Public Radio Digital Transmission Conversion Costs

A First Generation Projection
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I. EXECUTIVE SUMMARY

The end objective of a digital radio conversion is to provide new and improved public radio services to the listening public. This will require substantial investments in programming, interconnection and studio equipment in addition to the core transmission equipment studied in this report – costs that this analysis projects to total $171,000,000.

During the past decade, as compatible in-band digital radio transmission was pursued in testing venues, significant digital studio conversion work has occurred at many public radio stations. Most public radio stations now possess digital audio workstations for limited local production needs and many have upgraded to digital consoles, digital studio and field audio recorders, and digital audio processors. Many stations now utilize digital audio workstations to time shift and automate off-hours programming, and a growing number of digital STLs, wideband terrestrial links and digital exciters have appeared in the system in recent years. Significantly, the Public Radio Satellite System (PRSS) upgraded to digital audio transmission in 1995. The next generation system upgrade, which is likely to support IP and DVB based digital protocols, is scheduled to commence rollout within the next 36 months.

These upgrades, along with station digital radio conversion efforts will enable public radio to reach the listener with a variety of new public radio services. Recently NPR, KenwoodUSA, and Harris Corporation announced the first of a series of new service demonstrations called the *Tomorrow Radio Project*. The first demonstrations are scheduled to commence in the 3rd Quarter of 2003 in Los Angeles to test the viability of adding a second audio program stream within the HD Radio signal. If the performance characteristics of this channel are sufficiently robust, market tests to determine the consumer response to "secondary channel" radios are expected to follow in short order. Such development offers the possibility to "open a window" to numerous public radio programs that are not offered in many locations due to time and format constraints, especially in sole-service markets.

Additional next generation services are expected to follow in rapid succession, including on-demand traffic, weather and other information. The likelihood of on-demand radio services following a "Tivo" or "Replay TV" model has recently been demonstrated by iBiquity Digital at the Consumer Electronic Show 2003, using mostly public radio content.

If the HD rollout proves successful, public radio will need to keep pace. Now that over a hundred stations have made the commitment to add digital transmissions, this study is designed to identify the likely scale of system-wide conversion costs, informed by actual pricing now that needed equipment is entering the market. This information should prove valuable in building funding partnerships.

Although ten of millions of annual receiver sales are not projected until calendar 2006, as NPR stated in the FCC's Notice of Inquiry on Digital Audio Radio Services in 1990, "it is clear that this is direction in which we must set out.

II. Public Radio's Digital Transmission Conversion Costs

The overall objective for this report is to estimate, as reliably as possible, the preliminary system-wide public radio transmission conversion costs for hybrid HD Radio operation. This universe was defined as the 863 NPR-affiliated and CPB-qualified AM and FM radio stations. The activity commenced in 2001 at the start of the iBiquity EASE assessment process and was periodically promoted by NPR to the NPR membership through electronic and in-person communications beginning with the Public Radio Engineering Conference in April 2001. At annual Public Radio Conferences, during regional meetings with station managers and at numerous specialty conferences stations were asked to complete the EASE evaluation to build the most accurate possible conversion cost estimates. During the spring of 2002 iBiquity complied an initial round of station responses based on the responses of just over 150 stations. During the summer and fall of 2002 NPR Member and Program Services promoted the need for higher levels of survey responses ultimately leading to 382 assessed respondents, a 44% completion rate.

III. Basic Capital Conversion Costs Common to Most Stations

Only 58 of the 863 public radio stations operate in the AM band. This represents just over 6% of the public radio stations currently operating. Thus, this report concentrates on the conversion costs associated with FM operations, while also compiling projected conversion costs for AM operations.

Recommendations for threshold conversion costs for most FM stations include:

- payment of the iBiquity one time audio licensing fee (slated for $4,125 in 2003[1])
- $12,000 for a digital audio processor
- $31,000 for an HD Radio exciter
- $15,000 allowance for actual installation, transmission line, fittings and power conditioning costs

Most stations will also require a $16,000 microwave or terrestrial feeder link. A budgeted 20% contingency figure in included based on capital costs as an allowance against foreseeable but non-universal costs such as permitting, architectural & engineering studies required by site owners, transmitter room realignment, and possible HVAC needs.

