NSA Signal Collection Equipment and Systems The Early Years – Magnetic Tape Recorders

[redacted]

and

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P.L. 86-36

(U) The following article is another chapter of a work in progress in the Center for Cryptologic History. The book describes key collection equipment and systems developed for HF collection during the first two decades of AFSA/NSA. Previous issues contained chapters on receivers and antennas.

A BRIEF HISTORY OF MAGNETIC RECORDERS

(U) Magnetic recording technology evolved rather slowly into its current capabilities for recording audio, video, and digital information. Valdemar Poulsen patented the principle of magnetically recording and reproducing sound on a wire in 1900 in the United States, following his 1898 patent in Denmark. Poulson worked for the Copenhagen Telephone Company at the time, and he called his invention the Telegraphone. Commercial success did not follow, however, and magnetic recording essentially disappeared for a quarter of a century thereafter.

(U) Magnetic recording resurfaced in the 1920s aided by the availability of electronic amplifiers and better sources of the type of recording wire required for good quality of sound. Various wire recording machines were developed and sold in Europe, particularly in Germany, but the development of most impact was the Magnetophone. A method of coating plastic or paper tape with a magnetic material was patented in Germany in 1928, and the Allgemeine Electrizitäts Gesellschaft (A.E.G.) demonstrated the first commercially available recorder to use this medium, the Magnetophone, in 1935. Improvements achieved in the quality of both the tape material and the machines during the period of World War II led to Magnetophone use in German broadcast and military applications.[1] A key improvement was the application of high frequency bias to the oxide-coated tape used with the Magnetophone (German patent taken out in 1940). This step "is generally recognized as the most potent factor in advancing magnetic recording from a back-room science to commercial importance. All present-day magnetic recording machines may be considered to stem from the German designs of the war years."[2]

(U) In 1945 when American troops pushed into Germany, they ". . . approached radio stations that were broadcasting but were found without personnel. The broadcasting was being done by a machine never seen before; the Germans called it a Magnetophone. A plastic strip, magnetically recorded, was broadcasting with a fidelity Americans had never before heard in a recording and without surface noise sound."[3] A number of these machines were shipped to the United States for evaluation by the Army Signal Corps. Also, some were shipped back as "war souvenirs."

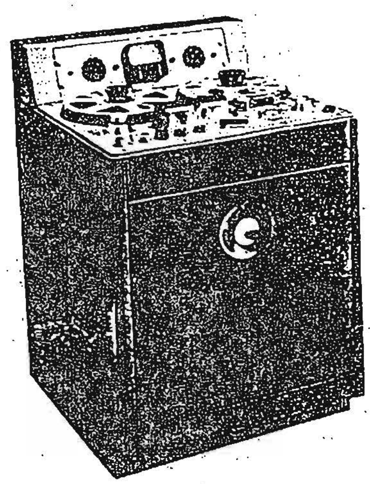
(U) Magnetic tape technology was not completely ignored in the United States during the 1930s. Bell Telephone Labs had an extensive research program on magnetic recording during that period.[4] This research contributed to the development in 1941 of the C-1 Time Division Scrambler (TDS) system, which was built around a small magnetic tape recorder. The essential part of the C-1 TDS was a magnetic tape recorder-reproducer in which a magnetic alloy was banded to the rim of a nonmagnetic drum or wheel. Eleven magnetic coils formed magnetic pole-pieces mounted around the drum to perform the recording and reproducing functions on the magnetic strip as the drum rotated. A switching system controlled the order in which segments of the signal were recorded for transmission or the order in which segments of the tape were reproduced during transcription. This coded switching system provided a flexible voice privacy capability. To the end of World War II, the TDS equipment was the only small and portable device for scrambling speech that was in factory production.[5]

(U) Up until about 1945, commercial telephone and repetitive message operations used wire recorders, as did the Allies during World War II. The wire recorder advantages of portability and rapid message changing gave it preference over turntable discs or cylindrical drum-type recorders. However, splicing the wire was a very unsatisfactory process. This required tying a knot in the wire and then fusing the knot with a match or even the hot end of a cigarette. The audio quality of the resultant splice was poor, and this unsatisfactory editing process doomed the wire-recorder technology as soon as tape recorders came onto the market.[6]

(U) The end of World War II idled a large number of U.S. companies which had been major suppliers to the government during the war. To reestablish themselves in the postwar market, they looked for consumer products to manufacture. Most manufacturers of wire recorders for wartime use converted to magnetic tape machines, and tape recorders manufactured by Brush Wollensak, Revere, Magnecord, and others became popular consumer products beginning in 1946 and 1947.

(U) During the war, a company in San Francisco had developed a strong capability in the manufacture of small, precision electric motors, electric generators, and dynamotors (a one-piece motor and generator). These small motors and generators had found extensive use in U.S. warplanes. The end of the war left this company with a large surplus inventory of small electric motors. The company, which became known as the Ampex Corporation, decided to manufacture tape recorders that used three motors in each. At the time, the tape recorders of other manufacturers incorporated one or two motors with belts and pulleys to achieve the play, fast-forward, and rewind functions. The major broadcast and recording studios quickly discovered that the Ampex tape recorder with three motors achieved higher quality and a more flexible tape recording capability, and it became a de facto standard. (Of note, the Germans had used three motors in their tape recorders, too.) The total production of Ampex tape recorders up to 1950 was sold almost completely to the major broadcast networks.

(U) The NSA and ASA organizations in the 1950s also recognized the audio quality of the Ampex equipment and quickly purchased Ampex Models 300 and 350 for signal intercept applications. Early in the 1950s, the Agency's approach to magnetic recorders began to move along two separate paths. Voice recording and processing is one path, and the other, called "instrumentation" for want of a better description, covers the nonvoice category. In instrumentation recorders the emphasis is on a highly linear transfer between input and reproduced output. That is, the goal is a highly precise replication of the input signal, including time base stability, on (typically) another recorder at a different location.



