How Did They Do That?

by Stanley B. Adams

How WBZ Pioneered Synchronized Timing

Using time code from WWV, GPS, or other sources, stations commonly synchronize many aspects of operation, from local clocks to network joins to synchronous booster transmitters. Nearly a century ago, the idea of such precision was daunting. And yet, as Stan Adams explains, a few radio stations stretched the technology of the day to breaking point, in the pursuit of better serving their listeners.

In the Analog Age audio was, for the most part, audio. Whether direct from a microphone to the transmitter, or subject to delays of up to 500 ms in program equalizers (or several seconds over transcontinental phone lines), the time alignment of audio was generally taken for granted, aside from one particular application that we will discuss.

Today, as we aggressively pursue the digital world of transmission, there is a lot to know about precision timing. Everything from digital consoles to digital STL's and transmitter exciters needs a precision timing source so that every frame is in perfect alignment.

LOCKING TO THE CLOCK

Even before the full advent of digital broadcasting, telephone switches were required to be locked to clock sources traceable back to Stratum 1 levels. T1's that carry programming and overhead signals over telco systems have cards that must be set to either loop timing to the reference of the telephone switch or they must be set to run on your timing.

We did this by using Loran-C signals which provided a perfect time and offset from slave and master stations. By using sophisticated logic, the receiver was able to auto-tune itself so as to lock up a 10 MHz oscillator, for example. Then this standard would become the standard to a secondary oscillator attached to the switch – providing perfect timing for all 1.544 MB T1s.

I was responsible for installing, aligning, and maintaining this equipment for MCI Telecommunications as early as 1983. The other telephone companies did the very thing, now they use a newer revision of Austron Company equipment where GPS has also been added to the existing Loran-C and Disciplined Frequency Standard (DFS) backup. We could easily maintain short term accuracy to one part in 10^{13}th – better than your frequency counter could resolve. In fact, we were furnished with specially made HP Counters that would count into the sub-digit category.

DIFFERENT TIME, DIFFERENT TOOLS

Now, let us roll the clock back to the early 1920's, when Westinghouse built WBZ at the factory in Springfield, MA. Soon after, they found that WBZ's 250 Watts was not able to cover the entire city of Boston. Power increases were tried, but did not completely do the job. Thus began work on a secondary transmitter to solve the problem. One roadblock: how to prevent the two transmitters from interfering with each other.

Today we have digital tools that eliminate many problems. To take care of signal coverage issues, synchronous transmitters (usually known as boosters) are not uncommon.

On the other hand, when WBZ began, back in those early days of broadcasting, it was a whole different story.

A whole series of issues had to be overcome. Not only was Westinghouse proposing to operate WBZA on the same frequency as WBZ, but other physical realities had to be taken into consideration. If the stations were close in frequency, but not synchronized, they would "beat" against each other and produce annoying tones from the beat frequencies.

Then, it was found that the Brunswick Hotel location of the WBZA transmitter would prove unsatisfactory.

TRIAL AND ERROR

The engineers discovered an effect opposite of that from which WBAY in New York City suffered. In NYC, the building steel was close enough in wavelength to actually shunt a tremendous amount of power to ground with WBAY, but with WBZA the hotel was of a frame construction and did not allow an adequate ground facility.

WBZA was later moved to the Statler Hotel in 1927, but not until after some experimentation already had been tried, helping to pave the way for several companies to "loop" time their stations in different cities. A great deal of the information about this is included in a paper published in the mid-1930's by Mr. S.D. Gregory, a Radio Engineer attached to the Westinghouse Electric Radio Operations Department in Washington, DC.

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We can break the experiment into about four time periods, the first being the original trial when WBZA was at the Brunswick Hotel, and then at the Statler Hotel, where different methods of generating the broadcast carrier frequency and the synchronization methods were developed and fine-tuned.

EARLY CRYSTALS

At WBZA a 50 kHz signal was derived from a piezo crystal. The output of the oscillator produced three harmonics: 150, 450 and 900 kHz.

The frequency stability in those days was poor at best. But the Westinghouse engineers still attempted to compensate. A 250-Watt tube supplied 125 Watts of 50 kHz down a phone line toward WBZA. When the weather was good the experimental lash-up would "sort of work," but when there was moisture, leakage helped to drop the synchronization signal to zero at the Boston end.