The average FM station digital transmission conversion cost for the EASE assessed public radio stations is $138,000. Conversion costs for all stations starts at $90,000 for the single station that has an HD Radio compliant STL. A group of just over three dozen stations are in the range of $100,000 to $110,000.

Stations having low power transmitter needs (less than 3.5-kw digital power) and having the requisite 10% analog transmitter power output overhead will fall well below the rough $171,000 conversion cost figure, with the largest group of stations falling in the range of $140,000 to $160,000 range for total transmission conversion cost (including project contingency).

[1] The iBquity one time perpetual license fee for all noncommercial stations is 15 times the lowest FCC regulatory licensing fee. For 2003 this figure is $4,125 (15 times the $275 minimum FCC regulatory fee).

Just over two-thirds (550 or 68%) of the FM stations are indicated to have conversion costs below $175,000. Some 97 stations (12% of the population) have costs ranging above $200,000. These are invariably higher power stations operating with above 20-kw ERP that lack overhead combining capacity (thus requiring new analog and digital transmitters under existing FCC rules).

Because the "projected" average FM conversion cost was nearly 25% higher than the average cost computed for "assessed" stations, and since higher dollar amounts are involved at the higher power levels, we looked closely at this group. Only 11 stations, however, appear in the range based on projected rather than assessed information. Nonetheless, an allowance for the number of stations likely to actually lack overhead combining capacity was separately accounted as described in the following pages. A large number of "projected" costs fall in the $180,000-190,000 range, explaining the higher average conversion cost among the "non-assessed" stations.

(See Charts I and II for station distributions in the cost ranges.)

Chart I EASE-Assessed Core Capital Cost Distributions (including 20% project contingency)

