Acentech

Sound System Evaluation

First Congregational Church

Bristol, RI

Prepared for Heritage Restoration

December 23, 2011

Acentech Project No. 621684

Existing Conditions

The Sanctuary Room is a worship space comprising approximately 5,000 square feet. The sound system is used primarily for speech reinforcement and consists of a number of microphone input receptacles (most located near or on the Pulpit), a pair of dedicated recording microphones (one mounted on the railing of each balcony), a 12-channel mixing console (used primarily for sub-mixing audio signals for recordings), a wall-mounted mixer/amplifier module located in the space between the Sanctuary and Lobby 105, and column loudspeakers mounted on either side of the pulpit.

The existing sound system is approximately 18 years old, and representatives of the Congregation have expressed an interest in upgrading/replacing it. Some of the problems with the existing system that were described to us and observed by us include:

- Cabling for the microphone connections is exposed, and, in many cases, is run along the corners between floors and walls instead of within walls.
- A loud buzzing and humming sound is amplified through the existing sound system's loudspeakers.
- The sound system's loudspeakers did not provide direct coverage to seating areas in the balconies.
- A significant deviation in the sound pressure levels at our measurement locations showing that sound coverage from the loudspeakers was not uniform throughout the space.

Additionally, the Congregation is interested in including audiovisual systems in the DeWolf Room and Diamond Room. The audiovisual systems in these spaces would serve as standalone systems, as well as overflow systems for the Sanctuary that allow video and audio signals originating from the Sanctuary to be displayed/played back in these spaces. The existing sound system is not capable of providing this overflow feature.

Measurements and Observations

Acentech visited the First Congregational Church on December 13, 2011. While on site, we performed a series of tests in order to inspect the performance and quality of the existing Sanctuary sound system. Figures 1A and 1B indicate the measurement locations (indicated by "M00##"). We have also shown the locations of the major sound system components.

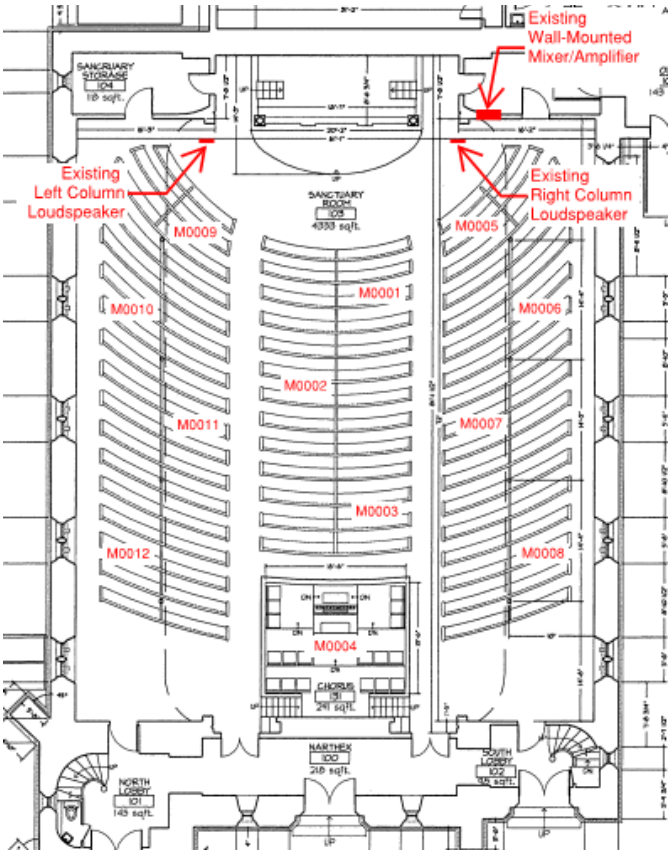

Figure 1A, Floor Measurement Locations

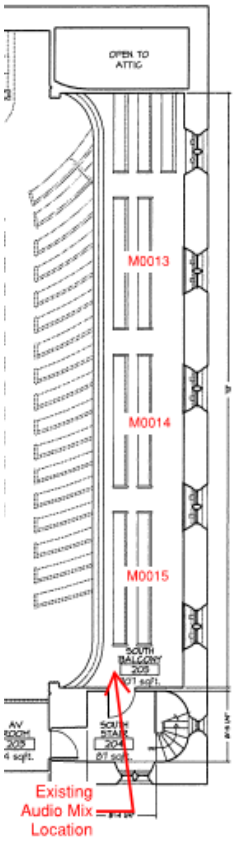

Figure 1B, Balcony Measurement Locations

Frequency Response

The frequency response of the Sanctuary Room's existing sound reinforcement system was measured at each of the locations indicated in figures 1A and 1B. The values were measured and then averaged together. The results have been compiled and are shown in Figure 2.