An Ampex Model 300 console. Some consoles included carrying handles on each side; users then referred to it, with tongue-in-cheek, as a portable model.

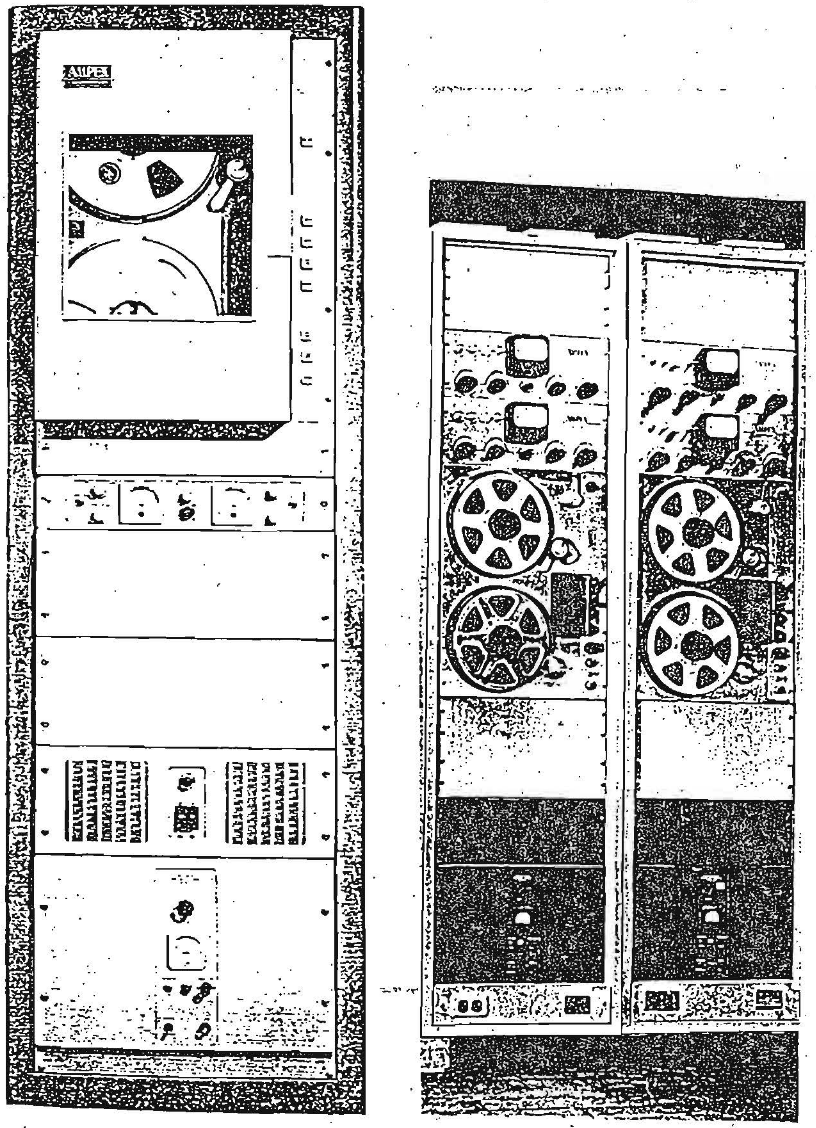
EARLY INSTRUMENTATION RECORDERS

(U) The Agency did no in-house development of instrumentation recorders per se, preferring to work closely with the recorder industry, testing and evaluating new models or new circuitry against the known requirements, and using contracts to push the industry in design and function directions that benefitted the Agency. The needs of the Agency and those of the commercial marketplace for this type of magnetic recorder were sufficiently parallel that this technique worked effectively and economically. (A portion of the 1974 NSA R&E Report described the relationship between internal and external COMINT equipment development this way: "NSA exploits the technology and techniques area in three distinct ways. First, it takes as much advantage as possible of the industrial, government, and university efforts which have been and are being developed. This allows us to plan for exploitation as well as to avoid unnecessary and wasteful duplication. Second, in situations where the directions taken or the time schedule [does] not match our unique needs, we attempt to influence the outside activities. This takes the form of contract support at times or, if possible, persuading the organization to direct its efforts closer to our needs. The third type of effort calls for us to perform the work with NSA financial and manpower resources. In these situations, we exploit the expertise available in the outside community in conjunction with our own in order to take best advantage of both worlds.") However, to fitting commercial recorders into the peculiar needs and requirements of COMINT led the Agency to develop a variety of auxiliary items such as frequency-regulated power supplies, signal-operated relays, time-code generators, audio delay units, etc. The Agency engineers also developed a variety of new testing procedures and methodologies in order to assess the acceptability of commercial recorders for Agency purposes.

(U) The workhorse instrumentation recorder of those early ears, particularly for recording of printer signals, was the Ampex S-3160A, also known as the AFSAV-510A. This upgraded version of the Ampex 300 and 400 series provided a dual-channel capability at tape speeds of either 3 3/4 or 7 1/2 inches per second (ips) and contained a power amplifier with tuning fork to drive the capstan motor. This last feature assured that the tape operated at the same constant speed during collection and processing despite voltage instabilities at either the field site or the processing center. In use, an intercept operator could expect to record forty-five minutes of uninterrupted printer traffic at 7 1/2 ips. (The nomenclature used with AFSA/NSA equipment evolved through various schemes in the early years. Initially each equipment was designated by an AFSAV number with the letter "D" used to indicate the equipment in the developmental or test stage. When equipment reached operational status [also called production models)]the letter dropped out. Hence, the Ampex S-3160A, initially named the AFSAV-D510, eventually became the AFSAV-510A. This methodology continued for several years after AFSA became NSA. By the late 1950s NSA shifted to the XR nomenclature for developmental/test equipment and obtained DoD standard Army/Navy [A/N] nomenclature when the item went into operational use. Also, at that time, the Agency changed currently operational AFSAV equipment over to A/N nomenclature. The AFSAV-510A then became the AN/TNH-10, and a variation, the AFSAV-510A/D2M, became the AN/TNH-13! For a number of years, the Agency issued cross-reference lists to help sort out this confusing array.)

