Broadcast Signal Lab

WBRS Spectrum Study – Expansion of 100.1 FM Signal Coverage

Summary Findings

March 14, 2006

Executive Summary

WBRS engaged the services of Broadcast Signal Lab to explore possibilities for improving the coverage of WBRS. Methods considered in the evaluation included the possibilities of increasing power, changing location, changing antenna height, changing frequency, and implementing a directional antenna. The FM band in the greater Boston area is very congested, but expansion of WBRS's broadcast reach is possible through a combination of a new transmitter location on top of the City of Waltham Water Tank (immediately adjacent to the Brandeis campus), a directional antenna, and (possibly) increased power.

Any change will require waivers to be sought from the FCC; however, WBRS has successfully received similar waivers in the past. There will also be political and, possibly, fiscal issues to address in the case of securing permission to broadcast from the owner of any new transmission location, but it is possible these will be minimal and well within WBRS's current budgetary abilities.

Summary of the Existing WBRS Facilities

WBRS is a Class D, non-commercial/educational (NCE) FM station, licensed to Brandeis University. A rules change in 1979 resulted in a frequency change five years later. It was displaced from its original frequency (91.7FM) by a change in the FCC Class D license rules. In 1984 it received waivers from the FCC to occupy a channel that is third-adjacent to stations on 100.7FM (currently WZLX) and 99.5FM (currently WKLB), and settled on its current frequency (100.1FM) as a "grandfathered Class D". Under those terms, it would normally be limited to 10 watts transmitter power output (TPO), and must not cause interference to adjacent stations (on frequencies from 99.5 to 100.7FM) as defined by a set of contour overlap restrictions. As a "secondary broadcast service" it must also accept interference from other adjacent stations, or go off the air if its operation is mutually exclusive with a primary service license.

While the TPO is limited to 10 watts, Class D stations were allowed to use antenna arrays to increase their effective radiated power (ERP) from their antennas, as long as it met the contour overlap restrictions. As such, WBRS was licensed for 25 watts ERP using a five-bay antenna array. At one point, after receiving lightning damage to the array, WBRS sought and received a waiver from the FCC to have a TPO of 25 watts to achieve an ERP of 25 watts, using a two-bay antenna with near-unity gain.

Currently WBRS has moderate coverage of the City of Waltham and reaches most parts of the Brandeis campus fairly well. It also can be received on car radios throughout a good portion of Arlington, Watertown, and parts of Newton and Allston/Brighton. However, coverage west of Route 128 is very spotty and penetration into the thick-walled dorms and campus buildings is problematic.

Broadcast Signal Lab, LLP
503 Main Street / Medfield, MA 02052
(508) 359-8833 voice / (508) 359-8837 fax

Broadcast Signal Lab

Primary Suggestions for Improvements to WBRS's Facilities

WBRS's signal reach is currently affected by four main factors. Any prospective improvement must try and balance solutions to as many of these issues as possible.

1. The relatively low height of the transmitting antenna, which makes it more likely for trees, hills and buildings to cause "signal shadows" for listeners.
2. The presence of a Class A facility broadcasting on 100.1FM from Southbridge, MA (WWFX), which causes significant co-channel interference in the western areas of WBRS's broadcast range.
3. The low 25 watt effective radiated power (ERP), which makes building penetration difficult.
4. The nearby presence of a large, metal structure (water tank) at the same height as the transmitting antennas, potentially causing significant multipath interference anywhere within reach of the signal and the tank's reflection, including on the Brandeis campus.

Keeping these challenges in mind, Broadcast Signal Lab examined potential solutions in four locations. We determined the best site to pursue based on a combination of factors, including:

- Balance of increasing height without sacrificing too much ERP.
- Projected signal coverage to the Brandeis campus.
- Projected signal coverage to the City of Waltham.
- Projected signal coverage towards the downtown Boston & Cambridge areas.
- Possible costs to WBRS adding and maintaining a transmitter facility to that site.
- Political factors affecting adding a transmitter facility to that site.
- Using a directional antenna array vs. an omni-directional antenna array.