The frequency was lowered to 25 kHz with a harmonic multiplier added at both stations. No crystals could be obtained at this time for such a low frequency so they used a free-running master oscillator with a UX-210 tube. In 1926, the two stations were able to commence their first continuous, synchronous operation.

A DIFFERENT LOCATION

As we noted, the transmitter was moved to the Statler building in 1927 because of the large number of grounding issues. A new transmitter was added and the synchronizing system installed improved filers to keep radio RF and audio from having more than minimal effects on the timing loop.

The antenna systems also were updated at that time. With an increase in power to 500 Watts, and with a higher depth of modulation, the Boston area was provided with a much better solution. Interference from each station was minimized in fringe areas – although not totally eliminated.

This situation lasted for almost two years until late 1928, when the new Federal Radio Commission's allocation plan for the broadcast spectrum went into effect. Both Westinghouse stations were moved from 900 to 990 kHz.

ANOTHER APPROACH

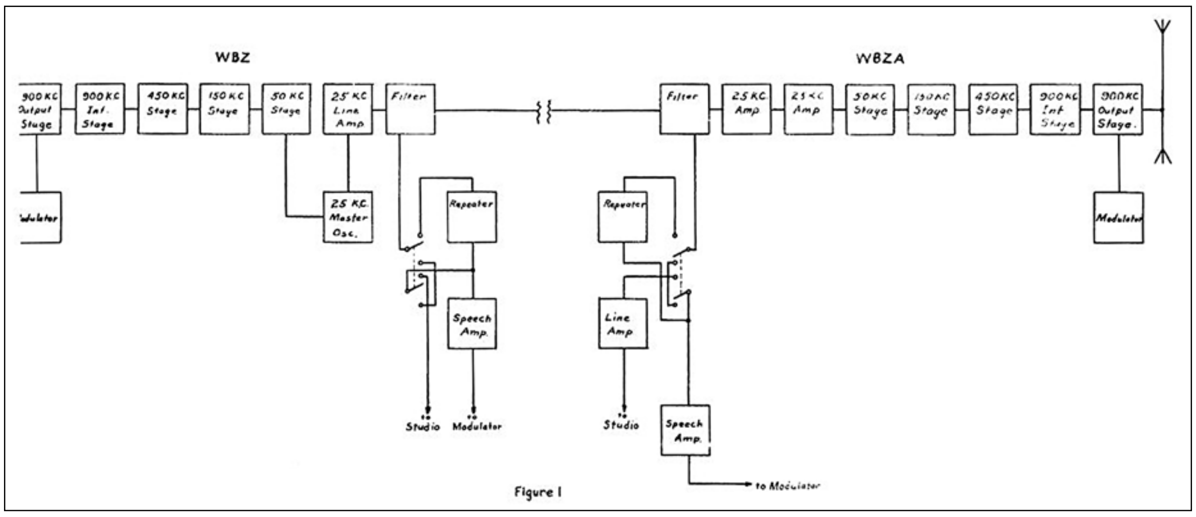
As 1929 came to a close, improved frequency multiplication equipment was installed at the stations, using lower power tubes of a better quality and in a better circuit. The oscillator acted as a wideband multivibrator with a crystal filter on the output, tuned to 990 kHz. Additional sharply-tuned circuits prevented any other frequency from getting into the power stages.

The WBZ transmitter used a 990 kHz crystal that would be common today, and then further divided this frequency to 165 kHz. A second multivibrator further divided it to 27.5 kHz. This signal was fed down the synchronizing line by using a power amplifier of four 845 tubes.

OBSTACLES TO OVERCOME

For a moment, consider some of the problems that they were facing: This was the first time that frequencies above the limit of hearing were actually sent down phone lines. Secondly, at the beginning there was little if any equalization and the concept of differential phase – where the sine wave would no longer be a sine wave and thus introduce very unwanted effects at the received end – was not well understood, if at all.

Phase hits, jitter and signal drop-outs all affected operation; nevertheless, this was just the way that Westinghouse decided to use as they sought a way to cover all of the major sections of Boston. They were willing to try



A schematic of the original WBZ-WBZA synchronizing circuit.