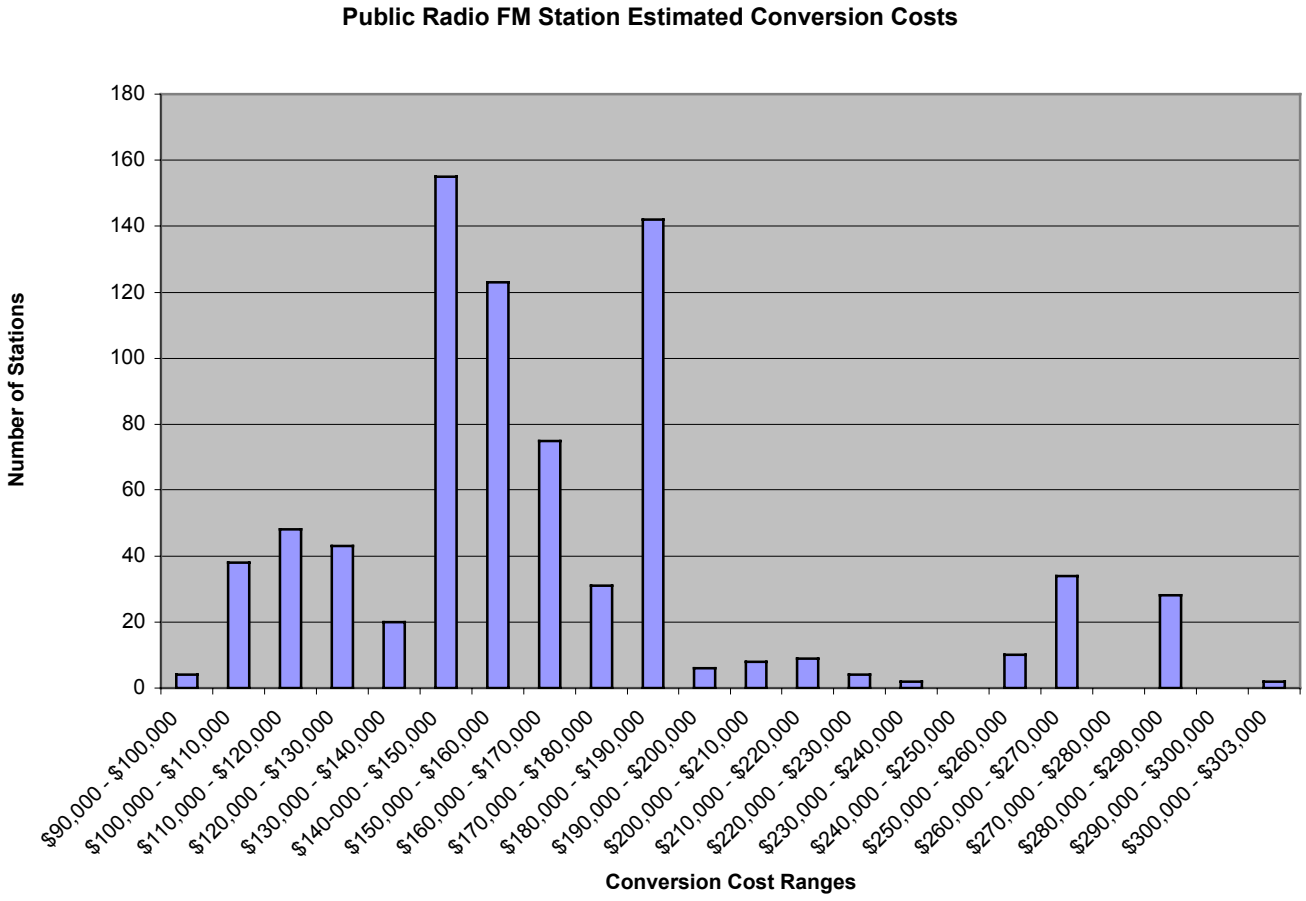
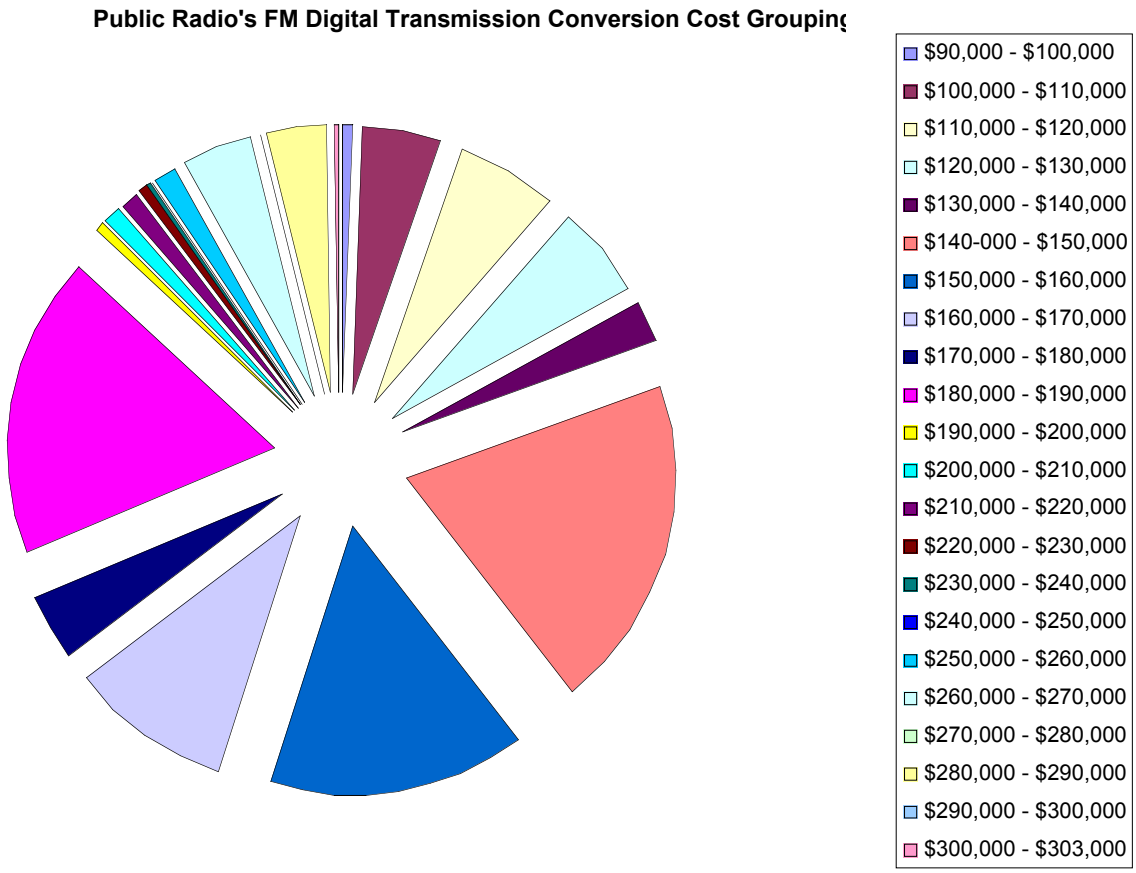