The four sites are:

1. **Water Tank:** A new (short) tower on top of the City of Waltham Water Tank, on top of the hill that the Brandeis campus resides on, and 0.15km from the existing WBRS facilities.
2. **Prospect Hill:** Adding a facility to an existing tower on Prospect Hill (42-23-20 N / 71-15-11 W), which is 2.2km north-northeast from WBRS.
3. **WTTT Site:** Adding a facility to the currently-unused FM array on top of the WTTT 1150AM in Lexington; adjacent to Route 2 and 6.3km from WBRS.
4. **Bear Hill:** Adding a facility to an existing tower on Bear Hill, which is 1.34 km northwest of WBRS.

After initial analysis, the Bear Hill site was rejected. While it is closer to the Brandeis campus than Prospect Hill or WTTT, it is also further west. Any movement westward would limit WBRS's final ERP in order to avoid causing interference to the WWFX 100.1FM facility in Southbridge. There is also the factor of tower rent, which would almost certainly be charged to WBRS, although the final dollar amount might be negotiated to a reasonable level.

The WTTT site was also rejected. The presence of an existing AM facility would require expensive methods to be employed to ensure a new FM facility did not affect the AM signal's pattern. In addition, the reach of a WBRS signal at WTTT would be excellent into Boston, but would be poor on the Brandeis campus itself.

Broadcast Signal Lab, LLP
503 Main Street / Medfield, MA 02052
(508) 359-8833 voice / (508) 359-8837 fax

Prospect Hill is the second tallest hill in the greater Boston area (after Great Blue Hill in Milton) and has an existing tower on it. The signal reach from Prospect Hill is a good balance of getting into Boston while maintaining a strong presence in Waltham and on the Brandeis campus. However, Prospect Hill is still 2.6km away from Brandeis, and Brandeis resides on the southern-facing side of a hill, whereas Prospect is north of Brandeis. This means the signal presence on campus is hampered by distance and the obstruction from the hill. Tower rent is a concern, as is whether or not the owner of the tower is willing and able to rent to WBRS. However, given WBRS's non-commercial status we believe tower rent might not be unreasonable.

The Water Tank has several advantages: it's very close to the Brandeis campus, which makes getting audio and transmitter control to the site much easier (and cheaper). It's owned by the City of Waltham, which means getting the rights to construct and maintain a facility on top of it is a *political* issue rather than a financial one. That means if permission is granted, it will likely cost WBRS little or nothing in "tower rent". While the burden of cost for building and maintaining the facility will be WBRS's, the tower or mast mounted on the water tank likely will only be approximately 20ft tall, and therefore relatively inexpensive. Best of all, by its nature it eliminates the current multipath interference from the tank. Plus it remains very close to campus, so the signal reach on campus by definition will only get better.

Note – a taller tower at the existing location on the roof of the Rabb Graduate Center was not examined. Retrofitting the Rabb building to support a taller tower is likely to be prohibitively expensive. Also, it would not solve the problem of multipath interference created by the water tank itself.

Broadcast Signal Lab recommends pursuing the Water Tank for a new WBRS transmitter facility. However, since both Prospect Hill and the Water Tank have certain advantages, we have included analysis for hypothetical WBRS facilities at both. In addition, we have shown facilities using both omni-directional antenna arrays and directional antenna arrays.

Pursing a Waiver for Significantly Increased Power

We have also examined the possibility of WBRS seeking a waiver from the FCC to operate at a higher power than is typically allowed for grandfathered Class D licensees.

Grandfathered Class D stations, like WBRS, are limited to a maximum of 10 watts of transmitter power (TPO); the actual power coming out of the antennas (effective radiated power, or ERP) is limited only by contour overlap restrictions (and the laws of physics in regards to antenna array gain). WBRS is unusual in that it has a waiver to use 25 watts TPO to achieve 25 watts ERP. But the waiver was very logical because it was already operating at 25 watts ERP before. While Class D originally defined 10-watt NCE stations, the Class has since been expanded to include other facilities that have secondary licenses, including translators and boosters whose maximum ERP's can be as high as 250 watts.

We believe it would be in the interest of WBRS to seek a waiver to operate at least at 100 watts ERP, and perhaps as high as 250 watts ERP, on the premise that many translators have been granted constructed permits that, were they Class D NCE's like WBRS, would not be allowed. As such, there is no technical basis for why translators are given more lenient rules that allow higher powers and heights than other secondary services. It is simply a regulatory construct rooted in the history of the various radio services. Such a request would have to be well-researched and documented not only from a technical perspective, but also from a legal one. An attorney experienced with the FCC should be involved in the application process, particularly if new precedents are being sought.

