RADIO PROGRESS

"ALWAYS ABREAST OF THE TIMES"

Vol. 2, No. 18 | DECEMBER 1, 1925 | 15c PER COPY, $3.00 PER YEAR

Throwing a Crystal Into Fifth Speed

Why You Get Fewer Squeals Now Than You Used To

By HORACE V. S. TAYLOR

SOMETIMES you like to hear a whistle. If it is the 5:15 train coming down the track to take you home, it is a welcome sound, but if it is a continuous whistle coming in through your loud speaker, it is not quite so pleasant.

The Bureau of Standards, after a long experience, has found that if two stations have waves which are closer together than ten kilocycles (kc) they will cause a reaction, one on the other, which is heard as a high pitched whistle. This spacing of ten kilocycles is constant all over the broadcast range, but the wave length separation which corresponds to it varies from two meters up to ten meters. Indeed, that is one of the advantages of using the kilocycle rating rather than the old way of naming the wave by its length.

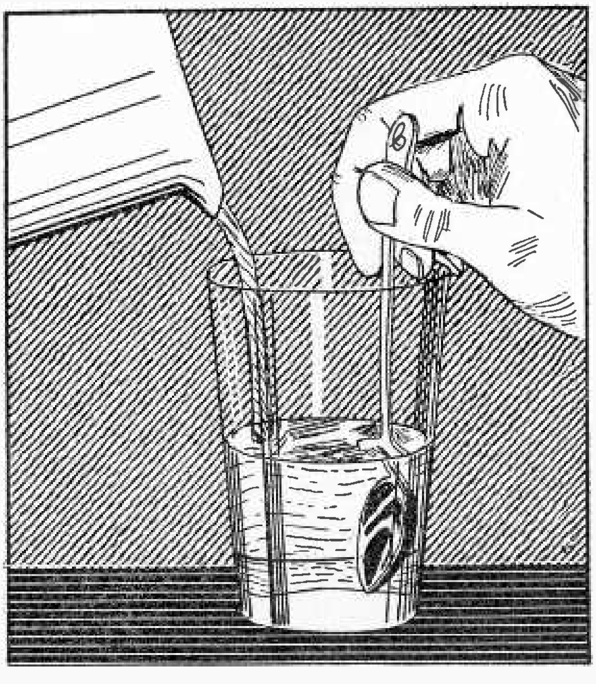

Fig. 1. Tea Glass Shows Principle of Cutting Down a Crystal to Adjust for Speed

Must Have a Yard Stick

In order to hold the waves spaced by this distance, of course it is necessary to have some sort of a standard to go by. Suppose you were told to put in fence posts just 30 feet apart, how would you be able to locate them unless you had some sort of yardstick or tape to measure the distance? When checking up on the frequency of a station, by far the most accurate way has been found to get a vibration which is correct and then adjust the sending aerial and condenser until it radiates the same waves.

That seems reasonable enough, provided we can find something which will vibrate at the right speed. But remember that the broadcast range varies from 550 kc. to above 1400 kc. Expressed in ordinary language, this is from 550,000 up to 1,400,000 complete oscillations every second. You must admit that that is going some. The ordinary tuning fork sounding middle C on a piano, oscillates only 256 times every second. This must seem like a snail to a man in an airplane by comparison.

Changing Speed When It Rains

How can you get anything to vibrate at this tremendous speed of around 1,000,000 per second? So far there has been only one practical way discovered

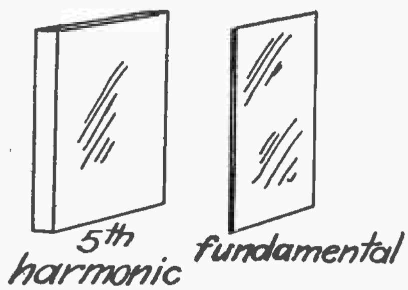

Fig. 2. See How Much Thicker the Sheet of Quartz is for Harmonic

and that is to use a crystal of pure quartz. Only recently the research engineers have discovered how to melt quartz by an electric vacuum furnace in such a way that pure crystals much clearer than glass can be obtained. It has been discovered that such a crystal possesses the remarkable property of shaking at these immensely high speeds, and furthermore, that the speed of vibration or frequency does not change