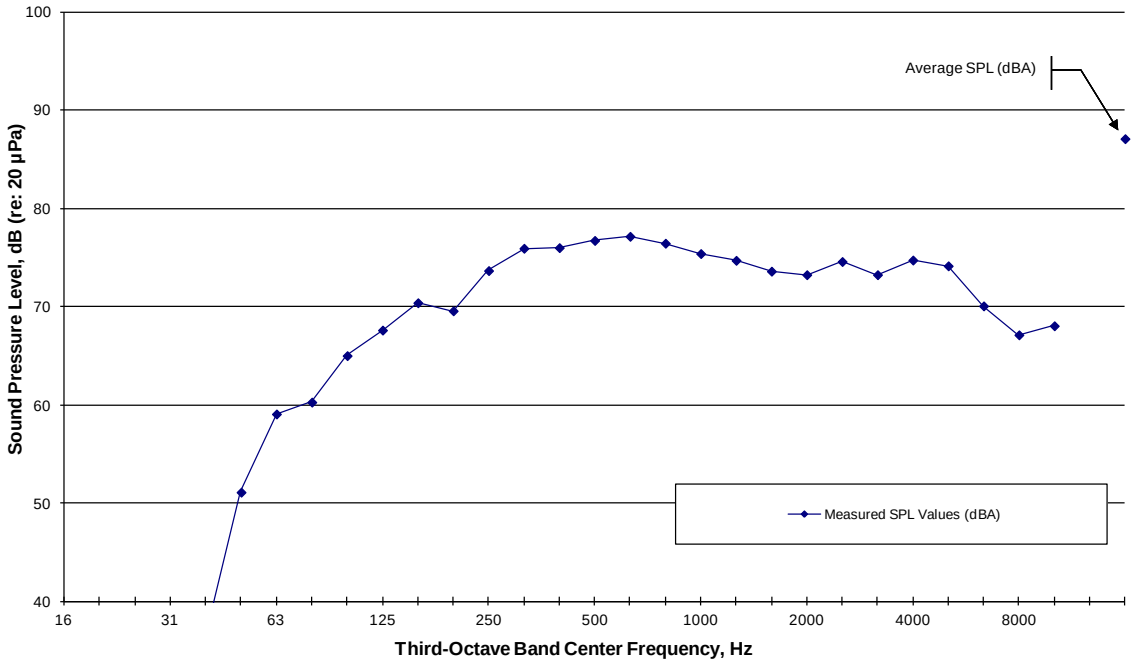

Figure 2 – Frequency Response of Existing Sanctuary Sound System

Before further discussion of the measurements can take place, it is important to discuss how the frequency response of a sound reinforcement system will affect the two most common uses for sound systems: speech reinforcement and music playback.

Figure 3 shows the frequency range of human hearing (between 20 Hz and 20,000 Hz). It also displays the overall range of frequencies that are the most important for a listener to be able to understand spoken word. This is labeled the Critical Speech Intelligibility Range.

Additionally, this critical range is further broken down into three categories; Speech Fundamentals, Vowel Recognition, and Consonant Recognition.

In regard to the contribution or importance for understanding speech that each category makes, the speech fundamentals range represents 16%, the vowels range represents 25%, and the consonants range represents 34%. The remaining 25% of energy is slightly above and below the critical range.

