

The Wayback Machine - <https://web.archive.org/web/20230329103029/http://lmwattstechnology.com/...>

The Polyribbon Story

[return](#)

I've always admired ribbon microphones, having built them in my high school years from gum wrapper foil, surplus magnetron magnets, and filament transformers.

Much Later after research and design engineering stints at Shure, Electrovoice, and other places I wanted to add a ribbon mic to my new microphone company. But I wanted something a little different from a standard figure 8 design.

I was fascinated with the multi pattern/non figure 8 ribbons of the past: The RCA 77 A, B , C, D , and DX....

the RCA KU and BK series, The RCA Starmaker pressure ribbons, and the Western Electric 639 and 670.

The multi pattern mics were pretty good for the day, but lacked the smooth response and full audio response

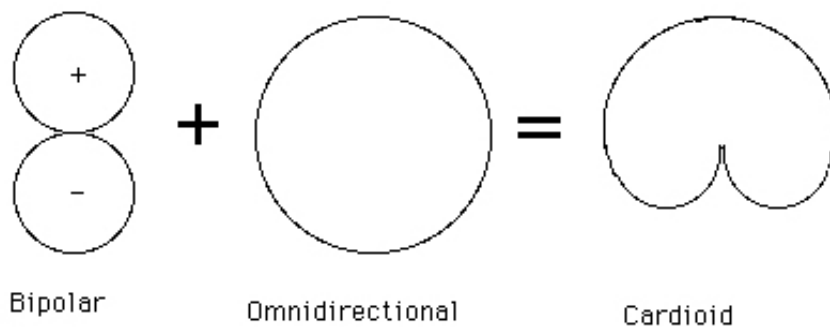
that I would want today. These designs were conceived with time domain and phasor analysis, but I sought

out to find ways to improve performance with modern network and computer methods. And listening.

First thing...most of them were made for and had a 10kHz bandwidth. This made sense at the time since there is a fundamental relationship between output level, noise, and bandwidth. Since very few transcription and broadcast means went past 5-10kHz and were relatively noisy, sacrificing the upper audio octave to gain more output made perfect sense. It certainly doesn't today.

The first non figure 8 ribbon microphones had two motors...a mass controlled ribbon for pressure gradient, and a resistance controlled ribbon for pressure. Mass control means that the largest reaction force is inertia, and resistance control means it's energy dissipation or transport. Both those conditions respectively are required for flat response in a system where the electrical output is dependent on velocity of a conductor in a magnetic field.

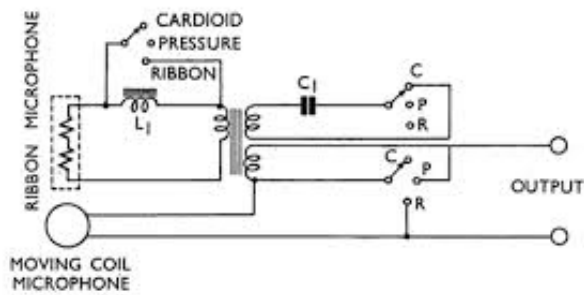
As has long been known the sum of those two ribbons can make cardioid or any other first order gradient pattern.



But there were some fundamental problems with this approach. The biggest was this: the omnidirectional pressure section wasn't really omni at all frequencies. Diffraction tended to make off axis response quickly drop off above about 2 kHz, so the cardioid and similar settings "grew a back Lobe" or tended to go figure 8 above that frequency. An ingenious solution was found though...realizing that the pressure element became unidirectional at high frequencies the pressure gradient ribbon was simply rolled off there...using the pressure ribbon only.

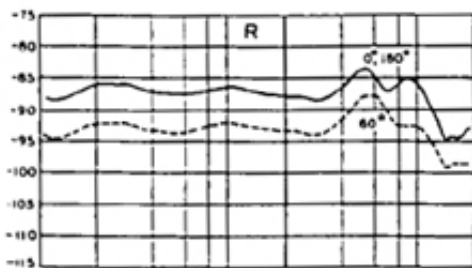
A little thought shows that the sum of two transducers at low frequency but only one at high frequency tended to make a bass shelf effect of 6 dB in cardioid for example. This was dealt with either with a crossover network or restricting the frequency range or both.