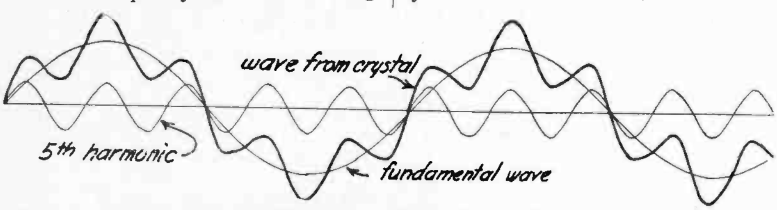

Fig. 3. Here Are the Waves as They Come Raw from the Tuner. They Must be Refined Before Using.

with the weather or the temperature. This is very important, as you would not want your radio stations to speed up their waves on warm days or to slow down whenever it looked like rain.

Now we have found a suitable material to vibrate at the right speed, the question is what size and shape to make it. A tuning fork has a shape which is about the best for the purpose of sending out slow air waves. However, it could never be speeded up to anything line the tremendous velocity needed for radio waves. A shape like an ordinary book with square corners and edges is found to do the work as well as anything. As this is a simple form to manufacture, it is the one which is always used.

Clinking the Glasses

When it comes to size we run into trouble. Of course, a smaller crystal will vibrate faster than a larger one. You can see this illustrated easily with a glass of iced tea or even of water. Fig. 1 shows a cut of pouring the liquid into a glass while a spoon is used to tap the sides of the tumbler. This gives out a musical clink, clink, as it is struck. If you continue to pour in the tea while you are hitting the glass, you will hear the tone start at a high pitch and gradually drop off lower and lower as the glass gets fuller. When the liquid is up to the top the tone will be lowest of all.

The reason for this change of note is that a big body naturally vibrates at a slower speed (lower pitch) than a small one, so when we experiment with our crystal of pure quartz, we find that the thinner it is the faster it goes. To get up to a million or so is not so bad, but when we want to reach 7,000,000, it requires a slip like a stick of chewing gum except a lot thinner. In fact, the thickness to go at this number of kilocycles will be so small (less than a sheet of paper) that the crystal is very fragile and easily broken.

Play Them in Bunches

How shall we get around this trouble? It is a good idea to see how they do it in music and perhaps take the hint from that. Suppose we have a parade marching along and the conductor or drum major waves his stick in time with the music. Pretty soon the musicians get to a fast part of the score where the notes follow each other in rapid succession. Does the drum major speed up his arms and jerk them around four or five times as fast as before? By no means. He will group four sixteenth notes together into a single beat and so will wave his stick only one-quarter as fast as the notes pour from the horn of the musician.

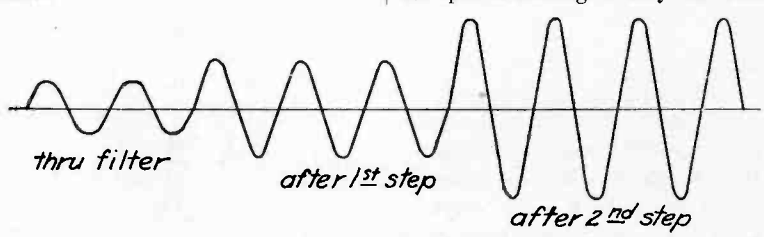

Fig. 4. The Waves of Fig. 3 Are Run Through Three Processes, After Which They Can be Utilized

By beating time only one-quarter as fast as the vibrations are coming there is no loss in the accuracy of the count. The parade continues to swing along with everybody in step, just the same as before. So perhaps we can get a crystal to do the same thing—pick out every fourth wave and emphasize it. However, in this case it has been found that while a crystal working on the fourth beat would do, it is still a shade too thin for practical purposes. By using the fifth instead of the fourth a larger size is indicated which works well in practice.

Which Crystal is Best?

Fig. 2 shows a picture of the thicknesses for these two crystals—one which beats at about seven million vibrations per second (at the right) and the other which picks out every fifth wave which gives it a speed of one-fifth of that. You can see at a glance that the left hand one is the better to use.