Chart 2 Station Core Cost Distributions as Percentage in $10,000 Assessed Tiers



IV. Transmitter Combining Headroom—the higher cost factor

Beginning at as low as the 5-kw power level, higher costs are reflected for stations that lack 10% overhead transmitter power output needed to account for hybrid combiner loss. Insufficient analog headroom triggers the requirement to purchase both a new analog transmitter and a new digital transmitter in addition to the associated combiners and filters, as well as the exciter, processing and feeder link equipment common to nearly all public radio FM stations.

Although numerous stations in the 20–60-kw ERP range have costs under $180,000, statistically all of these stations have the requisite 10% combiner loss overhead factor in the existing analog FM transmitter.

Individual stations, as well as officials at PTFP, have been encouraged to make future analog FM transmitter purchases with a 10% combiner overhead factor to avoid the cost penalties associated with replacing these systems once a determination is made to commence HD transmissions.

V. Approximation methodology for non-EASE assessed stations

To project the costs for the stations that did not participate in the iBiquity EASE assessment program, NPR analyzed the likely accuracy, taking the overall FM average and applying it as a placeholder value to all stations lacking an assessment. This method might eventually be shown to have generated a reasonably reliable projection. However, because the range of total station transmission conversion costs varied from a low of around $90,000 to a high of just over $300,000 (with a significant grouping of stations in the range between $180,000 to $190,000), the accuracy of inserting the "assessed average" was deemed of dubious reliability.

The higher costs are typically encountered where stations lack sufficient transmitter power to overcome combiner losses. Since under-reporting these higher cost situations would yield an artificially low total cost, NPR Engineering analyzed the data ranges based on transmitter power output as well as ERP levels to project likely tiers of conversion costs using the available station data from the FCC's CDBS.

NPR Engineering analyzed the population distribution within the actual assessed station population in power ranges associated with typical transmitter classes to determine what percentage of stations within each range lacked the requisite combiner overhead capacity. The average number affected was 24%.

By sorting the "projected" station class into the power groupings used to derive the percentage of stations lacking overhead capacity, the difference in the cost of purchasing new analog and digital transmitters was calculated against the overhead-blind recommended method (LLC or HLC). These recommendations were based on transmitter power output levels, with LLC always recommended below 3.5-kw. The cost penalty associated with the estimated number of instances lacking overhead capacity was totaled and shown separately as a $3,554,000 contingency.

Although EASE recommendations were complied as station data was submitted to iBiquity Digital over the past two years, routine data sorts revealed generally consistent results. For example, most stations were assessed as requiring new STL links to transmit the HD Radio signal to the transmitter site[2], and all stations were shown to need separate audio processing for the digital signal. Preliminary numbers were provided by iBiquity Digital for the one time licensing fee assessment, which NPR updated in this report to the amount applicable for those stations not in the initial round of fee waivers based on early adoption commitments received at iBiquity by December 31, 2002[3].

Conversion costs for non-EASE assessed stations within the NPR and CPB affiliation lists were approximated by analyzing power output levels.

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[2] Only 21 out of 357 assessed FM stations were shown to have HD compliant feeder link systems in place, just under 6% of the reporting population. Therefore, in projection scenarios NPR anticipated that non-assessed stations are most likely to require a compliant digital STL and budgeted the full $16,000 placeholder value.

[3] As this report was going to bed it has been reported that iBiquity Digital and the Corporation for Public Broadcasting have reached an agreement in principle that any noncommercial station be eligible for the fee waiver if they record their commitment for conversion by June 1, 2003. Since the identity and number of stations likely to take advantage of this waiver extension is currently unknown no placeholder savings are projected as part of this analysis.