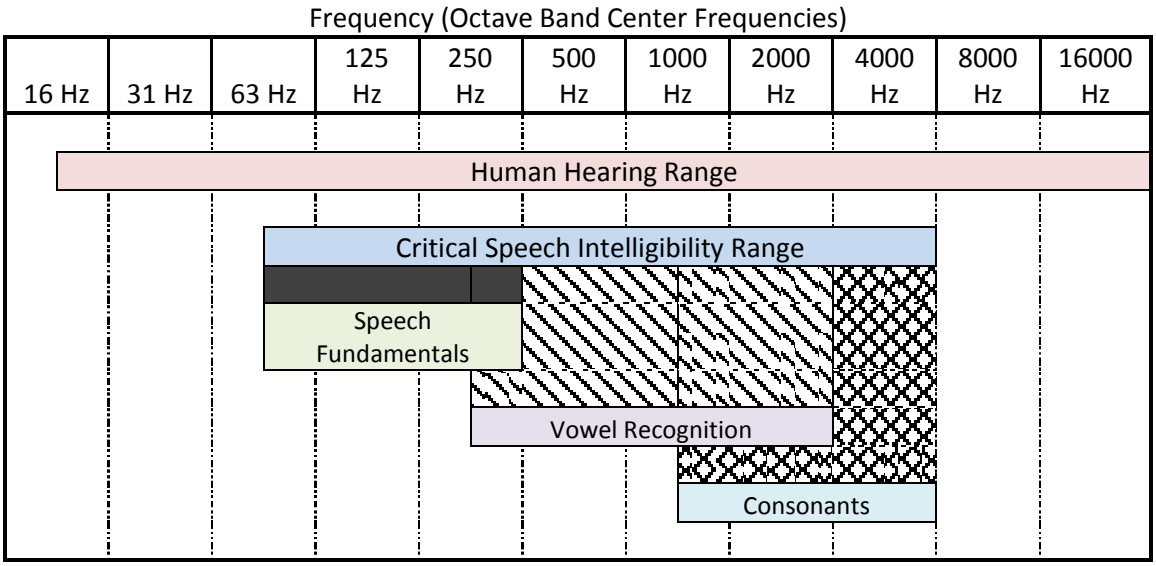

Figure 3 – Frequency Range of Human Hearing and Critical Speech Frequencies

In order for a sound system to achieve a substantial level of speech intelligibility at the listener's ear, it is important that the sound system be capable of reinforcing these critical frequencies at each of the listener locations; especially in the Consonants range.

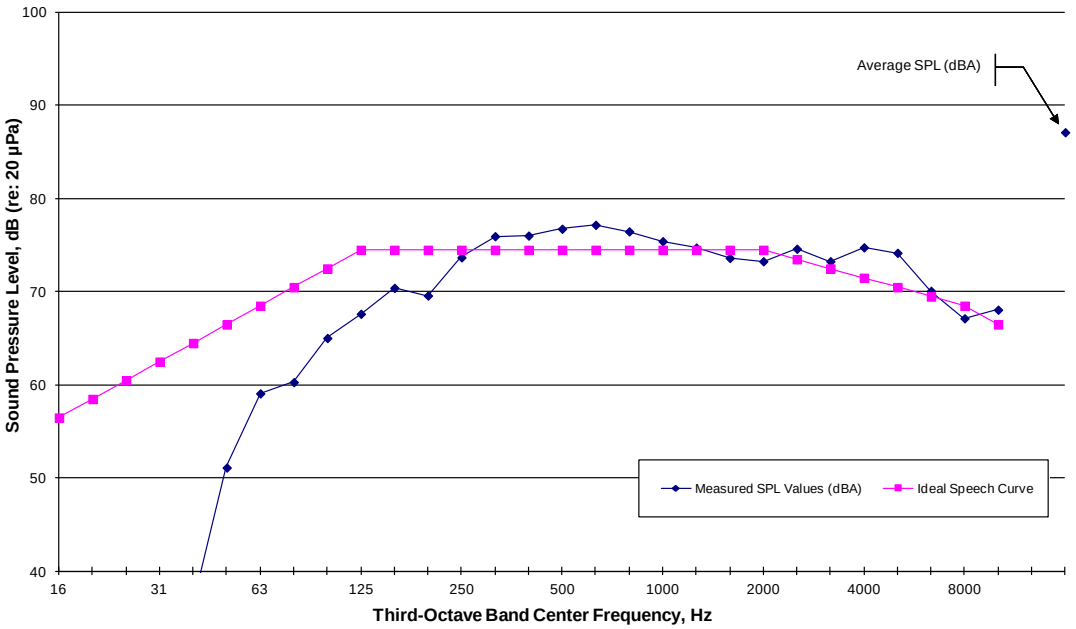

Figure 4 – Frequency Response of Existing Sanctuary Sound System vs. Ideal Speech Curve