When this crystal is set into motion by putting it between the two plates of a condenser which is used in the grid tuning circuit of a radio tube it will vibrate as shown in Fig 3. There is a main, or slow vibration which is labelled "fundamental," and on top of this is a ripple, five times as fast, named the "fifth harmonic." To understand how these two waves can go on at once look at the ocean where you will see big waves perhaps twenty feet apart and on top of the waves will be a series of ripples, caused by the wind.

Vibrates Like a Rope

Another illustration is a long clothes line. If you wiggle one end back and forth you can make the rope sway as a whole, but if your hand is a trifle unsteady, you will observe that there are also a series of small waves on top of the big one. Of course, the rope at any one spot is moving in only one direction at a time. In the same way the curves of Fig. 3 are actually combined into the "wave from crystal" where you will see that every spot has only one position at the instant represented in this sketch. Both fundamental and fifth harmonics are being combined, however, just as in the clothes line.

Now it happens that the government

has assigned to Station WGY as an experimental wave, a frequency of 7,160,000 vibrations per second, or 7,160 kc. This corresponds to 41.9 meters of wave length. As just explained, this is beyond the range of any self-respecting crystal. However, to get a vibration of 1,432,000 is not at all difficult. Notice that the ratio here is 5 to 1, which is just pictured in Fig. 3.

A Million Times is Slow

In checking up on the wave which is being transmitted, it is the fifth speed

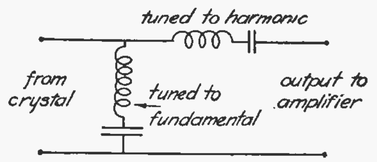

Fig. 5. Here is the Filter that Strains Off the Scum

ripple which is used in the sending station and the slow speed fundamental is of no use. In order to prevent its getting into the machinery and causing confusion, it is best to filter out this low vibration. We call it low by comparison although it is shaking back and forth at the tremendous rate of 1,432,000 times a second, or a wave length of 209.4 meters. We shall have more to say about the filter in a few minutes.

After the fundamental has been weeded out, the wave looks just as the ripple did in Fig. 3, except that the effect which we might call a ground swell has disappeared. This is seen in Fig. 4. However, the ripple was faint enough so it would not do much good in any man's size sending apparatus. It has a severe case of anemia. How shall we give it a little strength? You will say right away to run it through an amplifier, and this is just what is done. The first step gives the wave a lot of strength, while the second makes a robust vibration out of it, as shown in Fig. 4.

It Filters Waves

The filter, which gets rid of the unwanted vibration and lets the desired one through, is not as complicated as it sounds. It consists of nothing but two ordinary radio circuits, each combining a coil and condenser, as appears in Fig. 5. These work just like the tuner of your receiving set. The output from the crystal is fed to the input side of the filter. Right away the waves find a coil and condenser tuned to the 1,432 kc. waves and this you will notice from Fig. 5, returns right back on itself. Thus the low speed undesired wave is short-circuited without ever reaching the output of the amplifier. The high frequency vibration cannot get through this short circuiting tuner, however, as it is way out of tune for it.

Next the wave comes to a coil and condenser which has been adjusted to the fifth harmonic. Naturally, this seems like home to the 7,160 kc. wave and it enters it with the greatest ease. But if any of the fundamental is wandering along too, it finds that it does not fit this particular tuned circuit and can't get in. The result is that a pure wave of the desired speed of vibration comes from the output of the filter and is ready for the first step of the amplifier as already described.

"Brown Eyes" Does the Work

Now we have got it, what are we going to do with this wave? A glance at Fig. 6 will convey the idea. Here we have a lot of dancers who cannot keep together as there is no music or any way of keeping them in time. But now the orchestra starts up the tune of "Brown Eyes, Why Are You Blue?" Right away the dancers get the time from the music which you must remember is nothing but a vibration at the proper speed.

In the same way the radio apparatus at the sending station does not know how fast to oscillate, and as a result the wave frequency or wave length is apt to shift from day to day. Indeed there was quite a variation up to the time when the crystal was recently introduced. Now, however, the transmitter feeding to the broadcasting aerial hears the music from the orchestra (crystal) and immediately is able to swing into step. As long as the crystal plays its tune in correct time the waves will stay put at exactly 7,160 kc. And as we have already pointed out, the crystal has a mind of its own, and will not change its speed of vibration for temperature, weather, time or any other consideration.

