital-to-analog interference will be affected by whether 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel protections are amended. Changing these protections will require that the new receivers be designed with better filtering to protect the analog stations operating on these adjacent channels, which

could raise the cost of receivers. Finally, potential analog-to-digital interference could impact reception of the digital signal. However, the impact can be lessened by Lucent's digital IBOC system, which incorporates patented Multi-streaming PAC™ technology. Additional analog power into the digital signal will be tolerated up to a certain level, but with gradual loss within the strongest area of interference.

Based on what we know, some general propositions can be stated that would help maintain the capability of FM broadcasters to implement IBOC digital broadcasting in a seamless, consumer-friendly manner.

- First, should the Commission proceed with its LPFM proposals in any form, the digital IBOC signals of existing broadcasters should be accorded the same primary signal protection as their associated analog signals.
- Second, the new LPFM stations should not be authorized to transition to IBOC digital technology unless their signals comply with today's technical rules. The structure of IBOC signals makes this imperative if a consumer-friendly transition to digital is to be possible within the FM band.
- And third, new LPFM stations, if authorized, should be accorded only secondary status. This would offer some expectation of protection to existing broadcasters and listeners, both now and in the future.

A completely tested and ready IBOC digital system is only months away. Lucent succeeded recently in placing a Hybrid IBOC FM signal on the air. No cross-interference has been observed between the digital and analog FM signals. As indicated by other recent developments reflected in the announcements collected in Appendix B, substantial progress has been made in 1999 toward completing our IBOC system design and having it demonstrated in the laboratory and in the field. We believe that consumers will best be served by having assured access to digital audio and associated new data services in the FM band.

**Before the  
FEDERAL COMMUNICATIONS COMMISSION  
Washington, DC 20554**

In the Matter of	)	MM Docket No. 99-25
	)	
Creation of a Low	)	RM-9208
Power Radio Service	)	RM-9242

**COMMENTS OF  
LUCENT TECHNOLOGIES INC.**

**Introduction**

Lucent Digital Radio, by its attorneys, hereby files these comments concerning the above-captioned rulemaking.<sup>1</sup> Lucent Digital Radio (“Lucent”), a new venture of Lucent Technologies, is at the forefront of digital radio technology. Lucent is applying the expertise of Bell Laboratories to deliver to the American public a digital radio broadcast system that will enable broadcasters to deliver to their listeners superior digital audio and exciting new ancillary data services, yet protect investment in the estimated 600 million analog receivers that are in consumer hands.

Maintaining the capability for broadcasters to implement digital broadcasting without disrupting consumer listening should be a paramount goal for the Commission. Whatever the outcome of this particular docket, it is an essential element of the public interest that free, over-the-air broadcasting continue to be available to all in a

---

<sup>1</sup> *Creation of a Low Power Radio Service*, Notice of Proposed Rulemaking, MM Docket No. 99-25 (FCC 99-6, rel. Feb. 3, 1999).

communications marketplace that rapidly is becoming part of the digital domain. For this reason, if no other, the Commission must adhere to the commitments made by an earlier Commission that radio broadcasters would have a meaningful opportunity to implement new digital transmission systems. In 1990, the Commission opened an inquiry on the subject of digital broadcasting, including in the AM and FM bands.<sup>2</sup> In 1992 it stated that “existing radio broadcasters can and should have an opportunity to take advantage of new digital radio technologies.”<sup>3</sup> In 1995 the Commission reiterated that “existing radio broadcasters can and should have the opportunity to profit from new digital radio technologies . . . . When the test results indicate the feasibility of implementing such systems, we will act expeditiously to consider any appropriate changes to our rules.”<sup>4</sup>

The Commission is addressing details of an appropriate digital transmission system and related transition methodologies in a separate proceeding,<sup>5</sup> and has announced its intention to launch a rulemaking this summer.<sup>6</sup> It therefore is of significance that in this proceeding on low power radio all five Commissioners recognized the need to consider digital broadcast opportunities when they assess the capacity for additional low power

---

<sup>2</sup> *Amendment of the Commission’s Rules with Regard to the Establishment and Regulation of New Digital Audio Services*, Notice of Inquiry, 5 FCC Rcd 5237 (1990).