(U) The S-3160A tape recorder used in these applications was not, by any definition, a portable machine. A rugged machine based on vacuum-tube technology, it filled a standard, six-foot-high equipment cabinet. In 1962 an AFSAV-510A cost a bit over $9,000, while a voice recorder such as the AN/TNH-11 that is discussed below cost about $2,000.[7]

(U) The Ampex Corporation's crowning achievement, perhaps, was their development of a video tape recorder, the VR-1000. The new Ampex video tape recorder first demonstrated its professional utility with the recording of President Eisenhower's inaugural address in January of 1957. For comparison, the AFSAV-510A had a high-end response of about 12,000 kHz at 71/2 ips; the VR – 1000 provided a frequency response ($\pm$3db) from 15 kHz to 2.5 MHz.



Two racks of S-3160 recorders (on the right) compared with an AFSAV-510A (on the left). Although cross-reference lists show the AFSAV-510A as being an S-3160, the AFSAV-510A was a slightly modernized version, having a dust cover, revised control buttons, and a more modern and compact electronics panel.

~~(S-CCO)~~ The following year the NSA directorate approved $120,000 for the purchase of two video tape recorders. Ampex delivered the recorders in 1958, and within several months CIA personnel visited NSA requesting that one of NSA's video recorders be made available to them [redacted] The launch of the Soviet *Sputnik* in 1957 had triggered this interest, [redacted] In 1958 Ampex was the only source of proven video recorders, so the heavy demands from the television broadcast industry for the recorders prevented prompt purchase and delivery for CIA. Under these circumstances, NSA released one of its Ampex video tape recorders; the return of the recorder by CIA, however, is not documented. In 1960 the second video recorder went into an operational system collecting broadcasts transmitted by Castro's Cuba.

EARLY VOICE RECORDERS

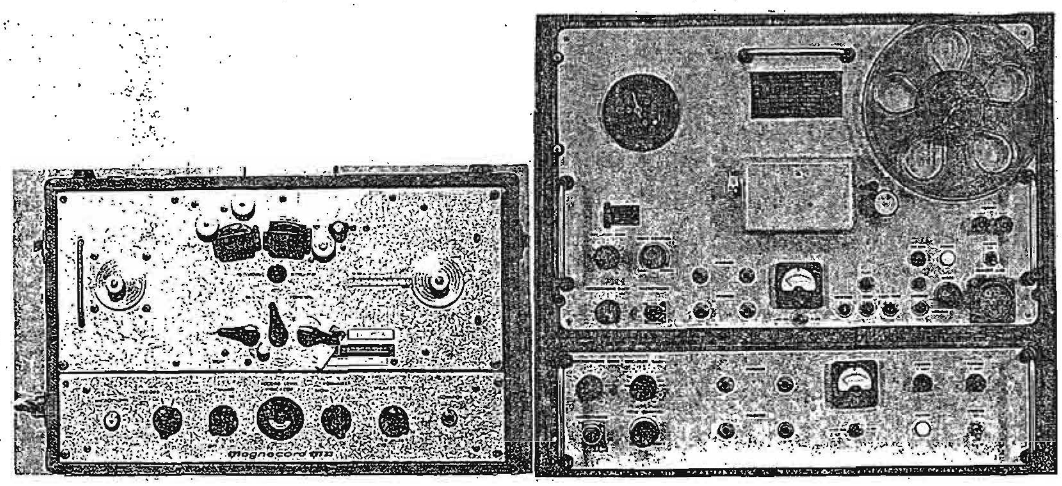
(U) In the voice recorder category, the needs of the SIGINT community could be met by the commercially available recorders, but the match was neither efficient nor economical. Problems peculiar to the community were the need to operate reliably on a variety of foreign power line characteristics and under unfavorable field conditions such as heat, humidity, dust, or, less commonly, extreme cold. (Not only did much of the rest of the world provide AC power at 50 Hz rather than 60 Hz, and at voltage levels different from the 120 volts common in the U.S., but during the ten to twenty years immediately following World War II neither the frequency nor the voltage was reliably constant. Old-timers claimed that in some of the Far East countries changes in the AC power-line parameters directly tracked with the rainy and the dry seasons.) Additionally, the voice transcription process required several unique recorder control mechanisms to facilitate that function. Further, because of the large quantities of voice recorders required for COMINT tasks, the cost of logistic support argued for a rugged, standard model that could perform equally well in the field or in a stateside transcription center.

(U) During the 1950s, it was necessary to use commercial tape recorders and upgrade or modify them as necessary. Most of the changes simply provided the capability to operate on the different AC line voltage or frequency available at an overseas site.

(U) NSA initiated development of a standard, voice-grade magnetic tape recorder by determining the required military characteristics and preparing a Purchase Description (PD) in 1954. Parallel contracts were awarded the following year to Magnecord Incorporated and the Revere Camera Corporation for the development of engineering models. The toughest technical problem in the development was that of maintaining a constant tape speed under a wide variation in AC line voltages and frequencies. The Agency eventually selected the Magnecord design as the winner in early 1956.

