Historical Notes on Radioteletype

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R. A. Heising of AT&T contributed a paper to Journal of the Franklin Institute vol. 193, no. 1, January 1922, p. 97 titled "Printing Telegraph by Radio." This presents the results of AT&T experiments transmitting between New York City and Cliffwood, New Jersey, a distance of 25 miles. The experiments were done in 1919, using a wavelength of 450 meters (666 KHz). The operating speed was 180 wpm, using a four-channel time-division multiplex at 45 wpm per channel. He noted that the principal source of interference in NYC came from spark transmitters.

Federal Telegraph Co. conducted experiments on the West Coast USA circa 1920 using frequencies in the 35-70 KHz range. [RTTY Magazine, April, 1955, p. 7.] Their transmitter used a Poulsen arc, and therefore was frequency shifted rather than keyed on and off; however no use was made of the properties of FSK. It was simply too hard to key the arc on and off. The path was between Hillsboro, OR and the KFS site near San Francisco. The test results were not sufficiently good to recommend the system for revenue service.

John B. Brady received four patents on radioteletype
1,485,212 Filed Dec. 28, 1921 - Issued Feb. 26, 1924
1,523,377 Filed Aug. 14, 1923 - Issued Jan. 13, 1925
1,562,820 Filed Aug. 22, 1923 - Issued Nov. 24, 1925
1,563,958 Filed Dec. 28, 1921 - Issued Dec. 1, 1925

These patents are assigned to the Morkrum Co.; however Brady's residence is given as Somerset, Maryland so he must not have been a regular employee of Morkrum. All of these patents cover make-and-break keying of the transmitter. In the first of these he says that the system has been successfully operated between the U. S. Naval Aircraft Radio Laboratory at Anacostia, D.C. and the U. S. Naval Radio Research Laboratory, Bureau of

Standards, Washington, D.C. Points stressed in the first patent are:

- Use of printing telegraphy, not requiring skilled operators
- System is "substantially" secret in that signals cannot be copied by ear
- Code can be changed from time to time for increased secrecy.

The illustrations show a vacuum tube transmitter grid-block keyed by a relay connected to the keyboard contacts. The receiver has a regenerative detector followed by two stages of audio amplification. The final stage is tuned to a particular audio frequency, which is then applied to two paralleled triodes operating a relay in the printer circuit. An odd item is a series-tuned circuit shunting the relay, with a switch to disconnect it. There is an illustration of a tape strip printer with a typewheel inside. He gives a hand-waving description of the Morkrum machine. He shows what look like single-magnet selector magnet coils, but doesn't show what goes on between these coils and the rest of the machine; so it is not clear whether this is a machine with a single-magnet selector. The coils are identified as "teletype coils", showing that the word "teletype" was in use at this early date.

Patent 1,523,377 shows a system in which teleprinter signals are transmitted by radio to any of a number of receiving printers. Circuits are shown for both make-and-break keyed transmitters and transmitters modulated with audio tones. A principal feature of this patent is use of signals at one frequency to transmit the intelligence and signals at a slightly different frequency to control the motors of the receiving printers. With the make-and-break transmitter the start-stop keyboard key is arranged to change the transmitter frequency slightly. With the audio modulated transmitter the tones are generated by buzzers at two different frequencies, one for the message signals and the other for motor control. Hence the receiver may or may not need a heterodyne oscillator to produce an audio signal from what it receives.

The receiver employs a sharply-tuned filter to detect the motor control frequency. The motor control detector drives a plunger-type solenoid relay which reverses each time it is energized, so that one signal turns the motor on and a second signal at the same frequency turns it off. The speed-governed motor uses electron tubes in its control circuit, the subject of another patent applied for by the same inventor. Presumably this is to reduce the RF noise generated by the motor governor. The message-signal-frequency channel of the receiver operates a relay which controls the teleprinter receiving magnet.

Points stressed are:

- One transmitter to any number of receiving stations
- Automatic (suggesting unattended) reception
- Motor control of receivers
- Selecting some groups of receivers to receive to the exclusion of others

The keyboard in the illustration looks something like a Model 14. The printer is not shown.