Because of the substantial costs reflected for those stations above 3.5-kw ERP lacking 10% analog power combining headroom, call outs were initiated to determine transmitter power output (TPO) vs. effective radiated power (ERP) in the 13 seed markets when such data was not reflected in the station license files in the FCC's Consolidated Database System (CDBS). Additional call-outs were required for stations whose data contained obvious clerical errors, as well as for stations with outstanding construction permits reflected in the CDBS to determine whether the CP was being actively pursued and was therefore relevant to the conversion cost analysis.

All approximations are shown within the spreadsheet as shaded information, with the method of approximation being based on TPO when such figures are shown in the relevant column or as being ERP-derived when no TPO information was available from the CDBS. (TPO figures were available for over half of the stations covered by this report through the EASE assessment process or via the CDBS.)

However, to compute recommendations on LLC, HLC Existing, or HLC New where TPO was not known, TPO was imputed based on an approximation of known ERP to TPO. These ratios were consistent with expected results and our understanding of the number of antenna bays in most common use at identified power levels.[4] Moreover, we believe that imputing TPO based on the actual ratios from this population is preferred since it accounts for typical transmission line losses[5] and the varying height of the radiating antennas.

Table I TPO to ERP Ratio

ERP	Average TPO to ERP Ratio
0–3-kw	1.24 to 1
3–6-kw	0.92 to 1
6–10-kw	0.62 to 1
10–20-kw	0.469 to 1
20–30-kw	0.413 to 1
30–50-kw	0.354 to 1
>50-kw	0.236 to 1

A simple regression analysis was conducted on the assessed data to determine the transmission cost tiers iBiquity Digital had recommended based on power ranges and the relationship between TPO and ERP. In general, iBiquity's recommendations sought to avoid the relatively costly High Level Combining situations since the combiner costs and the need for new, larger transmitters escalate under this approach. NPR updated these recommendations based on actual costs and power levels reflected in the marketplace.

VI. Low Level Combining for Stations Below 3,500 watts ERP

At lower power levels it is recommended that stations employ the Low-Level Combining approach, obviating the need for external combiners and requiring the purchase of only

[5] Line losses vary based not only on length of the transmission line but from additional factors such as whether the line is rigid or flexible, the type of dielectric employed, as well as the area and size of the conducting surfaces.

a single new digital transmitter which, at lower analog TPO levels, is just moderately above the cost encountered for a separate digital transmitter. This is especially true when factoring in the installation, space, electrical efficiency and heat loss issues associated with High Level Combining. NPR consistently recommended Low Level Combining at power levels below 3.5-kw TPO in the eight cost tiers reflected in Table II below. At these power levels FCC data for the non-assessed stations typically revealed the Transmitter Power Output levels since the TPO should be calculated with specificity to stay within the licensed class and assigned ERP level.

Table II Low Level Combining Transmitter Costs below 3.5-kw

TPO	TX Costs
10–125-w	$12,000
126–250-w	$14,000
251–375-w	$15,000
376–500-w	$17,000
501–1,000-w	$30,000
1.001–1.5-kw	$48,000
1.501–2.5-kw	$56,000
2.501–3.5-kw	$59,000

VII. High Level Combining with Existing Analog Transmitters

At power levels above these figures the recommendation is for High Level Combining with the existing transmitter whenever the transmitter's rated power is 10% above the station's assigned transmitter power output (TPO). This is the critical information required to determine whether stations above the low power levels shown in the previous section will need a new analog transmitter as well as a digital transmitter to achieve HLC digital transmission for hybrid operation. This information is best derived by corroboration from the Chief Operator at each station with knowledge of the actual TPO, transmission loss, and antenna field gain.

In several instances it was possible to predict whether the 10% transmitter overhead was available. Where a station was licensed to operate at “less than maximum allowed power" the station can be assumed to lack the requisite 10% overhead margin. In these situations it is assumed that both a new higher power analog FM transmitter as well as a separate digital transmitter and high level combiner will need to be purchased[6].

