AC Bias at Bell Telephone Laboratories, 1936...1939

(http://www.aes.org/aeshc/pdf/mcknight_ac-bias-at-btl-1936-1939.pdf)

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Search for "magnetic recording at BTL", and you'll only find some dictating machines, and the fact that BTL suppressed developing magnetic recording. So it was a surprise when we found a 1976 interview with Dean Wooldridge describing his research at BTL on the theory of magnetic recording. They employed him from 1936 to 1939, when he independently discovered ac bias. BTL was going to patent it, but they found the 1927 patent of Carlson and Carpenter, which killed their hope of a "fundamental" patent.

0 Introduction

AC bias is a crucial element for "high fidelity" magnetic recording. The history of magnetic recording is well documented by Camras [1], and by Daniel, Mee, and Clark [2]. But along the way, one of the early discoveries of ac bias was lost, and has just recently been found.

In magnetic recording as proposed by Smith in 1888 [3], the signal to be recorded is simply applied to the winding of the recording head. When Poulsen in 1899 first actually implemented magnetic recording, he found that the recording process was of very low sensitivity, and very distorted [4]. Poulsen soon discovered that adding a fixed dc current (dc bias) to the audio signal decreased the distortion, but the signal was still distorted and noisy – magnetic recording had much lower quality than mechanical disk recording or optical film recording of the day, and was of little practical use other than for dictation [5]. It has been said that "once you hear a recording made with dc bias, you'll never want to hear another magnetic recording."

In 1921, Carlson and Carpenter accidentally discovered that adding a large high-frequency signal (ac-bias) to the recording head winding would greatly increase the recording sensitivity [6], but this invention was "before its time" and it was soon forgotten (see Camras, [1], p 112).

So magnetic recording systems continued using dc bias until around 1938...1941, when ac bias was independently and accidentally rediscovered by three different (groups of) engineers as reported variously by S J Begun in the early (first?) English-language book on magnetic recording [7]; and also reported by Westmijze [8] (Nagai, Sasaki, and Endo in 1938, and Braunmuhl and Weber [9] in 1940); and a third rediscovery by Camras in 1941, as reported in a footnote by Wooldridge [10] (see below).

Starting soon after 1940 many magnetic recorder makers started using ac bias, as we do to this day.

You may have noticed that the Bell Telephone Laboratories (BTL) – the inventor and/or developer of much of "professional audio" – is conspicuously missing from this Introduction. That's because BTL's work in magnetic recording, as described by Clark [11] didn't amount to much – BTL management feared that the availability of a recording device would make customers less willing to use the telephone system.

1 AC Bias at Bell Telephone Labs

But there's more to the story: Begun [7] also reports magnetic recording work by Hickman at BTL, and more importantly, he reports a paper by Dean Wooldridge[1] that leads to a discovery of magnetic recording research and patents at BTL [10].

[1] If the name "Wooldridge" sounds vaguely familiar, it's because he is the Wooldridge in "Ramo-Wooldridge", and the "W" in "TRW". See "Dean Wooldridge" on Google, and the complete interview at [13] for more information about him.

Wooldridge, in a footnote, reports:

> "Credit for the discovery of this [ac-bias] recording method apparently belongs to W. L. Carlson and G. W. Carpenter, who filed a patent application on it in 1921 (United States patent 1,640,881, issued on 1927 August 30).
>
> "The first commercial use of the method is believed to have been the audience participation stereophonic recording display of the Bell System exhibit in the New York World's Fair, 1939...40.
>
> "Some new techniques for handling the high frequency erasing and biasing problems are disclosed in United States patent 2,235,132, [filed 1939-07-29], and issued to D. E. Wooldridge on 1941 March 18.
>
> "See also United States Patent 2,351.004, filed by Marvin Camras on 1941 December 22."

This stereophonic recorder mentioned by Wooldridge is actually described and shown in Begun's book [7], on pages 156...158, which is reproduced here below. Altho Begun doesn't mention it, this is the recorder with ac bias that Wooldridge mentions.

Wooldridge's paper and its footnote leave us wondering – how and when did he learn of ac bias? Did BTL already know of the Carlson and Carpenter patent, or was Wooldridge another independent discoverer of ac bias?

Recently Noah Simon, in preparing a talk on the History of Bell Labs for the 2009 AES 127th Convention [12], found an oral interview with Dean Wooldridge that unlocks all of these puzzles [13]. It is a long and very interesting interview, well worth reading in its entirety, and I have excerpted from it the conversation between the interviewer, historian Lillian Hoddeson, and Dean Wooldridge, on the subject of magnetic recording.