<sup>3</sup> *Id.* Notice of Proposed Rulemaking and Further Notice of Inquiry, 7 FCC Rcd 7776 (1992).

<sup>4</sup> *Id.* Report and Order, 10 FCC Rcd 2310, 2314 (1995).

<sup>5</sup> *Amendment of Part 73 of the Commission’s Rules to Permit the Introduction of Digital Audio Broadcasting in the AM and FM Broadcast Services*, RM-9395 (submitted Oct. 7, 1998); Public Notice (DA 98-2244, rel. Nov. 6, 1998).

<sup>6</sup> *Creation of a Low Power Radio Service*, *supra* note 1, Order at para. 6 (FCC 99-112, rel. May 20, 1999).

stations. Chairman Kennard and Commissioner Tristani, in a joint statement, said: “. . . we will do our part to make sure that local radio is not left on the sidelines of the digital revolution.” Commissioner Ness in a statement said: “IBOC technology appears to be almost ready for commercial application and should not be undermined or compromised by any action we take on low power FM.” Commissioner Powell wrote in a separate statement: “I would be concerned if authorizing some or all of these low power radio services would make in band on channel conversion to digital radio unworkable for existing terrestrial services. Again, I encourage commenters to focus specifically on this issue, so that we can make a fully informed judgment.” And Commissioner Furchtgott-Roth, in a dissenting statement, said: “The creation of low power radio by elimination of current interference rules may also have a similar effect on the FM radio band itself by hindering the development of new, advanced services such as in-band, on-channel digital radio.”<sup>7</sup>

### **Digital is Broadcast Radio’s Future**

In these Comments, Lucent addresses only those issues related to the future implementation of digital IBOC technology by current FM broadcasters. Lucent’s digital IBOC system design is based upon and compliant with the Commission’s existing FM technical power and separation rules. Taking those rules into account, each broadcast station using Lucent’s system will be able to initiate digital broadcasts while also continuing to broadcast using standard analog transmissions for as long or as short a period as it wishes.

Lucent approaches the technical issues raised in this proceeding solely from the perspective that the effect of any changes to the Commission’s technical rules governing the

---

<sup>7</sup> See *Creation of a Low Power Radio Service*, *supra* note 1. (Commissioner statements are appended to the *Notice*.)

FM service must not preclude the technical ability of broadcasters to initiate digital broadcasting by implementing a digital IBOC system in a fashion that permits replication of the existing broadcaster's complete service area during the interim period when both analog and digital signals will be broadcast. This ability is essential so that during the transition broadcasters can continue to serve their listeners that rely on analog receivers as well as consumers who purchase digital receivers. Lucent designed its system to ensure that there will be no additional perceptible interference to the host broadcaster's existing analog signal, nor to any neighboring signals, for consumers continuing to use analog receivers.

Service area replication is unique to Lucent's design. In today's FM radio environment each signal – analog and digital – generally will provide audio service to the entire coverage area of the host station without interfering with analog broadcasts, without requiring new spectrum allocations and allotments, and without requiring the Commission to decide difficult issues involving if and when to end analog broadcasting.

Lucent has designed these attributes into its system. They are extremely important because they enable each broadcast licensee to proceed at his or her own pace to transition from analog to digital. While ceasing to broadcast an analog signal will result in additional digital capacity for the broadcaster, at the same time it will eliminate service to those consumers who have only analog receivers. Consequently, empowering each broadcaster to make this decision based upon consumer needs and marketplace forces in each individual community and pursuant to each broadcaster's business plan will be of substantial benefit to the American public generally, as well as to individual listeners specifically. Adhering to such beneficial objectives will result in more and better service delivered to broadcast listeners in the shortest possible time.