(U) By November 1955, even though development of the engineering models was not yet completed, the Office of Production tasked R/D for construction of eight service test models. Although Magnecord received a contract for the test models, now called AFSAV-

D75s, Ampex received a parallel development contract because of concerns about the financial condition of Magnecord. Magnecord delivered in mid-1957. After a successful service test by the three military services and NSA elements, [redacted] then chief of COLL-2, in an 18 December 1958 memorandum, designated the AFSAV-75A as the standard recorder for use in all radiotelephone (voice) positions. The test models made by Ampex completed a successful service test also, but nearly a year later than those from Magnecord. The Ampex versions were abandoned at that point. P.L. 86-36



The single-channel Magnecord commercial recorder (left) was widely used by the SCEs (especially AFSS) under the designation of PT-6, until superseded by the AFSAV-75, later designated AN/TNH-11 (right). The addition of the applique chassis – shown mounted beneath the tape deck – provided a two-channel capability on the AFSAV-75 or AN/TNH-11.

(U) The production models of the AFSAV-D75 recorder received the military nomenclature of AN/TNH-11 prior to the initial deployments that began in 1960. Over a period of several years thereafter, U.S. recorder manufacturers produced more than three thousand AN/TNH-11 recorders under contract to NSA. The AN/TNH-11 recorders satisfied the requirement for improved data storage for the voice and manual morse problems and, to a lesser extent, for recording facsimile or low-speed printer transmissions. In the transcription area, the combination of foot-switch controls and variable playback speed control significantly increased productivity.

(U) The AN/TNH-11 was a milestone in tape recorder equipment used in the SIGINT community. It was the first tape recorder whose development was specifically tailored to match the Agency's operational requirements in voice intercept and processing, and it was designed to meet military specifications. Production of AN/TNH-11 recorders began in 1959; operational use began in 1960. The recorder had numerous production runs and a long life in the SIGINT community. Its use extended into the 1980s even though it was superseded in the early 1970s by a four-track, three-speed, solid-state version, AN/TNH-21.

EXPANDING THE ROLE OF RECORDERS

~~(C)~~ During World War II and the beginning years of AFSA/NSA, SIGINT collection remained essentially an on-line process. Morse, voice, and printer signals went directly into hard copy, or an equivalent, at the collection position. The primary machine-based recording techniques were the ink-based undulator (paper) tape recorders used on Morse signals and the hard-copy or punched-paper tape used on single channel printer transmissions. As the quantity and complexity of transmissions increased after World War II, the role of magnetic recorders to store signals for off-line processing either at [redacted] rapidly expanded.

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~~(S-CCO)~~ Those operational requirements driving nonvoice tape recorder developments for the SIGINT community began to push the technology into two seemingly opposite directions: recorders with very high frequency response and recorders of "DC" pulses. The basic problem was that as more and more analog tapes came back to NSA for processing, NSA needed to process the recorded signals at higher than real-time rates. By 1958, the time and effort required to convert printer intercept received on analog (that is, tone recorded) magnetic tapes into a form suitable for high-speed computer processing began to create a warehouse-sized backlog of unprocessed field tapes. A paper written in 1961, for example, reported that during July of that year more than 17,000 reels of magnetic tape, primarily containing [redacted] arrived at NSA.[8]

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~~(C)~~ The two types of signals most commonly recorded for subsequent NSA processing were frequency shift keyed (FSK) and double-frequency shift keyed (DFSK). Recorded FSK signals contain two tones, one representing a mark and the other a space, with a typical separation of 500 or 1000 cycles per second (Hz). DFS recordings contain four such tones, providing two simultaneous channels. For reasons of filter design and recorder stability, DFSK and FSK field recordings produced tapes with the tones positioned between 4 and 7 kilohertz per second (kHz), recorded at 7 1/2 ips.

(U) Recorders available to the conversion process had a maximum frequency response of 60 kHz. This limited the playback speed of these recorders to a speed eight times faster than the recorded speed of 7 1/2 ips in order to keep the highest frequency (56 kHz) within the 60 kHz limit. As advantageous as the eight times faster conversion process was, even higher factors were needed. This involved development of recorders with frequency response of 120 kHz and beyond, or field recorders with sufficient stability to permit recording the signals at a slower rate, such as 3 3/4 ips, 1 7/8 ips, etc.

(U) In practice, both advances in the technology came about in the recorder industry, but by that time the impetus for solving this processing problem had shifted away from analog recording toward the use of direct pulse recording, also called "DC," digital, or binary recording. The advances in frequency response capability of recorders led to the creation of the Wideband program, which will be discussed later.

DIGITAL RECORDERS

(U) All digital computers use the binary system of notation. In this system, every digit is defined by combinations of 1s and 0s. Either of these can be defined to be a pulse or a "no pulse" (space). Tape recorders operating in this mode made an attractive option for the recording of printer signals, which, although not designed for computer application, use only two conditions, mark or space. Frequency response and linearity, so critical in analog recordings, are of secondary concern in pulse recordings, since all the information is contained in the starting and stopping of pulses.

(U) Tape recorders used for pulse recordings could use either of two basic design approaches. In the first, a "1" pulse is achieved by driving enough current through the record head to saturate the tape in a positive (or negative) direction, and a "0" is achieved by saturating the tape in a negative (or positive) direction. After each momentary saturation, the current through the record head is cut off, so this type became known as RZ (return-to-zero). Thus an entire RZ tape contains only three conditions: positive saturation, negative saturation, and zero head current.

(U) In the other design approach, the zero head current condition is eliminated. The tape is driven into either positive or negative saturation for the "1" or "0" and remains there until a pulse change occurs. Then the tape is saturated in the opposite direction. That is, to record a 11011 sequence the tape would be driven into positive (or negative) saturation for the duration of the first two pulses, reverse saturation for the third, and go back to positive saturation for the last two pulses. This design concept, called NRZ (non-return-to-zero), is considered more efficient than RZ, permitting more bits of information per inch of tape because of the less frequent changes in the direction of magnetization.