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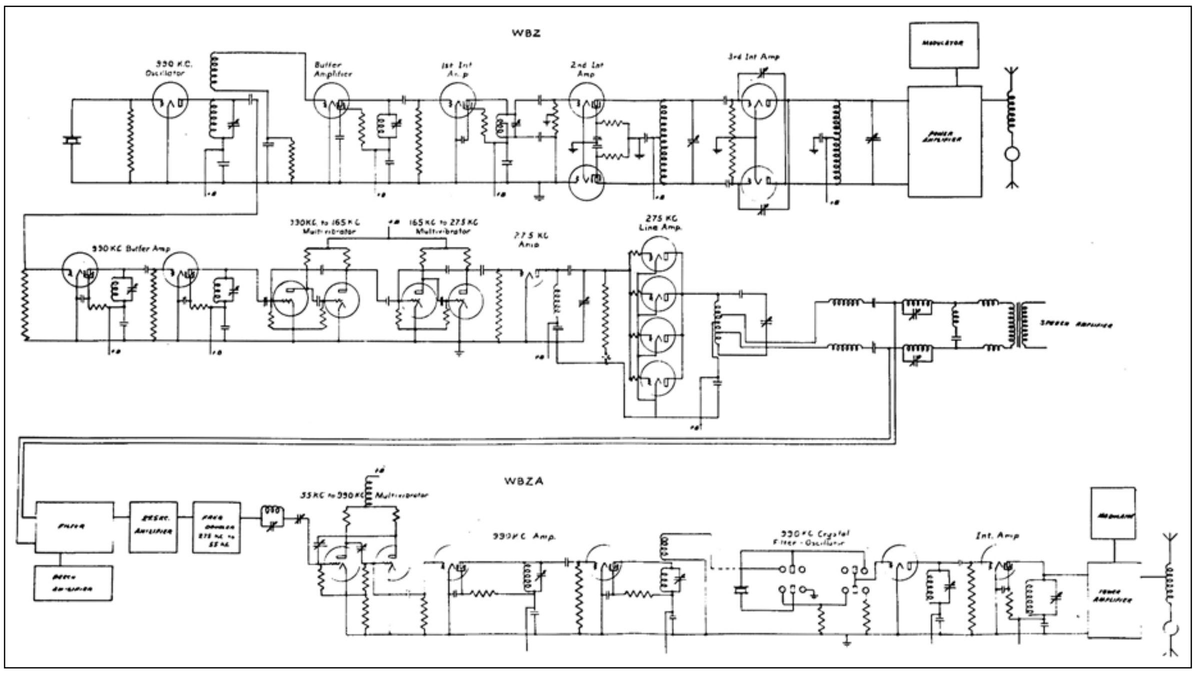
on the customer, as it were, their "tinkering." It would not be the last time this philosophy would be used (some might point to IBOC today as an example).

including KDKA, Pittsburg and KYW, Chicago. A master tuning fork was operated at 5,000 cycles and by passing through a system of harmonic amplifiers be-



The schematic for the new WBZ-WBZA synchronous circuit.

Similar experimentation was going on at other sites with the goal of devising a permanent solution of frequency control for other Westinghouse stations, came the control frequency of the KDKA shortwave transmission system to Chicago and also to KFKB in Hastings.

PRETTY SOLID

Westinghouse Radio Director, Dr. Frank Conrad, was not yet satisfied with the solution for WBZ and WBZA. During these trials it had become clear that it was important for the timing loops at all receive ends to be made able to stand on their own during the fade periods of the feeding transmitter. Hence, the principle of a loosely "locked" master oscillator came into being.

Successive upgrades of equipment during this time led to a poor division of RF power and thusly poor population coverage over the population centers of Boston, Providence and Worchester. It was at this time that WBZ was moved to Millis, MA (Southwest of Boston) whle WBZA was moved out to East Springfield. All calculations and power tests from an experimental test transmitter proved that this would be an ideal site. WBZ then installed an RCA Model 50B.

The developmental progress was documented in the Institute of Radio Engineers *Proceedings* for October of 1930 by Kaar and Burnside. Duplicate crystal control units were placed within the transmitter and a new type of frequency multiplier was used.

In essence, the transmitter crystals served as the back-up if the synchronizing tone from East Springfield were to fail. This system worked well enough that WBZ used it until they discontinued operations of WBZA in 1962.

As Mr. Gregory put it: "In achieving success in the automatic synchronization of the Westinghouse stations WBZ and WBZA our engineers were forced to depart from prevailing practices in many instances and to carry on developments along new lines."

The full text and associated schematics of the Gregory's Westinghouse document are posted at www.radio-guide.com/technical.htm

I am especially indebted to Mr. Roy Humphrey of KDKA Radio, Pittsburgh.

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