**The Proposed Rules Changes Have the Potential to Impair Transitioning to Digital by Potentially Diminishing Analog and IBOC Digital Coverage Areas**

Maintaining the capability to implement new and improved digital broadcast services without consumer disruption should be an important Commission goal. Accomplishing it will depend upon leading-edge breakthrough technology, such as that developed by Lucent that will enable each existing broadcast station to duplicate its audio service area without requiring a new allocation of additional scarce spectrum. Lucent's digital IBOC system relies on the existing basic protections against signal interference. Defining and preserving that necessary basic protection, while the subject of the digital radio proceeding referenced above, also is implicated directly in this proceeding by the proposals to change the underlying interference rules.

The analysis that we have conducted to date, while not complete, leads us to be pessimistic about the effects of permitting low power FM stations on adjacent channels. Changing rules governing interference inevitably will have consequences for plans to move FM stations from analog to digital without the disruption and cost to consumers of lost coverage and a mandatory switch between systems.

The Commission's proposals to repeal second and third adjacent channel assignment restrictions and to authorize low power stations on these channels generally either will constrain the technical capability of an IBOC system to replicate each station's analog service area with a digital audio signal during a transition period, or the digital signal will cause interference to the analog LPFM signal in a portion of that station's service area. This is especially true with the higher-powered (LP1000 and LP100) proposals for operation on

second adjacent channels. Impairments to the digital transition plans of broadcasters will be harmful to the listeners of the stations affected, as well as to the stations themselves. Interference is caused by differences in signal strength (desired-to-undesired signal differences, known as the “D/U ratio”) rather than absolute power levels, and this element has a high dependence upon the relative locations of the two stations being analyzed. Characterizing the extent of potential interference as a general matter is complex because each situation is determined by a specific mix of multiple variable elements. There is no single answer for how much interference will be caused by putting a low power station of 100 or 1000 watts on a channel that is second or third adjacent to an existing station because, in addition to the power level and antenna gain of the two subject stations, the geographic location of the new station also contributes to the result. In addition, the result of interference analysis is heavily influenced by the particular characteristics of the receiver being used.

These conclusions generally apply to analysis of signal interference, whether analog or digital, although signals of differing characteristics have varying degrees of immunity to some types of interference. For example, analog FM signals exhibit a quality known as “capture effect” that results in substantially more “robustness” to interference than an analog AM signal. In the same fashion, IBOC systems of different design can be expected to have different degrees of robustness. Lucent’s IBOC system incorporates patented Multi-streaming PAC™ technology as an integral part of its transmission system to improve the robustness of its digital signal in all kinds of difficult interference environments. Incorporation of this technology allows Lucent’s system to replicate the entire audio service area of most of today’s stations.

Due to current receiver characteristics, analog broadcasting is not permitted on either the lower or upper first adjacent channel within a specified distance of the main channel. This protection, coupled with the limits on out-of-band emissions (known as the “emission mask”)<sup>8</sup> provides the opportunity for a low-power digital signal to be transmitted on either side of the analog signal. If done correctly, the analog signal can be recovered independent of the digital signal, and *vice versa*. The IBOC proponent systems rely on this basic signal architecture. Lucent’s digital signal, by remaining under the emission mask for the main analog channel, does not encumber any additional spectrum, although the digital signal does reduce by 100 kHz the separation (guardband) between the main channel and the 2<sup>nd</sup>- and 3<sup>rd</sup>- adjacent channels. Notwithstanding the closer proximity of the two signals, because of the relatively low power of the digital signal it complies with the Commission’s applicable separation requirements and does not interfere with any analog signal or other digital IBOC signal compliant with today’s rules.

Regardless of the proposed station powers and other technical characteristics, interference caused both by IBOC stations to LPFM stations and by LPFM stations to IBOC stations must be considered. Each case presents a variety of defined channel relationships, powers, and locations to be analyzed.