~~(S-CCO)~~ The initial NSA foray into pulse recording was the AFSAV-D100, later given the nomenclature AN/TNH-14. This device, which used the NRZ design, played a key role in a number of tests during 1958 to compare the processing of binary and audio recordings of printer signals for accuracy and speed. Overall the tests confirmed that binary recording in the field of [redacted] printer signals yielded the better product.[9] Subsequently the Agency installed these recorders worldwide in the [redacted]

~~(S)~~ Experience gained in processing the NRZ recordings produced by the [redacted] positions led to reconsideration of its merits and a switch to RZ recording in succeeding recorders. The primary problem stemmed from noise or some other common signal interruption causing loss of a flux transition – the indication that the "1" changed to a "0"

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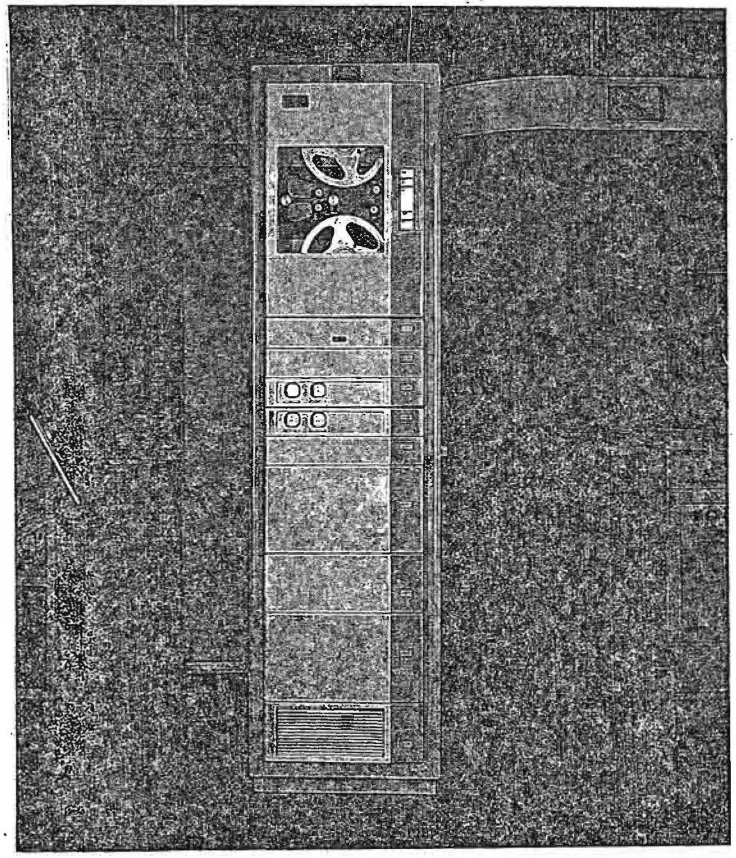
or vice versa. Unfortunately this not only corrupted the character in process but it reversed all the succeeding character patterns until some event, most likely another missed transition, restored synchronism. Because of the redundancy of the RZ technique – the characteristic that renders it less efficient than NRZ – a missed flux change corrupted only the immediate character.



The vacuum-tube-based AFSAV-D100 (later AN/TNH-14) was the first digital recorder (NRZ type) used operationally by NSA. The four circles in about the middle of the rack were small CRTs for monitoring input and output signals.

(U) The next iteration of digital serial tape recorders occurred in the ROOMETTE system. The PD for ROOMETTE, which went under contract to Westinghouse Electric Corporation (WEC) in May 1962, called for "a complete field equipment for receiving, demodulating, regenerating, and recording radioteletype communication signals."[10] The PD called for the Serial Data Recording System, XR3-44, to be capable of recording and reproducing both analog and digital signals on 1/2-inch tape, using the RZ format for the latter with a packing density of 225 bits per inch. Each of the eight parallel tracks on the heads could be set up via different amplifier electronics for either analog or digital operation.[11] Depending on the selection of record and playback speeds and several related factors, such tape provided a minimum processing speed-up factor of 64 times the tape speed used for recording, and speed-up factors of 128, 256, or 512 might be possible.

(U) When the ROOMETTE development began, only Ampex and CEC (Consolidated Electrodynamics Corporation) produced serial digital recorders that the Agency deemed acceptable for field use.[12] Although previous in-house testing favored the Ampex unit, CEC was selected to produce the XR3-44 ROOMETTE service test models because of a much lower cost and a faster delivery schedule.[13] CEC nomenclature for these models was PR3300.

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(U) Service testing of the ROOMETTE systems at three field sites began in January 1963. As stated in the Service Test Summary of April 1963: "The RZ recording concept hs [*sic*] proven itself and the (XR3-44) equipment has functioned satisfactorily." However, during the time frame of the service testing of the ROOMETTE system, the Agency's R/D organization concluded that recorder developments had reached a level of maturity that made computer-compatible recorders suitable for field station use. Even though the serial digital recorded tape permitted conversion at very high speeds to the format required for computer processing at NSAW, the conversion process could simply be eliminated by making the recordings in the field in the blocked, parallel "IBM 729" format. [redacted] service test models continued tasked operations in the field until replaced in 1967 by the [redacted] systems.

(U) As general-purpose computers and their associated tape recorders moved through their early development period in the fifties and sixties, the users needed to provide an operational environment that catered to the equipment: relatively dust-free air with temperature and humidity controlled within narrow limits, a stable AC power system, well-trained computer operators, and maintenance personnel experienced in digital circuitry. COMINT field stations did not fit this image! Hence the direct production of IBM 729-compatible magnetic tape at the intercept sites was not the simple step it might appear to be.