A picture of the apparatus actually used may interest you. Fig. 7 shows how it looks. The action starts in the crystal at the right hand side. This unit is contained in the little cell, which appears right under the coil, in the middle of the right hand corner. The coil just above it is connected to the right hand tube as its control. This tube is the master oscillator and runs at the combined frequency of 1,432 kc., and also 7,160 kc. (209.4 meters and 41.9 meters.)

This combined wave is fed to the filter, which is the combination of coils and condensers seen near the middle of the cabinet. The variable air condenser in the lower right hand corner is the adjustable element, and this group suppresses the fundamental as already explained. The wave passing through the filter (Fig. 4) reaches the grid of the next tube (second from the right) where it is stepped up to much larger volume. From there it runs to the pair of tubes of the second step of amplification. This is a balanced or "push-pull" step, such as is often used as the last stage of an ordinary radio. The output from here is now powerful enough to be used by the

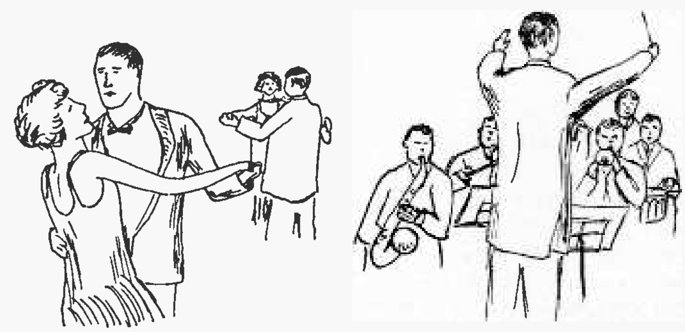

Fig. 6. Waiting to Get the Time of Vibration. This is Like the Transmitter at the Studio.

Continued on Next Page

THROWING A CRYSTAL

Continued from Previous Page

transmitting station in tuning its wave.

Although this description fits particularly the high speed vibration, which is being put out experimentally, the same general idea is used in ordinary broadcasting, and indeed who knows when these high frequency (short length) waves will become standard for ordinary broadcast programs?

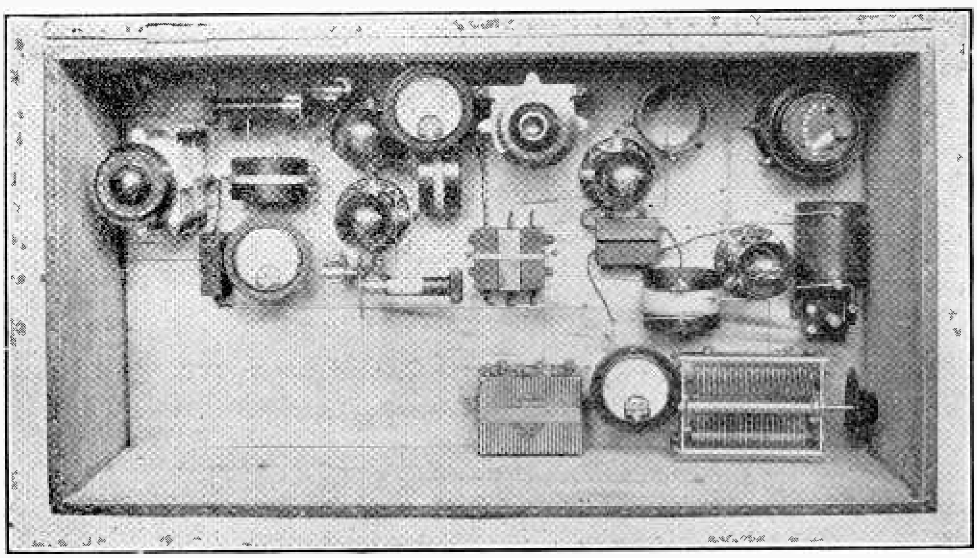

Fig. 7. A View of the Crystal, Tuner, Filter, Amplifier, and Push-pull Tubes.