**Existing Receiver Analog-to-Analog & Digital-to-Analog Interference.** The potential for interference to existing analog FM broadcasters by the introduction of new low power analog stations warrants careful examination and analysis that includes consideration of the analog receiver technical characteristics. There are an estimated 600 million analog receivers in consumer hands. These receivers, or ones like them, are long-lasting and will

---

<sup>8</sup> 47 C.F.R. 73.317.

continue to exist in declining numbers through the digital transition period. Accurately assessing the impact of these receivers is important for purposes of considering the rules changes proposed in this proceeding.

While Lucent has studied the existing analog FM environment for purposes of designing its digital IBOC system, it has been outside the scope of its work to analyze the potential for LPFM stations to interfere with reception of other stations for consumers continuing to use today's typical analog receivers. Lucent defers judgment to Commission technical engineering experts on the extent and probability of interference. The expert opinions of the Consumer Electronics Manufacturers Association (CEMA), the National Association of Broadcasters (NAB), the Society of Broadcast Engineers (SBE), and possibly other similarly expert entities should be carefully considered. In doing so, the Commission should take into account the characteristics of existing analog receivers as set forth in studies expected to be submitted by some of these organizations, as well as its own receiver appraisals.

**Dual-Mode Hybrid Receivers, Analog-to-Analog Interference**. Performance of new hybrid analog/digital receivers in the analog mode could be designed to be equal to or better than that of existing analog receivers. Nevertheless, note must be taken that receiver designs and operating characteristics are determined by cost/performance trade-offs that manufacturers make based on multiple factors. Similarly, the degree of receiver selectivity (ability to discriminate among signals of different powers and frequency) and overload immunity (blanketing)<sup>9</sup> – characteristics directly related to signal interference experienced by the listener – is determined by manufacturer design decisions. Digital proponents like

---

<sup>9</sup> See 47 C.F.R. 73.318.

Lucent, as well as broadcasters and listeners, must accept the performance characteristics of receivers as they exist. Often cost to the intended target market segment limits receiver performance. System designers must design their digital IBOC systems to work with receivers on the lower end of the cost and quality chart if general acceptance is to be gained.

**Dual-Mode Hybrid Receivers, Digital-to-Analog Interference.** Lucent's digital IBOC system will not interfere with existing analog broadcast signals that comply with the Commission's current rules. However, if 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel protections are eliminated, an IBOC low power digital signal could be located only 100 kHz from the nearest edge of a geographically near 2<sup>nd</sup> adjacent analog LPFM station, and 300 kHz from nearest edge of a nearby 3<sup>rd</sup> adjacent analog LPFM station. This relationship will markedly reduce the desired-to-undesired (D/U) protection ratio of both signals. The D/U difference potentially will require that new dual-mode hybrid receivers be designed with better filtering to reject the undesired signal (in this case the Hybrid IBOC FM signal). This would add to receiver costs.

**Dual-Mode Hybrid Receivers, Analog-to-Digital Interference.** Lucent's digital IBOC signal rejects analog interference substantially better than *vice versa*, due in part to incorporation of patented Multi-streaming PAC™ technology. Additional analog power into the digital signal will be tolerated up to a certain level, but with gradual quality loss within the strongest area of interference. Where additional interference from an analog signal is present on 2<sup>nd</sup> or 3<sup>rd</sup> adjacent signals on both sides of the Hybrid IBOC FM signal, the impairments would be worse and as the signal level of the interfering signal decreases, the quality of the digital signal will increase.

## **Conclusion**

The Commission's proposal to eliminate current geographic spacing requirements and introduce low power FM stations on channels that are 2<sup>nd</sup> and 3<sup>rd</sup> adjacent to existing broadcast stations presents a complex engineering problem. For any specific situation there are three and possibly more power and antenna combinations, coupled with a wide variety of desired-to-undesired signal ratios that result from the different geographic spacings that are possible between existing and low power stations of the various categories. Potential interference also is affected by the characteristics of existing and future receivers, both analog and digital.