~~(C)~~ Early Agency efforts on this problem also included testing of an incremental tape recorder in addition to work on the parallel block-type recorder. An incremental tape recorder moves the tape in discrete steps, each step containing the parallel (RZ) recording of a character and identification of its source. The resulting tape is functionally similar to that produced by a paper-tape punch. Although an incremental recorder tested adequately and offered some advantages over the serial-data machines used in ROOMETTE, the block type recorder also tested well and offered even more flexibility and operational advantages. [redacted]

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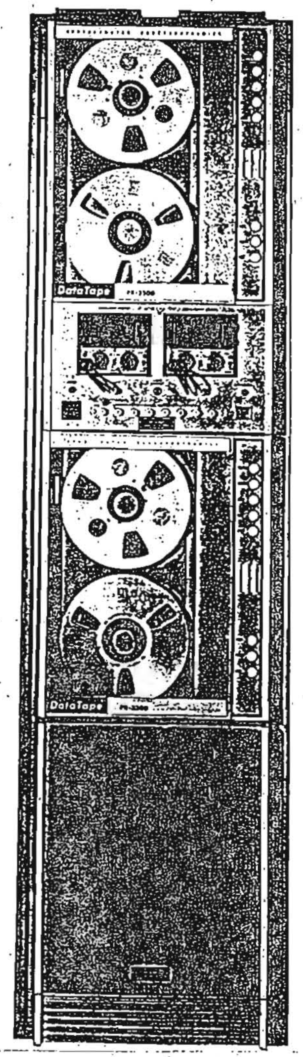
initially operated at 200 bits per inch (bpi); in later years a modification package increased the packing density to 556 bpi.[14]

(U) The only other significant application of serial digital recorders in COMINT collection came in the Automatic Morse Processing Systems designed around the CMP18A Morse Translators. These systems went into the operational inventory in 1964 using AN/TNH-11 recorders converted to serial digital recording in lieu of the original voice capability. The conversion required only an exchange of modular plug-in components to obtain the NRZ recording/playback capability.



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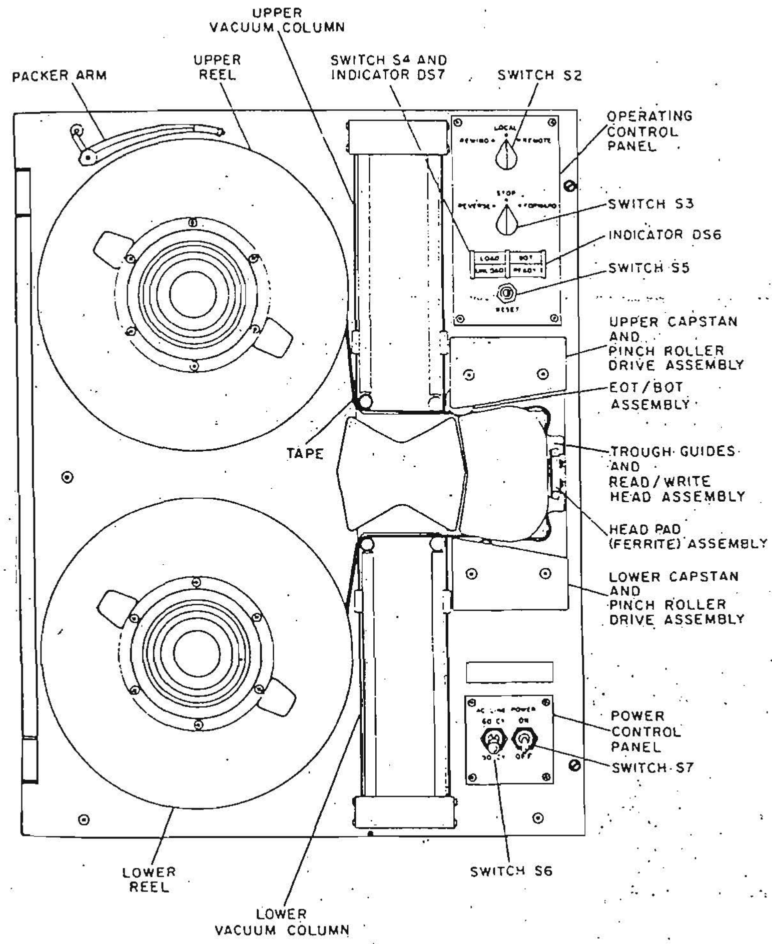

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WIDEBAND COLLECTION

[redacted] However, the context for the discussion that follows is the recording of a contiguous portion of the RF spectrum to obtain a record of all the narrowband signals active therein, to be processed after the fact either at the site of the recording or at a remote location. This operational technique is better described as Multiple Signal Collection, although that title never achieved wide use. Store and Forward Systems became the designated title in the late 1960s, followed by Multiple Signals Intercept. During the 1970s, the official title became [redacted]

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~~(SC)~~ Wideband (WB) Collection Systems began to play a significant role in the SIGINT community beginning in the mid-1960s,[15] but these systems began as by-products of [redacted]

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~~(C)~~ The D26, the first significant use of RF Wideband Recording,[16] initially used the Ampex 300-series recorder top-plate but quickly progressed to the AFSAV-100 type recorder. This recorder or similar tape transports became the standard for a series of other wideband systems such as the [redacted] etc. These recorders ran at 60 ips to record 100 kHz in each of fourteen tracks on one-inch tape. Using the normal 10 1/2-inch reels, this gave a total recording time of twelve minutes per reel.

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(U) Except for the AN/TLR-28 systems, the systems listed above were dedicated to specific high-interest signal collection, and the tapes were processed at the collection sites for the targeted emissions. Early on, it became clear that the tapes contained other signals which could be extracted productively at processing centers, and tests demonstrated the feasibility. However, at twelve minutes per reel a single twenty-four-hour position would chew up 120 tapes! Given a ninety-day pipeline for tape resupply of the site, the required 10,800 tapes effectively negated this option.