In 1936, Wooldridge got his Ph.D. in physics from Caltech.

Wooldridge: "[T]he man that hired me was Harvey Fletcher, head of the physics department [at Bell Laboratories].... [He] was the one going around interviewing...Fletcher must have told me that he was pointing me toward magnetic recording research....[C. N.] Hickman was the head of that department. ... I was given every encouragement to try to bring some science into it if I could and that is what I tried to do. I tried to learn something about the fundamentals which hadn't been going on in the Bell Laboratories.... I did bring in some work on the fundamental physics of magnetic recording.... I worked pretty much on my own. I was simply assigned the general subject to learn about the physics in magnetic recording.

"I was working with magnetic materials. So, I had to go to the magnetic people – Bozorth – to make my [steel magnetic tape] materials and then prepare it for me in the form that I wanted, and roll it out in the proper way, and heat treat it in the proper way, and take x-rays of it, and things of that sort. So, I had a great deal of contact with people who did this magnetic work."

There were physics colloquium talks. "I do remember on one occasion that when I had been working on magnetic recording for a while, I talked about my work for seven hours."

Hoddeson: "You wrote a whole series of technical memoranda on this in 1938 and 1939 and I was wondering why there wasn't any publication. Were you ever in a position at Bell Laboratories in which you were stopped from publishing?"

Wooldridge: "No, there was a publication.... I published a fairly long article," [10]. "Thirty-six to thirty-nine...is about when I was working on [magnetic recording]."

Hoddeson: "I see, well let me look at it now in the light. I gather you were encouraged to take out patents but there was a release procedure by which Bell Laboratories would decide whether or not you could publish."

Wooldridge: "You always had to get some kind of patent review. But, now, the thing about this is that I believed when I first completed this work – there was a great deal of excitement concentrated in me – I thought I had discovered something extremely fundamental."

Hoddeson: "What was that?"

STEEL-TAPE RECORDERS

TWO-CHANNEL MAGNETIC-TAPE RECORDER. The American Telegraph and Telephone Company demonstrated at the New York World's Fair a dual-channel magnetic recorder for showing the effect of binaural or stereophonic recording. Two tapes were wound together on the same supply and take-up reel.

These tapes were separated at the recording and erasing heads. Figures 6—29 and 6—30 show the top and rear view of the device.

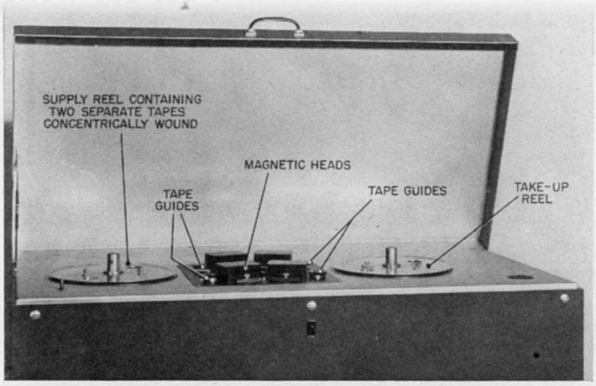


FIG. 6–29. Top view of two-channel stereophonic magnetic steel-tape recorder. (*Courtesy of the Bell Telephone Laboratories.*)