It is interesting to note that FCC operating power tolerances are between 90 – 105% of licensed TPO. It is conceivable that in a number of cases where a costly new analog transmitter would be required that station engineers could “push” the transmitter output level to make up for the combining loss and still stay within the Commission’s output power rules. Such a scenario would be dependent on the characteristics of each individual transmitter and would need to be sanctioned by the FCC, which has not yet reached this question.

[6] Although information on tower space constraints is not sought by the iBiquity EASE assessment survey the information could prove important in later generations of HD Radio scenario planning both for its relevance to the possibility of a dual antenna approach that becomes sanctioned in the future by the FCC as well as the possibility that adding additional antenna bays to achieve higher ERP, thus depressing TPO requirements to achieve the requiste 10% combiner loss capacity for the High Level Combining solution.

In instances where HLC with existing analog transmitter is recommended, the transmitter cost figures are projected in six tiers based on Table III.

Table III Existing HLC Transmitter Power Levels and New Digital Transmitter Costs (referenced to existing analog TPO)

TPO	Digital TX Costs
3.5–5-kw	$37,000
5.1–12.5-kw	$45,000
12.6–16.5-kw	$48,000
16.6–25.5-kw	$70,000
25.5–35-kw	$75,000
>35-kw	$165,000

VIII. High Level Combining—New Analog and Digital Transmitter Costs
Where existing transmitter power output capability was known to be insufficient to support High Level Combining, the projections were built assuming the need for both a new analog transmitter and new digital transmitter. (Again, transmitter power output was determined from the FCC's database or by communication from station personnel.)

Increasingly positive field gain antenna systems are reliably encountered at the higher transmitter power ranges due to the need to reach the authorized 50–100-kw ERP for maximum Class B and Class C facilities, which to some degree mitigates the cost of transmitter purchases and long term power consumption. The actual TPO/ERP ratios shown in Table I reinforce this. Transmitter Costs in Table IV represent the cost for both a new analog and a new digital transmitter.

Table IV High Level Combining, New Analog + Digital Transmitter Cost

Transmitter Power Output	Total New Analog + New DigitalTx Costs
5.0–7.5-kw	$90,000
7.6–10.0-kw	$106,000
10.2–20.0-kw	$137,000
20.1–30.0-kw	$147,000
>30-kw	$153,000

IX. Project Contingencies
A uniform project contingency factor of 20% has been applied to the hard capital costs to cover typical expenses associated with permitting, upgraded electrical power service, enhancements to the cooling systems associated with combiner reject loads, and other variables such as transmitter room space requirements. Such contingencies are prudent for broadcast projects of this magnitude.

X. AM Station Costs—the Need for On-Site Engineering Evaluations
Unlike FM IBOC, AM stations will benefit markedly from the improved audio quality over existing analog service. Despite uncertainties concerning nighttime digital operation,

this factor is likely to drive a number of AM stations to be early adopters of the HD radio format. In making the transition, AM stations will require 20 kHz wide transmitting antenna bandwidth, which can only be properly assessed through on-site antenna impedance sweep measurements by a qualified consulting engineer.

Some AM stations may need extensive work on their antennas, ground systems, transmission lines, phasors and antenna tuning networks to achieve Hermitian symmetry centered on the assigned carrier frequency. Without Hermitian symmetry and an acceptably flat +/- 10-kHz bandwidth, AM HD transmissions are likely to be compromised and may not achieve comparable analog AM coverage. Allowances for the cost of initial tests for bandwidth compliance are included as placeholders and it should be noted that AM stations may have unusually high conversion costs in some instances.

After consultation with iBiquity Digital and noted AM broadcast engineering consultants, it is NPR's recommendation that AM stations in the 13 seed markets should be assessed for bandwidth characteristics as part of the initial rollout where stations indicate the intent to convert. CPB earmarked an initial $1 million set aside to research and test the digital conversion challenges of four AM stations, two with directional arrays and two using diplexing techniques. Evaluations of these four stations should proceed as quickly as possible. AM stations intending to convert to digital transmission should undertake individual antenna system assessments prior to committing to equipment purchases. Early indications are that most stations are capable of passing the required signal with minor adjustments. No one, however, is recommending conversion committments without first making the appropriate antenna bandwidth measurements.