(U) To cope with this problem, the AN/TLR-28 systems incorporated new, fourteen-track Mincom CMP-114 recorders. These permitted recording 120 kHz per track at 15 ips, rather than 60 ips, and accommodated 14-inch reels, rather than the more commonly used 10-inchers. These changes produced an actual recording time of ninety-six minutes that was quite workable.[17]

(U) By the early 1960s magnetic recorders such as the CMP-114 had evolved to a level of capability that made wideband recording feasible, but there remained many technical shortcomings to be overcome by the engineers in NSA and industry. The key advances needed were wider bandwidth recorders in a more compact size, much lower flutter characteristics, and better dynamic range. (Dynamic range indicates the variation in input signal strength within which the reproduced output is a precise duplication. Since the wideband receivers had larger dynamic ranges than did the recorders, the systems included tuneable notch filters that the operators used to attenuate strong signals in each 100 kHz spectrum before input to a recorder channel.) The AN/TLR-28 and the other early systems all operated with a maximum frequency response per track of about 100 kHz, peak to peak flutter of about 0.2 percent, and a dynamic range of only 25–30 db.[18]

~~(C)~~ Following successful testing of wideband signal collection in 1960/61, nine wideband systems of various capabilities were assembled from standard, available equipment. Each consisted of a fourteen-track CMP-114 recorder fed from one or more (up to seven) receivers. The receivers could be either R-1039s or R-1151s. Each receiver produced two contiguous 100 kHz of spectrum, each of which was recorded as 10–110 kHz on a track of the recorder.

(U) During the 1960s and into the 1970s, a variety of developments, studies, and experiments led to newer, superior wideband systems. An early interest was the video recorder with its 4 MHz bandwidth achieved by transverse scan rotary head recording. In this type of recorder, record/reproduce heads mounted on the periphery of a drum rotated at high speed across a tape moving at 15 ips. This provided the high tape-to-head speed required with practical head gaps without getting into difficult tape handling problems and the use of very large reels. This type of machine was easily the most compact, and its flutter performance radically bettered that of the competing longitudinal scan machines. Unfortunately there were also amplitude and phase problems with the heads, reliability problems, and limited dynamic range. As tests and experiments progressed over the years, moreover, it became clear that the distortion products in the front end of any multiple signal, wideband system limited the bandwidth that could be recorded. That is, recording the spectrum as forty separate tracks of 100 kHz each provided a better product than a single track of 4 MHz.[19]

~~(C)~~ However, the compactness and portability of the rotary-head machine made it the preferred candidate for [redacted] collection locations, which, at one time, were expected to be the primary wideband collection sites. Thus the BURPEE/ZEAMAN systems were developed. BURPEE, the Acquisition Subsystem, consisted of a 4 MHz wideband receiver, the XR3-54D rotary head recorder, and a clock/time-code generator. The ZEAMAN Extraction Subsystem consisted of an XR3-70 rotary head recorder/reproducer feeding the recorded .05–4 MHz spectrum to an upconverter whose 4–8 MHz output could be searched by R-390 receivers. For better or for worse, little actual use was ever made of the BURPEE/ZEAMAN system because during 1966 the Agency decided little use would be made of [redacted] sites in "Store and Forward" operations. This made multichannel, longitudinal recorders the choice for wideband collection.[20]

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(U) The Agency developed KETCHUM, a Multitrack Acquisition Subsystem, and GOODMAN, a Multitrack Extraction Subsystem, in the late 1960s as the most effective system for collecting, storing, and replaying large portions of the HF spectrum. The objective of KETCHUM/GOODMAN was to develop a system that eliminated the known deficiencies of the AN/GSR-2 and AN/GSR-4 store and forward systems then in use and that provided a state-of-the-art capability.[21] Primary functional improvements desired were reduction of manpower needed to operate KETCHUM and reduction in tape shipping costs.

(U) Ampex developed the KETCHUM recorder, designated AN/TSH-6, under an NSA contract and delivered it in 1968, but the rest of the KETCHUM subsystem was developed thereafter. By the time subsystem service testing was completed and production initiated in 1973, a modified and updated version of the AN/TSH-6, the AN/USH-18, was substituted. Both 42-track machines used one-inch tape and operated at 15 ips. Forty tracks each furnished a 100 kHz data channel, and the other two carried a servo reference tone and the time code. Overall, KETCHUM (formally designated AN/FSQ-78) consisted of six racks of equipment. It reduced operator manning by inclusion of automation features and reduced shipping costs through the denser data packing on the tapes. Four systems went into field operations.[22]

~~(C)~~ About 1970 the "4 MHz Environmental Collection/Extraction System," Project SESAME, went into service test using 42-channel XR3-55 recorders. These recorders operated at 15 ips, used 12 1/2-inch reels, and servo control mechanisms to correct for flutter.[23] Ironically, as wideband magnetic tape recorders reached a mature, reliable stage of development, the tide of COMINT collection began to flow in another direction: rather than recording the spectrum for processing elsewhere, either a spectrum of signals or remotely collected narrowband signals could be relayed in real time via a communications satellite to the processing location.

SUMMARY

(U) In the quarter-century following the end of World War II, the role of magnetic recorders in COMINT activities went from that of nonexistence to being an essential, critical component. During this era magnetic tape recorder technology moved through much the same sort of ferment and rapid advancement that computers demonstrated in the succeeding generation. At base, the tape recorder made possible the off-line, not-real-time processing of intercepted signals. As the quantity of targeted signals increased and their structures became more sophisticated and more complex, the necessity for equally sophisticated, complex analysis and processing at NSA Washington and other rear-echelon locations became absolute.