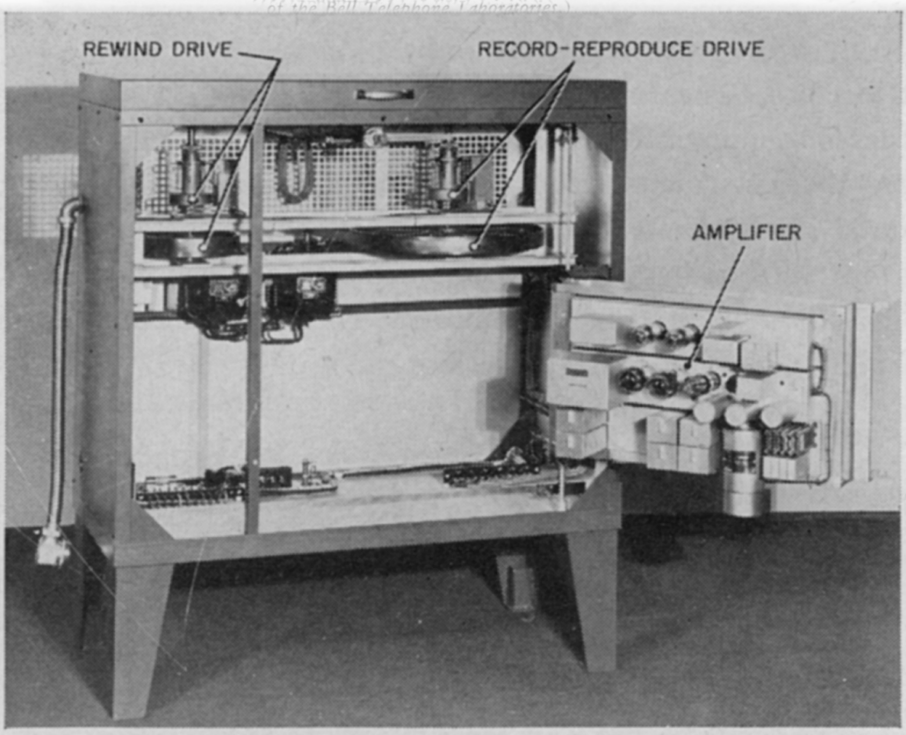


FIG. 6–30. Front view of two-channel stereophonic magnetic steel-tape recorder. (*Courtesy of Bell Telephone Laboratories.*)

Figure 1 Text and pictures from Begun [7], pages 156...158.

Wooldridge: "I had discovered something extremely fundamental. There were two things required to make magnetic recording practical and I discovered one of them.

"In those days, we were using a metal tape that had to be made of a metal alloy and rolled out. I guess that this was never quite practical enough so they had to get to the plastic tape which was worked out by the Germans in [actually, before] World War II. That was one of the great requirements — plastic recording medium.

"The other requirement was superposed high frequency on the recording. You have to, at the same time as you are putting in your growing magnetic fields, to put down the sound record you have to superpose a high frequency bias on it. The physics involved there is just a little more abstruse than you might imagine[2] [14]. But...it does two things: first of all, it greatly reduces the amount of noise that comes through, and in the second place, it greatly improves the quality. Now, I discovered that process.

"The way I discovered it was entirely by accident. I had rigged up some electronic test rig so that I could make various kinds of changes in my electrical recording techniques on some tape that I was dealing with. And, since my electronic wiring wasn't very good and I hadn't shielded some of my wires, quite by accident some of the output of a 20,000 cycle oscillator that I had going over in one corner leaked onto the wires that were going into the recording unit, and accidentally put some high frequency on it, and I discovered that I was getting some amazingly low noise and high-quality recording. I had to run it down and this looked like a very exciting invention.

"The only trouble was, when we ran it on down, we discovered that this thing had been invented and patented, I think, 17 years earlier. This was 1939 I'm talking about, and I think the patent was issued [actually, applied for] in 1921 or 2, almost before there were vacuum tubes to use in such an experiment. But, nobody had done anything with it. There just wasn't anybody in magnetic recording then; the thing was simply laying there in the patent office for all those years and nobody knew anything about it. Nevertheless, it was enough to make this patent worthless.

"We couldn't get a general patent. Now, it took quite a while, it may have taken a year or so to discover that, so we ultimately then went in for some more specific patents instead which weren't worth nearly as much. I think that is one reason this thing was delayed. I think it was believed at one time that it might be pretty valuable from the patent point of view. It wasn't characteristic of Bell Labs to stand in the way of a report publication that long."

Hoddeson: "Why were they interested in magnetic tape recording in the first place?"

Wooldridge: "Oh, it could be used in a variety of ways. They were interested in most anything having to do with sound. As a matter of fact, Western Electric, even...before this, back in 1938 or 1939, they actually played around with putting out a commercial magnetic recorder. They tried to sell it for four or five hundred dollars using loop of [steel] tape. Western Electric designed and put out some of my techniques. The only thing is, there really wasn't any particular demand for them, it was given up and they became quite popular later on."

3 SUMMARY

The addition of ac bias changed analog magnetic recording from "low fidelity" (noisy and distorted, with narrow frequency response) to "high fidelity" (low noise, low distortion, with wide frequency response).

AC bias was originally discovered in 1921 by US Navy engineers Carlson and Carpenter. But they were "before their time", and ac bias was forgotten for almost 20 years.

Then around 1938...1941, ac bias was independently rediscovered and reported by Japanese engineers Nagai, Sasaki, and Endo in 1938; German engineers Braunmuhl and Weber in 1941; and American engineer Camras in 1941.