Lucent's analysis to date suggests that it will be difficult for additional low power analog and new digital IBOC signals to co-exist and serve their intended service areas. While this work is not exhaustive for purposes of analyzing the potential interference effects from additional low power FM stations on 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channels, the results do strongly indicate that the Commission should carefully consider the characteristics of the embedded base of receivers in reaching conclusions on the interference potential of any contemplated rules changes. Receiver manufacturers are an oft-overlooked but critical stakeholder in this process.

The Commission's most important goal should be to maintain the capability for FM broadcasters to implement digital broadcasting in a seamless, consumer-friendly manner. By doing so, the Commission will best serve the public interest in ensuring that consumers continue to have access to competitive, state-of-the-art free over-the-air broadcast services.

Based on what we now know, some general propositions can be stated that would help attain this goal. First, the digital IBOC signals of existing broadcasters should be

accorded the same primary signal protection as their associated analog signals. Doing so would establish a clear order of rights, should the Commission proceed with its LPFM proposals in any form.

Second, the new LPFM stations should not be authorized to transition to IBOC digital technology unless their signals comply with today's technical rules. The structure of IBOC signals makes this imperative if a consumer-friendly transition to digital is to be possible within the FM band.

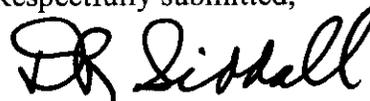
And third, new LPFM stations, if authorized, should be accorded only secondary status. This would offer some expectation of protection to existing broadcasters and listeners, both now and in the future.

A completely tested and ready IBOC digital system is only months away. Lucent succeeded recently in placing a Hybrid IBOC FM signal on the air. No cross-interference has been observed between the digital and analog FM signals. As indicated by other recent developments reflected in the announcements collected in Appendix B, substantial progress has been made so far in 1999 toward completing our IBOC system design and having it demonstrated in the laboratory and in the field. We believe that consumers will best be served by having assured access to digital audio and associated new data services in the FM band.

Diane Law Hsu  
Corporate Counsel  
Lucent Technologies Inc.  
1825 I Street, N.W.  
Washington, D.C. 20006  
(202) 756-7092

August 2, 1999

Respectfully submitted,

A handwritten signature in black ink that reads "DR Siddall". The letters are cursive and fluid, with the "DR" initials being particularly prominent.

David R. Siddall  
Verner, Liipfert, Bernhard,  
McPherson and Hand, Ch.  
901 15th Street, N.W.  
Washington, D.C. 20005  
(202) 371-6326

Philip L. Verveer  
Willkie Farr & Gallagher  
1155 21st Street, N.W.  
Washington, D.C. 20036  
(202) 429-4740





## Lucent Digital Radio

---

# LUCENT DIGITAL RADIO'S MULTI-STREAMING TECHNOLOGY

Lucent Digital Radio (LDR) is using its patented Multi-streaming technology in its InBand – OnChannel (IBOC) digital radio systems to significantly improve system performance. The specific IBOC benefits compared to other, conventionally designed systems include:

1. Improved signal robustness to first and second adjacent channel interference
2. Significantly extended range of digital signals
3. Graceful digital degradation at the edge of coverage
4. Fast digital station acquisition time

Multi-streaming, which is incorporated in the latest generation of Lucent's Perceptual Audio Coder™ (PAC™) and channel coding design, offers robustness to degraded channel conditions, including interference and fading. This technique enables high-quality digital reception of audio even when part of the signal is severely interfered with, by recombining the remaining streams. Under fading channel conditions, part of the spectrum is impaired at a particular time. With Multi-streaming, the system continues to operate smoothly by constantly switching to the highest-quality combination of streams available.

The improved signal robustness, thanks to superior interference tolerance and higher error protection, leads to significantly extended range of digital signals, compared to previously available digital designs.

A related benefit arising from Multi-streaming is that it emulates the graceful degradation characteristic of analog signals. Earlier digital systems have typically accompanied the annoying "cliff effects" or "digital drop-outs," significantly diminishing the listening experience. Graceful degradation of audio quality allows for high-quality digital audio at the edge of analog coverage.