~~(C)~~ Achieving the precision, reliability, economy, and unique applications needed in the various types of COMINT tape recorders involved many engineers and specialists at NSA with the commercial organizations developing tape recorders (and magnetic tapes) during this era. The close interplay between these two groups contributed significantly to the rapid, simultaneous advancements in magnetic tape recorder and magnetic tape technology, and it provided both enhanced capabilities and new collection techniques.

Notes

1. (U) S. J. Begun, *Magnetic Recording* (New York: Rinehart Books, Inc., 1954 - fifth printing), 2–10.

2. (U) R.E.B. Hickman, *Magnetic Recording Handbook* (London: George Newes Limited, second edition, 1958), 5–6.

3. (U) Erick Barnouw, *The Golden Web* (New York: Oxford University Press, 1968), 204.

4. (U) Begun, 10.

5. (U) *Summary Technical Report of National Defense Research Committee (NDRC)*, Vol. 3, "Speech and Facsimile Scrambling and Decoding." NDRC 1946, 13–17.

6. (U) Barnouw, 240–241.

7. (U) NSA letter, serial M22/202, dated 6 February 1962, Subj: SIGINT Collection and Analysis Equipment Available for Procurement during FY63 and FY64.

8. (U) NSA, "A Brief Description of the MOSE System Concept and its Evolution" by Ray Bowman, K25, October 1961, 2.

9. (U) Memorandums for Record, Subj: Single Channel Evaluation of Audio and Binary Tapes, dated 15 August 1958, signed by [redacted] COLL-22; and Subj: Evaluation of Binary vs. Audio (Flex), dated 15 August 1958; unsigned, but probably also [redacted]

10. (U) Monthly Progress Report #1 (May 1962) by Westinghouse Electric Corporation for Contract #DA18-119-sc-2622.

11. (U) Westinghouse Electric Corporation Specification for Serial Data Recording System, Code 89661, Drawing #380A686, dated 14 June 1962.

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12. (U) Memorandum R33/M40 from R33 to M22 [redacted] Subj: Recommendation for Sole Source Procurement of the XR3-44 Serial Data Recording System, dated 31 May 1962, signed by J. Kenneth Lewis, Chief R33.

13. (U) Memorandum for Record, Subj: Integration of Serial Binary/Analog Recorder and IBM Parallel Recorder in the Bauded Signal Receiving System, dated 30 July 1962, signed by J. M. Gallo, C1221.

14. (U) NSA Monthly Operational Summary, R65, for December 1972.

[redacted]

16. (U) Technical Development Plan for Wideband Intercept and Processing Systems, Task 330-5300 (EAGLE), dated 1 August 1963; prepared by J. Kenneth Lewis, Chief R33, 4.

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17. (U) Ibid., 5.

18. (U) Ibid., 4. Flutter refers to the minute, rapid fluctuations in the movement of the tape through the transport, thereby changing the frequency. (For instance, with 0.2 percent flutter, a 100-kHz signal would be offset by 200 cycles during playback.) The range of amplitudes of intercepted signals is much greater than 30 db. Signals exceeding the dynamic range of the recorder cause distortion products in the recording.

19. (U) Ibid., 7.

20. (U) NSA Technical Development Plan No. TR-R82/02/67, "Store and Forward System," dated 19 April 1967.

21. (U) Ibid.

22. (U) Variously from ADST Memorandum to HF Study Group, Subj: "RDT*E associated with the HF Spectrum," Serial D92/11/72, dtd 11 February 1972 with inclosed KETCHUM/GOODMAN Report; R Monthly Operational Summary for February 1973, item "374-5352-130 Multitrack Recorder/Reproducer," written by A. [redacted] Project Engineer; and "Integrated Logistics Support Plan for Project KETCHUM (AN/FSQ-78)" forwarded by ACL, under Serial:N 0519, dated 10 May 1973, same subject.

23. (U) "Project SESAME, Preliminary Collection Sub-System Description," dated 8 July 1968, otherwise unidentified NSA paper.

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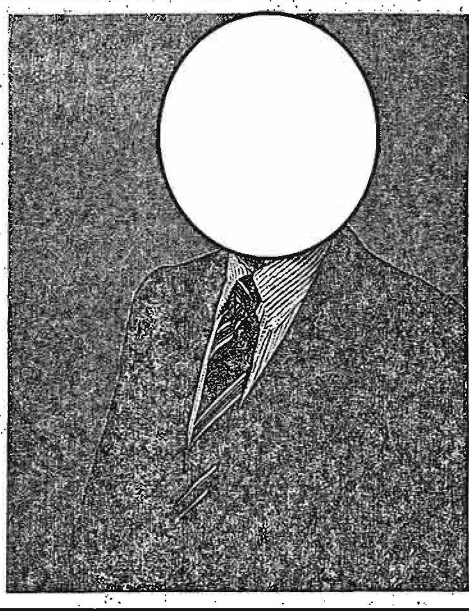

~~(S-CCO)~~ [redacted] retired from NSA in 1992 and has been a volunteer with the Center for Cryptologic History since then. During his career, which began in 1954, [redacted] held various engineering, management, and field support positions. He served four years in [redacted] and as [redacted] for the first [redacted] remote system on [redacted] during 1974–75. [redacted] was with the Naval Security Group for two years before joining NSA. He holds a bachelor's degree in electrical engineering from North Carolina State University and was professionalized as an Engineer.

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(U) Mr. Gallo retired from NSA in 1988 after a thirty-five-year career with the Agency. He is currently serving as a volunteer in the Center for Cryptologic History. During his career, Mr. Gallo held numerous supervisory positions in organizations dealing with signals collection systems. He holds a B.S. degree from the City College of New York and is a graduate of the Armed Forces Staff College. Mr. Gallo was professionalized as an Electronic Engineer.

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