There is a possibility the FCC will reject a power waiver because the ERP is too high. The 100dBu[1] contour of a hypothetical 250-watt WBRS will cover 3.1 square kilometers and 8221 people[2]. Therefore, it may be necessary to amend the application for a lower power level the FCC would find more acceptable.

[1] See more info about the importance of 100dBu contours in the segment on "FCC Waivers"
[2] Based on the 2000 US census.

Coverage Analysis Table

A good way to determine how much a given hypothetical site will improve WBRS's reach, is to see many more people and square kilometers a new site covers vs. the existing site. As such, we have the following analysis table. Two service areas were tabulated for each facility, 60 and 54 dBu. Each service area is analyzed twice; once with the traditional F(50,50) contours areas, and once with the more precise propagation matrix that accounts for specific terrain conditions and propagation losses in a matrix of calculation cells. (Map graphic files are in Appendix A)

Area is presented in km^2 and population is in the number of residents (according to the 2000 US Census). HAAT (Height Above Average Terrain) is in meters. Directional antenna arrays are denoted as "dir", omni or non-directional arrays are denoted as "ND". Power levels at each location are maximized under the rules and to protect adjacent stations.

For assistance in comparisons, we have included the percentage change of population count covered by the proposed 54dBu service.

Site	ERP	HAAT	60dBu service				54 dBu service				
			F(50,50)		*Matrix*		*F(50,50)*		*Matrix*		
			Area	*Pops*	*Area*	*Pops*	*Area*	*Pops*	*Area*	*Pops*	*Pop%*
Existing	**25 W ND**	**49.88 M**	**79.7**	**120,784**	**48.2**	**76,869**	**158.1**	**223,890**	**102.9**	**142,846**	**0%**
Water Tank	25 W ND	75.68 M	122.2	163,412	61.3	86,644	244	338,454	142.8	187,562	31%
Water Tank	100 W dir	75.68 M	225.9	332,759	128.3	184,372	449	799,309	282.8	378,092	164%
Water Tank	250 W dir	75.68 M	343	615,778	204.4	279,022	683.9	1,274,782	448.5	603,870	322%
Prospect Hill	4 W ND	166.84 M	110.7	134,312	29.6	41,489	225.7	272,357	80.3	96,449	-32%
Prospect Hill	25 W dir	166.84 M	255.1	355,101	94.9	130,166	500.8	825,147	254.5	352,050	146%
Prospect Hill	250 W dir	114.84 M	504.6	921,804	298.2	446,090	1044.8	1,699,739	655.8	853,347	497%

Coverage Analysis Review

The cost of a directional antenna array could be two to three times higher than that of an omni-directional array. However, as the table indicates, an omni-directional array will "cost" WBRS significantly in broadcast reach; only a minimal increase will be realized and the lower wattage will mean greater problems with building penetration (especially in thick-walled dorms). As such, we recommend pursuing only directional solutions.

Here is where the benefits of the Prospect Hill site become more noticeable; the old axiom of "height is king[3]" with FM broadcasting is noticeable as the Prospect Hill tower has the advantage of nearly 90 meters of extra height. (for political and structural reasons, the Water Tank cannot be expected to support more than a 20ft tower on the top) As such, there will be more people and land area covered from Prospect Hill.

However, looking at the actual predicted coverage matrices of the on- or near-campus sites versus the Prospect Hill site, Prospect Hill would offer substantially weaker coverage over the Brandeis

[3] The frequencies of FM are substantially "line of sight" so the higher the antenna is, the less terrain is in the way of the listeners' radio reception.

campus itself. That's because of the hill Brandeis resides on is "in the way". 250 Watts transmitted from Prospect Hill might offset some of the signal losses to the campus resulting from the distance and terrain blockage. The coverage plots support this hypothesis (see coverage plots in Appendix B). The Prospect Hill site has a fair amount of woods and parkland around it, making the 250-watt level more tenable to the third adjacent stations and the FCC because the population encompassed by the 100dBu interference contour is significantly lower[4] than with 250 watts on campus. Still, given the campus-centric focus of WBRS programming and events, we would suggest the Water Tank is a better site to pursue.

Overall, the benefits of any move become noticeable through the population count served, especially the 54dBu service. Even a simple increase to the top of the Water Tank brings more than 30% improvement, and pursuing the 250 watt idea could yield more than triple the current potential listenership, with substantial reach towards Boston and Cambridge.