Figure 4 compares the existing sound system measurements with a frequency response curve that is typically used as ideal for speech reproduction. This curve takes into account the frequencies most critical for achieving speech intelligibility, and also the sensitivity of the human ear at different frequencies. The average measured frequency response is not far off from ideal for speech reinforcement purposes at mid and high frequencies.

As can also be seen in figures 2 and 4, the sound system's frequency response begins to roll off in the lower (bass) frequencies at approximately 250 Hz, and in the higher (treble) frequencies around 6 kHz. For music playback and reinforcement, it would be desirable to have a better low and high frequency response.

We primarily attribute the low and high frequency losses in the system to the type of loudspeakers being used. Improvements could be made to the sound system that would extend the frequency response, and therefore provide better low and high frequency support. By replacing the existing loudspeakers with higher performance loudspeakers, and including any necessary "support" loudspeakers (in order to provide additional coverage to areas that are not in direct view of the primary loudspeakers), the sound system could have a more "musical" quality, and still maintain an excellent response for speech reinforcement.

Speech Intelligibility

Speech intelligibility defines the quality of audio at a listener position, and describes how well a listener will be able to understand speech (typically through a sound reinforcement system) at a particular location. The metric that we use to quantify the level of speech intelligibility is known as the Speech Transmission Index (STI). STI provides a numeric value between 0 (no intelligibility) and 1 (perfect intelligibility). As shown in Figure 5, subjective descriptions of speech intelligibility are also provided for given value ranges.

Figure 5 – Speech Transmission Index (STI) Scale

Figure 6 shows the results of the STI measurements that were taken in the facility using the existing sound system and existing acoustical conditions in an empty space. The plan diagrams at the beginning of this report (Figures 1A and 1B) show the loudspeaker locations and measurement locations used in this evaluation.

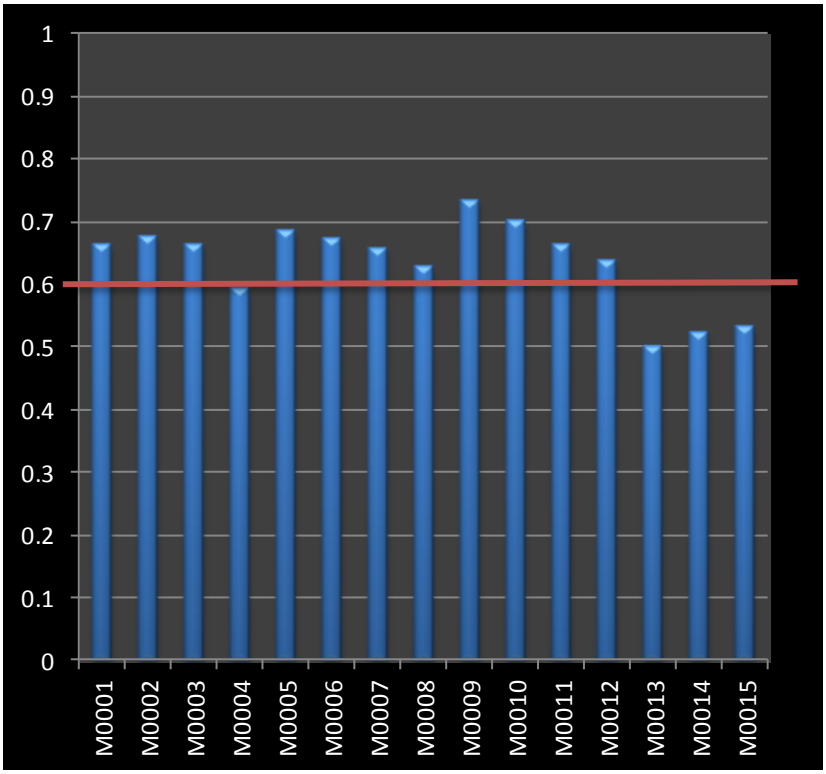

Figure 6 – Intelligibility Values (STI) Existing Sanctuary Sound System at each Measurement Location