This was done quite cleverly in the dynamic/ribbon Western electric 639A using a series inductor and a capacitor on a tertiary transformer winding to allow reasonable capacitor values:



This made much better pattern control, as long as the frequency range was restricted particularly on the figure 8 setting.

There was a compromise in vertical pattern, because the two elements are spaced apart.



RCA did a similar thing earlier on the 77 A, B, and C and KU2 by acoustical filter means.

But Dr. Harry Olson later decided to eliminate the issue by using a variant of Ben Bauer's Shure development of the single element unidirectional microphone, the model 55 Unidyne.

This was commercialized as the RCA 77D and 77DX. In this case only a single ribbon was used, but it had a rear port

resistance/inertance opening that formed a constant group delay low pass filter to sound presented to the back of the ribbon.

A variable shutter was fitted to the opening to allow mechanical selection of polar patterns. Fully opened resulted in a figure 8 pattern and fully closed an omni pattern, with cardioid and the like in between.

The result was an Iconic microphone.

In general the patterns were better than the two ribbon approach, but the labyrinth (we'll talk about that later) and rear port assembly did tend to create a longer front to back path and thus reduced high frequency response particularly in the figure eight setting. Again, not so much a problem in a ten kHz world...and at lower frequencies it raised sensitivity. At non figure 8 settings it was less of an issue....the rear port low pass filter cuts off at high frequencies, resulting in a pressure interference

unidirectional microphone.

So....

Dual ribbon... required crossover network and restricted frequency range. Fairly poor vertical patterns due to element spacing.

Single ribbon...no crossover. No need to restrict frequency range per se, but the added hardware on the back of the ribbon increased front to back path and did restrict range on the figure 8 setting. Good vertical polar pattern.

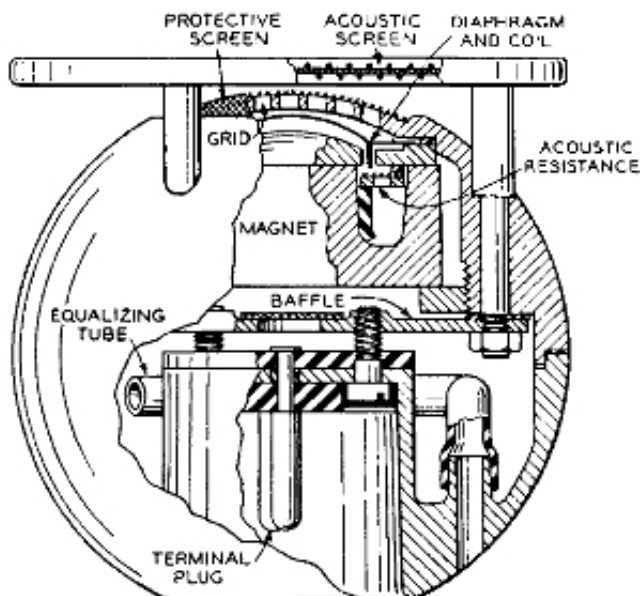
The solution quickly became obvious to us. Use an open unencumbered ribbon motor for the figure 8 setting, and use a inductance resistance phase shift back port on a second ribbon that is electrically selected. Close the port on this section for omni. Only one element is active at a time, so better vertical patterns are achieved as well.

This gives the advantages of both types, with none of the disadvantages. It would require a more complicated system consisting of electrical switching along with mechanical valve opening and closing. But we knew this was the way to go, and proceeded with it.

The Labyrinth

What is it? the RCA 77s had it as well as the KU2 skunk, KU3, BK5B, and Starmaker. It turns out that any velocity sensitive pressure microphone like a dynamic or ribbon has to be *resistance controlled*...that is the largest reaction force needs to be a dissipative friction like force. This was done early on at Bell Labs by having a dynamic mic diaphragm pump air through a layer of silk fabric or the like between it and a compliance chamber, resulting in the famous eight ball mic. It's still done today on pressure microphones, and in the case of variable D as developed by Electrovoice unidirectional mics as well.

This works quite well for heavy dynamic mic diaphragms....their mass resonating with the compliance chamber can easily be tuned to mid range frequencies...in the range of the geometric mean of the desired frequency extremes.