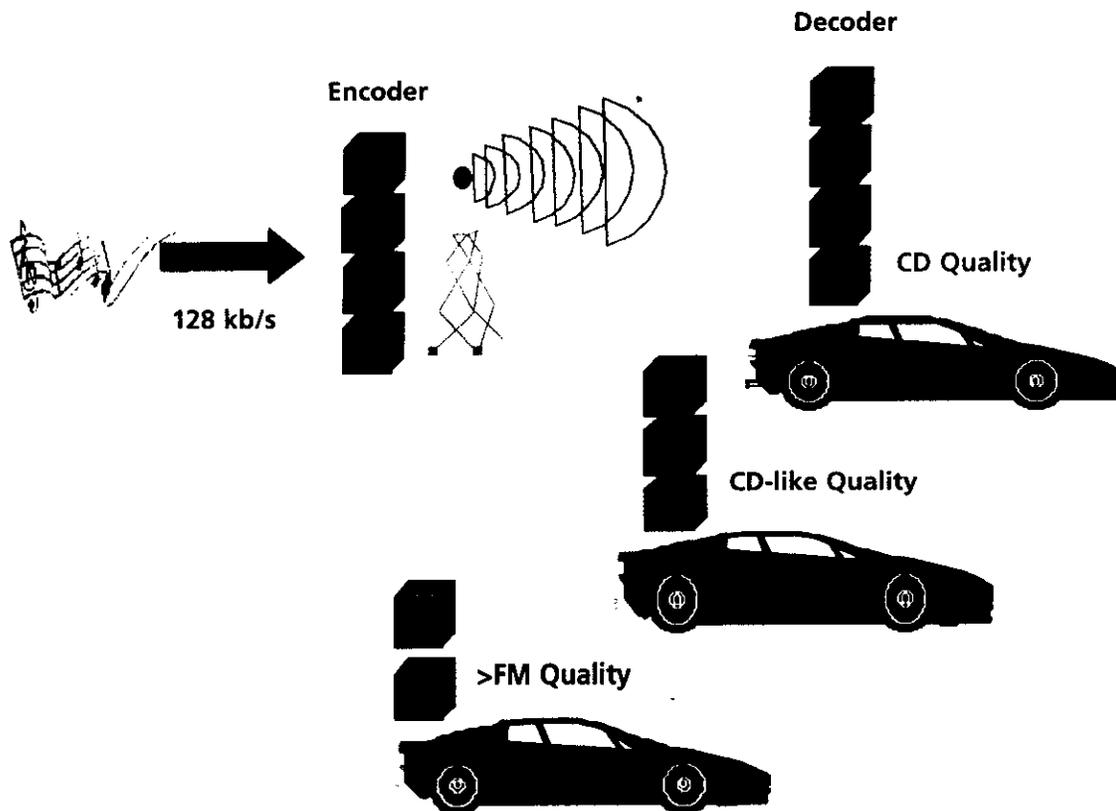
In addition, station acquisition time is minimized, because the receiver can initiate the capturing process with only one of the streams, whereas in other systems the receiver has to wait until the entire single stream is delivered.