According to the International Standards Organization, the minimum acceptable STI value is 0.50. The measurements in Figure 6 show that the Sanctuary meets this minimum value in each of the measured locations. As demonstrated by the horizontal line in Figure 6, the average score in the Sanctuary space is approximately 0.60 (a value that can be subjectively described between "Fair" and "Good", as indicated by Figure 5).

As expected, the highest intelligibility scores were measured at the measurement locations in closest proximity to the loudspeakers. Similarly, the lowest intelligibility scores occurred at the positions furthest away from the loudspeakers, and in the balcony.

Uniformity of Coverage

Another design criterion that we review is known as Uniformity of Coverage (ANSI-Infocomm 1M 2009 Audio Coverage Uniformity in Enclosed Listener Areas Performance Standard). One of the fundamental goals of sound system performance for both speech reinforcement and audio playback is the delivery of uniform audio coverage in the listening areas. A well executed audio system design is one that allows all listeners to hear the system at approximately the same sound pressure level throughout the desired frequency spectrum range, no matter where positioned in the designated listening area. This standard provides a characterization of and a procedure to measure this spatial coverage, with criteria for use in the design and commissioning of audio systems.

In short, the standard states that the audio level should not deviate more than 3 decibels (dB) in six octave band measurements throughout the space. Figure 7 shows the results of the testing on the existing sound system.

	Octave Bands											
	250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz		8000 Hz	
Median Level	85	+/-	84	+/-	80	+/-	75	+/-	77	+/-	67	+/-
Location												
M0001	86	1	86	2	82	1	78	3	78	1	67	0
M0002	86	1	85	1	82	1	78	3	80	3	69	2
M0003	84	-1	84	0	81	1	76	1	78	1	68	1
M0004	83	-2	85	1	78	-2	72	-3	71	-6	61	-5
M0005	85	1	87	3	82	2	78	2	77	0	71	4
M0006	83	-1	84	0	81	0	76	1	77	0	68	1
M0007	85	1	83	0	80	0	75	0	77	0	67	0
M0008	81	-4	81	-3	78	-2	74	-1	74	-3	63	-4
M0009	87	3	86	2	82	2	80	5	80	3	70	4
M0010	83	-2	84	0	81	1	77	2	80	3	71	4
M0011	85	1	83	0	80	0	75	-1	76	0	68	1
M0012	82	-3	82	-2	80	0	74	-1	73	-3	63	-3
M0013	86	1	83	0	78	-3	70	-5	71	-6	63	-4
M0014	85	0	83	-1	78	-3	70	-5	71	-6	64	-3
M0015	83	-2	81	-2	77	-3	70	-5	69	-7	61	-6

Figure 7 – Audio Coverage Uniformity – Existing Conditions

The areas in red show the locations and corresponding octave band frequencies where the standard is not met. We attribute these failures primarily to the size, quantity, location, and type of loudspeakers being used. The two loudspeakers in this space do not provide even sound coverage to all listener areas.

Other Concerns

As noted in the beginning of this report, the sound system contains hum and buzz which is being amplified through the loudspeakers. Typically, the primarily reason for this is that the sound system is exposed to multiple AC power grounds. Also, audio cabling may be in close proximity to "noisy" electrical lines. Shielded audio cables and dedicated electrical conduit can help to reduce the sound system's exposure to this electro-magnetic interference.

We believe that an AC power system, dedicated specifically to audio and video system equipment, with an isolated ground, will significantly reduce the potential for interference that creates the audible buzz. Additionally, conduit lines and new cabling will also further reduce the chance of noise entering the system.

Audiovisual System Improvements

We will discuss our general recommendations for audio and video system improvements, define audiovisual technologies for different spaces, and present a budget estimate in our forthcoming Audiovisual Program Report. This report will focus on the Sanctuary, DeWolf, and Diamond rooms.