With low tuned ribbons a compliance chamber would have to be very large...a patent of the day for such a thing mentioned a 15 cubic inch volume!

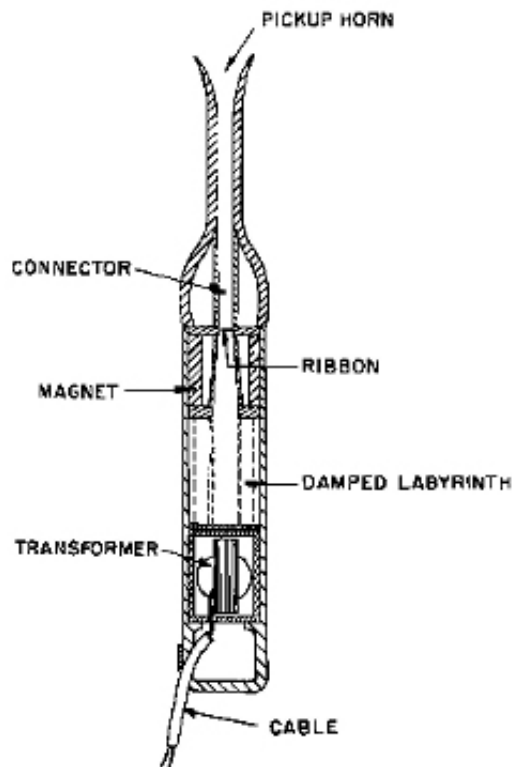
Dr. Harry Olson seemed to realize this pretty much from the beginning and chose another method for creating a stable, known resistance: a *transmission line*.

An infinite lossless transmission line presents a purely resistive input impedance. In the acoustic case the resistance is a simple inverse function of cross sectional area of a pipe. The right loading for the ribbon was found to result in a pipe of 6-9 mm diameter.

So a fairly small diameter pipe could be coiled up inside a microphone to provide resistance loading for the ribbon. To be the predominant reaction force of the ribbon it had to be greater than the mass or spring force reactance of the ribbon and its air load, but not so much that it reduced overall output by "driving with the brakes on".

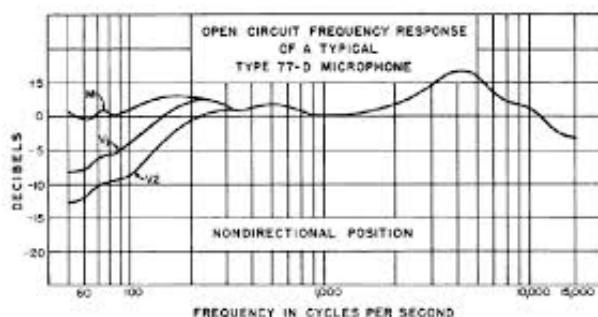
Hence it was called the labyrinth. In the 77 it was created either as stacked spiral plates or a phenolic block drilled with many interconnected holes.

In others, like this probe microphone (the Starmaker), it was part of the body casting:



But it of course was not infinite in length. In a reasonable size about a meter was the maximum practical length. But as we know an open pipe resonates, and the impedance is neither constant nor resistive. Organs, horns, and other musical instruments rely on this. Dr. Olson had to suppress this resonance, and he did so by stuffing the tube with fibrous sound absorbing media resulting in a *lossy transmission line*.

This interestingly gives the line a reactive impedance but does suppress reflections. We did find that corners where the labyrinth turned around abruptly still caused some pretty bad resonances, particularly in the RCA 77 series, that created a very large midrange response hump as shown. We were able to correct this very effectively with geometry changes and some acoustic networks.

