

Report from

**BELL
LABORATORIES**

Making voices from the depths sound deeper

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Bell Telephone Laboratories has had a long-term interest in speech research—tracing back, indeed, to the work of Alexander Graham Bell. It was for this reason that the U. S. Navy asked us to investigate a

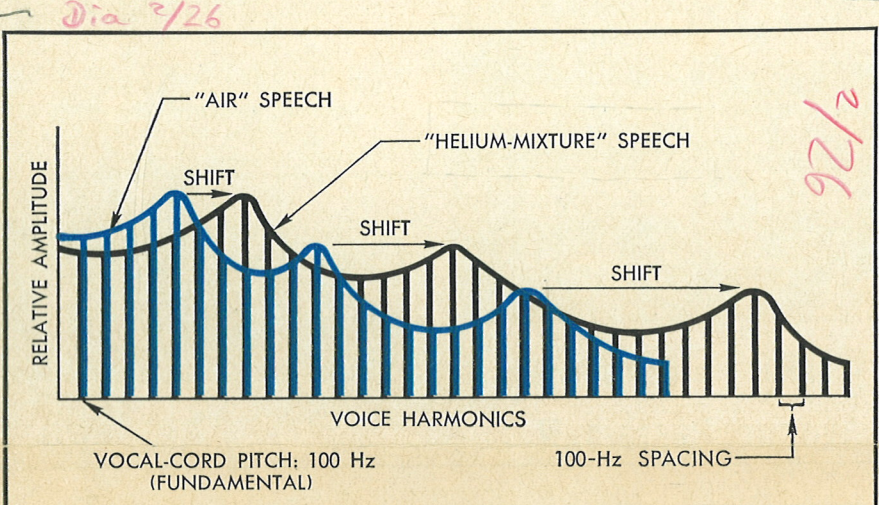
problem encountered in Sealab II. To prevent "bends" and nitrogen narcosis, the divers breathe a pressurized mixture of oxygen, nitrogen and helium, but the helium gives their voices an unnatural,

squeaky, Donald-Duck-like quality. As a result, voice communications between divers and people on the surface are seriously impaired.

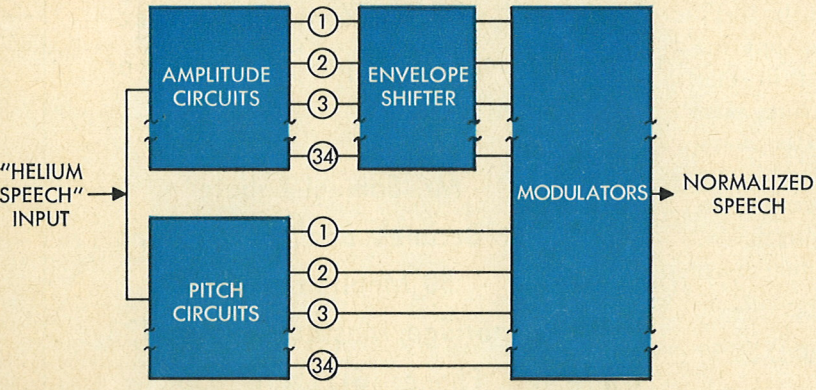
THE MAJOR PROBLEM is that the velocity of sound in the helium mixture is much higher than in air. This does not appreciably affect vocal-cord frequency, but does strongly affect the acoustic resonances of the vocal tract—which give the voice its characteristic sound quality. So, though fundamental voice pitch remains approximately the same (about 100 Hz in men), the amplitudes or loudness values of the various harmonics change markedly. Specifically, the pattern of these resonances (the envelope) shifts toward the higher frequencies (see graph), and voice timbre is grossly distorted.

THE SOLUTION to this problem was found at Bell Laboratories by research scientists M. R. Schroeder, J. L. Flanagan, and R. M. Golden. The distorted "helium speech" is separated into harmonic frequencies and their amplitudes are measured (see diagram). Then the envelope of the harmonic amplitudes is shifted back toward the more normal or low-frequency condition. In other words, the amplitudes of the harmonics are adjusted to match a more normal envelope.

As a test, the technique has been used on recordings of helium speech made in the U. S. Navy's Sealab II. The processed voices are readily understandable and sound enough like the speaker's "air" voice to be identifiable.



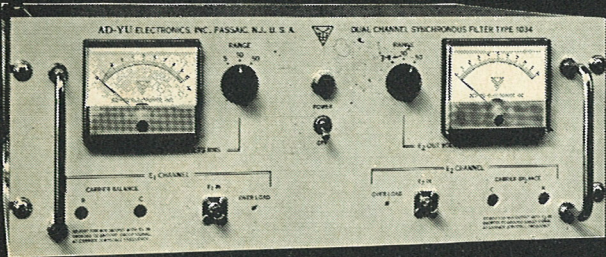
Fundamental pitch and harmonics (vertical bars) for normal "air" voice sound (color) and "helium speech" sound (black). Note that the frequencies of the fundamental and harmonics do not change very much, whereas the envelope of the amplitudes shifts toward the right. Note also that the magnitude of the shift increases with increasing frequency.



Block diagram of system for restoring helium speech to normal voice quality. Helium speech is fed to amplitude and pitch circuits. In the pitch circuits, the frequencies of the 34 lowest harmonics are determined. In the amplitude circuits, the power levels within each of 34 150-Hz intervals of the speech spectrum are determined. The amplitudes are shifted and applied to harmonics of lower frequency. In the modulators (right), these power levels control the loudness of the 34 harmonic frequencies... thus producing a pattern or envelope closely corresponding to the envelope of normal speech.

7 b.w.

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SPECIFICATIONS:

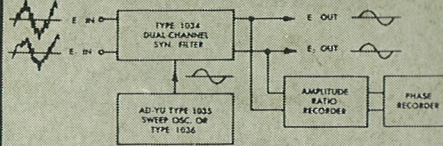
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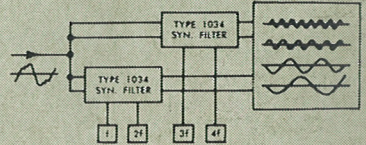
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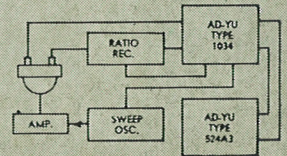
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