# Lucent Digital Radio

## How Multi-Streaming Works

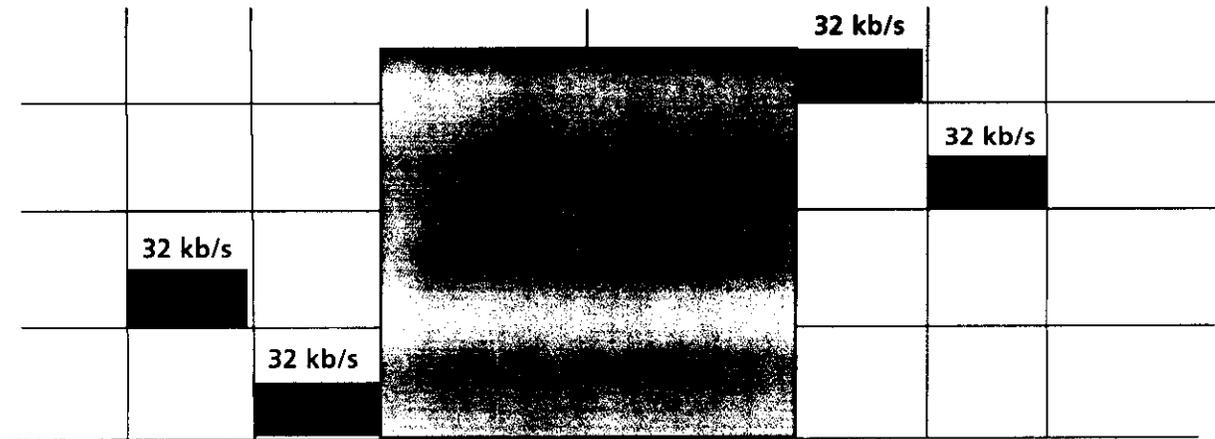
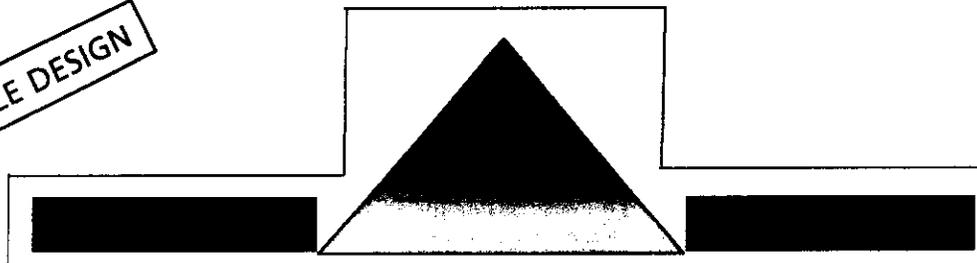
Multi-streaming breaks audio information into multiple packets (streams), each of which can stand alone and provide quality audio. Adding up streams will increase the audio quality. When all streams are added, CD-quality audio is recovered. LDR calls the concept of splitting an information source into complimentary streams "Information Diversity."

As a specific example of information diversity, audio coding operating at 128 kb/s can be broken into four 32 Kb/s streams. The streams can be reassembled at the decoder in any combination to provide increasingly better quality audio. When all four streams are combined, the original audio is recovered.



By breaking audio information into separate streams, the information can be spread across both time and frequency. LDR's implementation of Multi-streaming takes advantage of time and frequency diversity available in the IBOC channel. As illustrated in the FM-band example below, the LDR algorithm generates four streams of 32 kb/s each. These four streams are distributed not only across the different frequencies in the FM band but also across time, as illustrated by the streams designated A through D below.

EXAMPLE DESIGN



Frequency

# Lucent Digital Radio

---

At the receiver end of the audio delivery chain, the decoder incrementally recombines the building blocks as channel conditions dictate. Thus, the audio quality to the user is not uniformly compromised due to bad channel conditions. The table below compares single-stream to multi-stream across different criteria.

## COMPARISON OF SINGLE STREAM VERSUS MULTI-STREAM

	SINGLE STREAM	LDR SYSTEM WITH MULTI-STREAM
Coverage of digital signal	Limited	To noise-limited analog contour (today's listenable area)
Audio quality at edge of coverage	Analog	Gracefully degraded
Digital station acquisition time	Relies on analog for tuning	Fast digital acquisition
Coverage under 1st and 2nd adj.	Problems under fast fading conditions	Improved coverage (>10 dB margin improvement)
Performance under slow fading	Simulation results indicate coverage problem with slow fading	Significantly improved performance for slow fading

---

### Contact Information:

William Casey, Director - Marketing & Sales  
Lucent Digital Radio  
20 Independence Blvd.  
Warren, NJ 07059 USA  
Phone: +1 908 580 7008  
Fax: +1 908 580 7152  
Email: [williamcasey@lucent.com](mailto:williamcasey@lucent.com)  
Website: <http://www.lucent.com/ldr>

**Lucent Technologies**  
Bell Labs Innovations