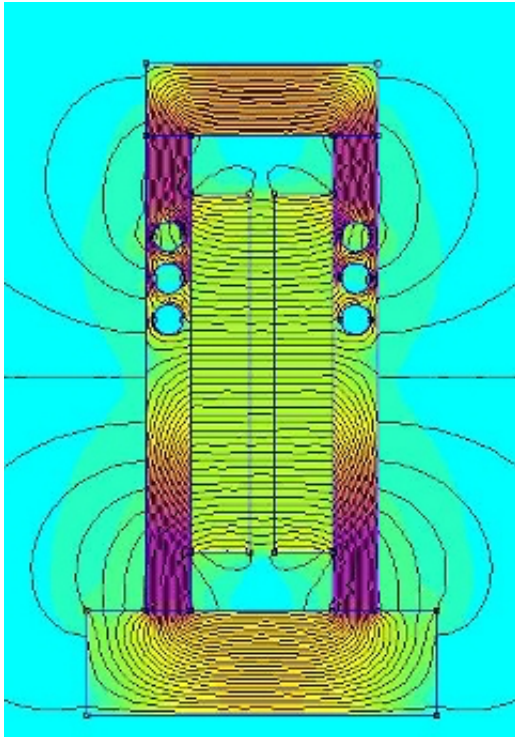


Other considerations

Magnets

Obviously we have great advantage today with modern neodymium magnets. Fairly

large flux density is required to get good output from a ribbon microphone. In past times high flux densities were possible only with large heavy magnetic structures. We were able to get high flux with much smaller magnets and a FEA optimised magnet structure.



Voicing and frequency tailoring

We used several methods to get the desired wide smooth frequency response.

We carefully controlled the diffraction peak created by the transducer assembly. We used wave plates as RCA and BBC/Coles did to tune the extreme high end. This is particularly effective as the boost provided gradually diminishes off axis, where the pressure gradient ribbon naturally has better HF response due to the decreased front to back distance. This maintains good off axis response/

Body reflections are always an issue. We use carefully placed resonant traps to eliminate them.

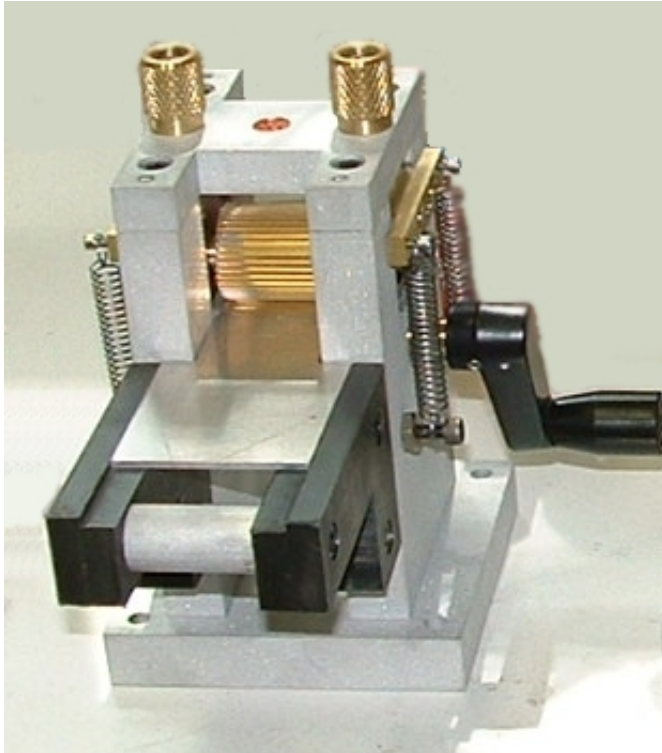
Mass controlled ribbons need some acoustic damping to prevent large peaks at harmonics of the ribbon fundamental resonance.

Doing so tends to reduce bass response and sensitivity however. To recover that we use a low resistance baffle around the ribbon.

It's transparent at high frequencies where the reactance of the predominately inertive near field dominates, but at low frequencies it becomes a significant portion of the near field path impedance and acts as an obstacle, increasing output.

Mechanical accuracy.

The ribbons must be formed accurately and consistently for predictable performance. To achieve the performance we want the ribbon to pole piece gap is only 0.1mm. We developed a precision preloaded ball bearing corrugating machine to insure this. Several other ribbon microphone firms bought these machines from us for their production.



The ribbons are then tuned off microphone as they are on field replaceable cassettes. A special fixture allows precise alignment and tuning testing with an electrical impedance meter.

The labyrinth stuffing operation is monitored with an acoustic impedance meter.

Finally each Polyribbon Has individual response testing with NIST certified Bruel &Kjaer laboratory reference microphones and the results are printed and included with each microphone.

What we've tried to achieve is a modern manefestation of the classical variable pattern ribbon microphones, with condenser like frequency range and very smooth response but retaining the warm quality ribbons always had.

Les Watts
L M Watts Technology