Conclusion

Any application for improved facilities for WBRS would require the FCC to make an exception. Requesting exceptions that are more commonly granted is most likely to succeed. However, it may help WBRS and small NCE broadcasters nationwide to seek an exception that is new, but is supported by good technical and legal arguments. To select the best strategy (or strategies) the technical and legal options should be discussed among the station, Broadcast Signal Lab and a qualified attorney.

The viability of any of the new sites, must be considered before they can be placed on the options list. The following sequence is suggested moving forward:

1. WBRS identifies most-preferred solutions; rule out obvious non-starters.
2. A cost estimate of the most preferred solutions is assembled by Broadcast Signal Lab. First-pass rough estimates are drafted to establish an order of magnitude for costs…including estimated lease expenses, FCC application work, equipment costs, and construction costs.
3. Options that are deemed too costly are removed from the list.
4. Input from attorney is sought on the viability of the open options.
    a. Attorney, or attorneys, need to be versed in both town government permit applications, tower siting legal issues, and FCC regulations and case law.
5. A primary option is selected, with fallback plan(s) as agreed upon. An application is prepared by Broadcast Signal Lab and the attorney (or attorneys).
6. The application(s) is submitted to the appropriate governmental and legal authorities, and pursued by the team until decisions are rendered.
7. If the FCC grants the application it will issue a Construction Permit (CP). WBRS will have 36 months to complete the facility and file for a License to Cover (LTC).
    a. Immediately after any CP is granted, the team will pursue the appropriate actions that may be required.
8. If the facility is constructed according to the CP, the FCC will issue the LTC and WBRS will officially be on the air from the new facility.

[4] See more info about the importance of 100dBu contours in the segment on "FCC Waivers"

FCC Waivers

WBRS's existing facility required a waiver from the FCC in regards to two third-adjacent (600 kHz away on the dial) stations: WZLX on 100.7FM and WKLB 99.5FM. Sec.73.509(b) of the CFR states that:

b) An application by a Class D (secondary) station, other than an application to change class, will not be accepted if the proposed operation would involve overlap of signal strength contours with any other station as set forth below:

Frequency separation	Contour of proposed station	Contour of any other station
Co-channel.....	0.1 mV/m (40 dBu).....	1 mV/m (60 dBu)
200 kHz.....	0.5 mV/m (54 dBu).....	1 mV/m (60 dBu)
400 kHz.....	10 mV/m (80 dBu).....	1 mV/m (60 dBu)
600 kHz.....	100 mV/m (100 dBu)....	1 mV/m (60 dBu)

As such, any change of WBRS's facility will require a similar waiver from the FCC as WBRS's 100dBu contour is entirely within both stations' 60dBu contours, and likely will need approval (whether explicit or tacit) from WZLX and WKLB again as well.

The original argument was that WBRS's 100dBu contour was fairly small, and was primarily located over the Brandeis campus. Any argument for a new waiver will be based on the same principle. Among most of the new facility concepts, the Water Tank remains the best choice overall. However, with the 100 or 250 watt concept, the interference population for the Water Tank nearly doubles, although it's still below 10000 people (considering WZLX and WKLB serve areas with millions of people living in them, it's still a small number). However, Prospect Hill does have the advantage of affecting even fewer people than the existing facility…making it in WZLX & WKLB's best interests to support a waiver.

The following matrix shows the area (in square kilometers) and population affected[5] by the 100dBu contours of each proposed site. The FCC contours used are the F(50,10) interfering contours to meet with the requirements of 73.509 mentioned above.