XI. Future Possible Savings With Dual Antenna Installations

At this writing the FCC has not endorsed any method of transmitting the HD radio signal with a dual-FM-antenna configuration. Only common transmission via high-level or low-level combining through the existing analog FM antenna system is currently authorized.

Nonetheless, an ad-hoc working group of interested broadcast engineers was formed shortly after the FCC endorsed the HD Radio system to test the efficacy and desirability of transmitting the HD Radio signals via a separate, closely located antenna.

The theoretical advantage of this approach is that, by dispensing with the need for the analog and digital combiner network, such an approach obviates the need for the 10% combiner loss overhead and drops the digital transmitter power output requirement by nearly 90%. iBiquity has anticipated the possibility of such a breakthrough in HD Radio deployment by reflecting the cost savings anticipated for a possible dual antenna deployment.

For now, it is unknown whether the compatibility of the analog and digital signals would be compromised through separate antennas thereby skewing the desired-to-undesired signal strength ratio within the existing coverage area (on which compatibility with host analog FM is critical). Even if the D/U ratios fall well within acceptable performance characteristics for most receivers, the existing coverage areas could be altered through such an approach absent standardized safeguards reasonably necessary to match the radiation performance patterns of the separate antenna arrays.

At the moment, this is not an FCC-sanctioned approach for HD Radio transmissions. Even if ultimately endorsed, the dual antenna approach will not apply to all stations since tower space, windloading and other requirements will not be universally available. Moreover, no data has been gathered to determine the number stations that might be capable of using this technique. Nonetheless, this is a promising avenue which if successful could reduce public radio system conversion costs by as much as 15 to 25%.

The raw capital cost figures (which do not factor in tower space or windloading obstacles) reflect a projected overall drop in core capital conversion costs to an average of roughly $131,000 (including 20% project contingency) versus the projected $171,000 average for non-dual-antenna FM operation. If available en masse to the public radio station community this could theoretically represent a roughly 20% reduction in total system digital transmission capital costs to just over $139 million.

The final savings of such an approach would require an intensive round of station assessments focusing on tower space, windloading, and related secondary antenna issues. As with the projections made for non-assessed stations, the dual transmitter costs were fairly easy to predict based on known transmitter power levels. They were included in this analysis as previously shown in Tables II and III. The attractiveness of the relatively modest transmitter costs reflected at these power levels is self-evident.

XII. Translator Conversion Costs

FM Translators serve significant populations throughout the United States, particularly in rural, sparsely populated communities. Within the past thirty years over 600 translators have been established helping fulfill the coverage needs for public radio service.

At this writing no digital radio translator products are in production and costs estimates are necessarily "soft." Only one manufacturer has offered an estimate of $40,000 as the likely cost for the typical 10-watt translator capable of passing the HD Radio signal. This is based on the projected $31,000 price of that manufacturer's exciter coupled with a high performance receiver capable of receiving and remodulating the HD Radio signal through the exciter. Thus, the estimated cost to convert all 638[7] public radio translators is $25,520,000. iBiquity Digital has indicated that translators and boosters licensed to Part 73 (full facility AM and FM) broadcast stations will not require payment of the iBiquity license fee.

XIII. Summary of First Generation Public Radio System Digital Transmission Costs

AM Stations	
Core Capital Transmission Costs (incl. 20% contingency)	$8,321,250
Average Total Per Station	$143,478
Number of Stations	58

[7] Source: CPB, A. Bruno, February 2003

FM Stations	
Projected Core Capital Transmission Costs (incl. 20% contingency)[8]	$138,293,000
Average Total Per Station	$171,367
Number of Stations	807

FM Translator Stations	
Projected Translator Costs	$25,520,000
Average Total Per Translator	$40,000
Number of Translators	638

Total Projected Cost	
AM Stations	$8,321,250
FM Stations[8]	$138,293,000
Translators	$25,520,000
Total	$171,134,250

XIV Suggestions for Future Generation Conversion Cost Estimates

Three segments of data warrant further study to improve the accuracy of projected conversion costs:

1. availability of the 10% overhead power factor at higher power stations
2. exact number of FM translators and boosters currently in operation
3. likelihood of tower and related antenna capacity for any subsequently sanctioned dual FM antenna method

[8] Including $3.554,000 allowance for lack of combiner capacity at non-reporting stations