Among those early discoverers of ac bias was also Dean Wooldridge, working at Bell Telephone Labs from 1936 to 1939, who hoped that he could patent

[2] This qualifies for the "understatement of the century" award – at this time (2013) there is only one satisfying physical explanation of ac bias [14], and it is so concise that few audio engineers can understand it. We are working on an explanation at the audio engineering level. Rev 2013-10-20 jm

this really fundamental invention. But the BTL lawyers found the earlier Carlson and Carpenter patent, so there could be no BTL patent.

But AT&T did demonstrate a BTL stereo recorder/reproducer using ac bias at the 1939 New York World's Fair – a two-channel steel-tape recorder for showing the effect of binaural or stereophonic recording. Two tapes were wound together on the same supply and take-up reels, and were separated at the heads. And apparently they said nothing at the time about using ac bias.

Unfortunately the BTL management feared that the availability of a recording device would make customers less willing to use the telephone system, so they didn't publish anything about this discovery of ac bias until 1946, and even that was hidden in a rather obscure footnote.

REFERENCES

Note 1: Papers marked "*" are reprinted in Camras [1].

Note 2: All of the patents mentioned below are available at no charge from the German Patent Office, at http://www.aes.org/aeshc/patent.search/get-patents-from-depatisnet.pdf .

[1] Marvin Camras (editor), "Magnetic Tape Recording", Van Nostrand Reinhold Co, Benchmark Papers in Acoustics, Vol 20, (1985, now out of print). Camras reproduces 46 original historical technical papers on the significant developments in magnetic recording, and provides interesting and informative "Editor's Comments" on these papers.

[2] Eric Daniel, C. Denis Mee, and Mark H. Clark, "Magnetic Recording – The First 100 Years", IEEE Press, (1998), who give a detailed history of all sorts of magnetic recording .

[3] * Oberlin Smith, "Some Possible Forms of Phonograph", The Electrical World, 1888 Sept 8, and Oberlin Smith and the Invention of Magnetic Sound Recording, http://www.richardhess.com/tape/history/Engel--Oberlin_Smith_2006.pdf (with the complete text of Smith's papers of 1878, 1888 and later, mostly not to be found in Camras' book)

[4] * Valdemar Poulsen, "Method of Recording and Reproducing Sounds or Signals", US Patent 661 619, applied 1899 July, granted 1900 Nov 13,

[5] * Valdemar Poulsen and Peder Olof Pedersen, "Telegraphone", US Patent 873 083, applied 1902 Jun 12, granted 1907 Dec 10.

[6] * Wendell L Carlson and Glenn W Carpenter, "Radio Telegraph System", US Patent 1 640 881, applied 1921 Mar 26, granted 1927 Aug 30.

[7] Semi Joseph Begun, "Magnetic Recording", Rinehart Books, Inc., (1949). See especially the Bibliography to Chapter 4, "Theory of Magnetic Recording", pp 88...91.

[8] * Willem Klaas Westmijze, "Studies on Magnetic Recording", Philips Research Reports 8 (1953) pp 395, 396.

[9] Friedrich Engel, "Walter Weber's Technical Innovations at the Reichs-Rundfunk-Gesellschaft" http://www.richardhess.com/tape/history/Engel--Walter_Weber_2006.pdf .

[10] Dean E Wooldridge, "Signal and Noise Levels in Magnetic [Steel] Tape Recording", *AIEE Electrical Engineering Transactions*, Vol 65 (1946 Jun), pp 343...352.

[11] Mark Clark, "Audio Technology in the United States to 1943 and Its Relationship to Magnetic Recording", presented at the 94th Convention of the Audio Engineering Society, *J Audio Eng Soc (Technical Program)*, vol 41, p 390, (1993 May), preprint 3481. http://www.aes.org/aeshc/docs/magnetic-recording/clark_audio-tech-in-us-to-1943.pdf

[12] Noah Simon, "The History of Bell Labs", http://www.aes.org/events/127/historical/session.cfm?ID=2040 .

[13] Interview of Dean Wooldridge by historian Lillian Hoddeson on 1976 Aug 21, Niels Bohr Library & Archives, American Institute of Physics, College Park, MD USA, http://www.aip.org/history/ohilist/4981.html . For the magnetic recording parts of the interview, search on "magnetic".

[14] H. N. Bertram, "Monte Carlo Calculation of Magnetic Anhysteresis", Journal du Physique, Colloque C1, supplement au nr 2-3, Tome 32, pp C1-684 (1971 Feb-Mar), http://mrltapes.com/bertram_monte-carlo-anhysteresis.pdf .