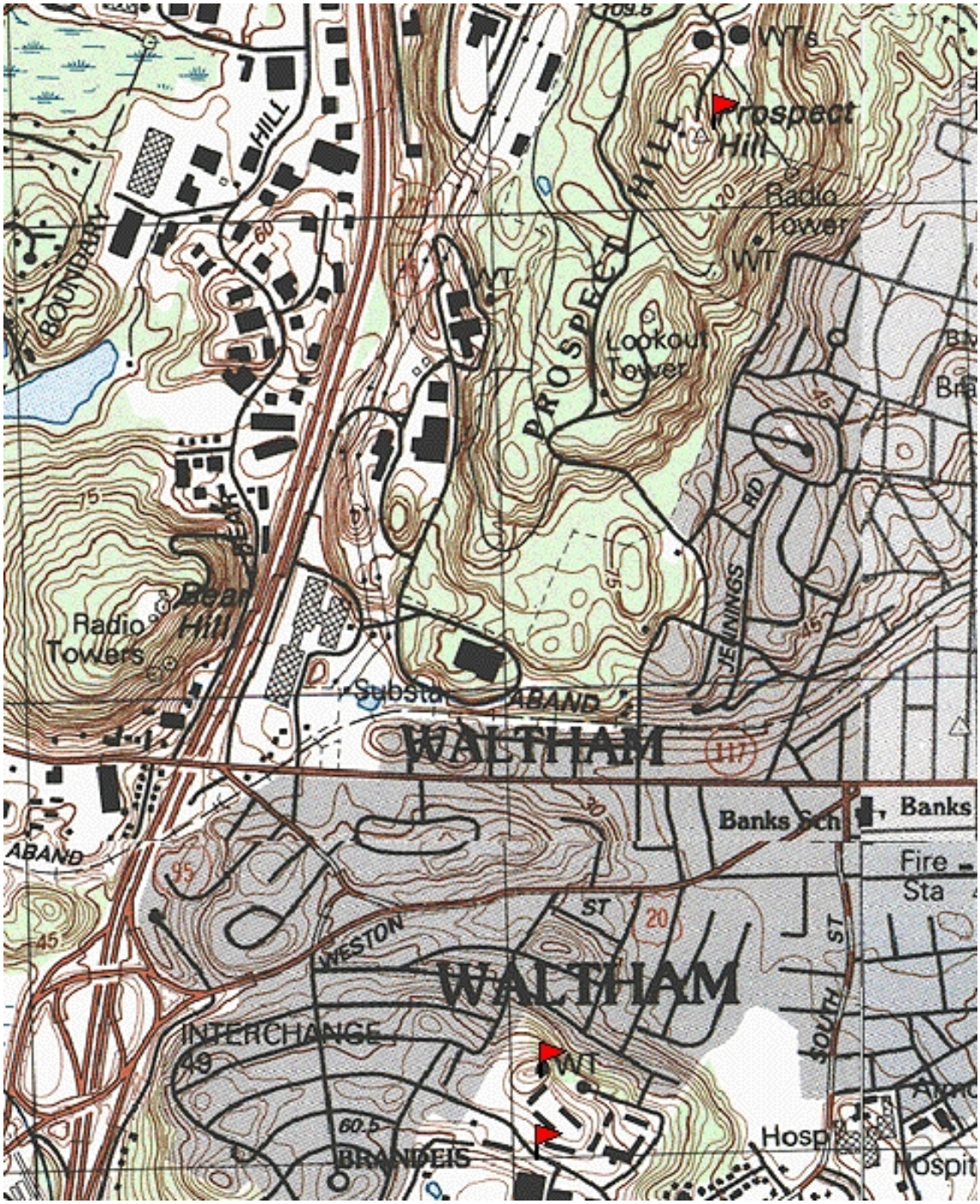
Site	ERP	HAAT	100 dBu interfere		100 dBu interfere	
			F(50,10)		*Matrix*	
			Area	*Pops*	*Area*	*Pops*
Existing	**25 W ND**	**49.88 M**	**1.1**	**4,114**	**0.1**	**46**
Water Tank	25 W ND	75.68 M	1.1	4,632	0.1	47
Water Tank	100 W dir	75.68 M	2.1	6,361	0.1	47
Water Tank	250 W dir	75.68 M	3.2	8,278	0.2	136
Prospect Hill	4 W ND	166.84 M	0.2	393	0.1	393
Prospect Hill	25 W dir	166.84 M	0.9	489	0.1	393
Prospect Hill	250 W dir	114.84 M	3.1	3,474	0.2	393

[5] According to the 2000 US Census.

Broadcast Signal Lab

Topographical Maps

Red flags mark the location of the existing WBRS site and the proposed sites at the Water Tank (WT) and on Prospect Hill. Note that the Topo map indicates a radio tower but either the Topo map is inaccurate or it indicates a different tower as the latitude/longitude the FCC has on file for the Prospect Hill tower places it where the flag is.



Broadcast Signal Lab, LLP
503 Main Street / Medfield, MA 02052
(508) 359-8833 voice / (508) 359-8837 fax