Patent 1,562,820 improves upon 1,563,958 by using an AC-powered receiver instead of a battery model. Power for the Teletype selector magnet is obtained from the same AC supply, as is power for the printer motor. He notes that AC-powered printer motors generate a lot of RF noise and that DC motors are superior in that respect; but you can run the motor off AC if you want to.

He says the application is receiving news from a central radio station, stresses the simplicity and compactness of the arrangement for installation in business houses, banks, between warehouses and large stores. Suggests use of very high frequencies (10 meters) allowing directional antennas and confining the transmissions to a particular area. "Teletype" is capitalized.

Patent 1,563,958 shows radio receiver including a tone detector driving a relay which operates a Teletype printer. It goes into some detail about the selector mechanism.

The Navy also did some experiments in air-to-ground radioteletype, documented in Scientific American, March 1923, p. 173. The illustration shows something like a Model 12 keyboard in the airplane and a Model 11 tape printer on the ground. The article states that the next experiment would be transmission from ground to air. The Bureau of Standards was also involved in this work, and perhaps Mr. Brady.

Lawrence Schmitt, an employee of Morkrum, received two patents
1,705,211 Filed Aug. 28, 1924 - Issued March 12, 1929
2,012,407 Filed June 13, 1932 - Issued Aug. 27, 1935

1,705,211:
This appears to be the original concept of frequency-shift-keyed radio- teletype operation. It shows teleprinter sending contacts, or a relay, connected to

a radio frequency oscillator-transmitter to shift the frequency slightly. Another circuit shows an audio frequency shift keyed oscillator modulating a radio transmitter. The receiver has a pair of audio tuned circuits, one tuned to mark and one to space frequency, each feeding a triode detector that drives one winding of a polar relay. A differential milliammeter allows for accurate adjustment to eliminate bias. The inventor explains why his system is superior to make-and-break operation for teleprinter use in terms of not having the inertia inherent in a neutral relay. He also refers to radio transmitters used for Morse and having a "compensating wave". These were transmitters which were frequency-shift keyed because that was easier than make-and-break; but the compensating wave (space) was not desired and was ignored. Indeed it had to be placed at a frequency far enough away from the intended carrier to enable it to be ignored. He proposes a shift of 250 Hz with spacing lower than marking frequency as an example, with a marking frequency of 230.50 KHz. The patent also mentions the possibility of a two-channel multiplex, although the exposition of this idea is not very clear. (Presumably it applies to amplitude modulating two audio FSK signals on a single radio frequency carrier, as there is no suggestion of the logic required to operate a transmitter shifting among four radio frequencies.)

It is interesting that John Brady's signature appears on this patent as attorney. Brady also wrote a regular column in Proceedings of the I.R.E. in the 1920s in which he summarized recent patents in the radio field.

2,012,407:
This is said to be an improvement on 1,705,211 above. More accurately it is an adaptation of that system for use with make-and-break keying. A shunt, consisting of a variable resistor in series with an inductor, is placed to produce a marking bias current through the relay equal to half the current when a spacing signal is being received. The space filter is tuned to the signal frequency, and the mark filter is tuned to a nearby frequency. The assertion is that static and noise will be received equally in both channels and will cancel out. This is aided by the inductor in the shunt circuit, which makes the shunt ineffective on transients so that they affect both windings of the polar relay equally.

A recent article by Mischa Schwartz of Columbia University [published in Antenna, the newsletter of the Mercurians, a sub-group of the Society for the History of Technology, October 2007] calls attention to a paper by Armstrong, "Methods of Reducing the Effect of Atmospheric Disturbances", Proceedings of the I.R.E., January 1928, p. 15 (with discussion on p. 27). In this paper Armstrong proposed something very similar to Schmitt's patent - use of separate marking and spacing frequencies for telegraphy, and subtracting outputs from the two detectors. Like Schmitt, Armstrong makes the intuitive assumption that noise will affect both frequencies more or less equally and cancel out when the signals are subtracted. Note that in this application Armstrong was not yet using a limiter ahead of the mark and space filters, so that it is not true FM as he developed later. Schwartz then references a paper by Carson of AT&T, "The Reduction of Atmospheric Disturbances", Proceedings of the I.R.E., July 1928, p. 966. in which Carson argues that Armstrong's scheme is not effective in cancelling noise. Yet Armstrong had supplied ink recordings showing the superiority of two-tone operation. It seems that for a fair comparison the two-tone scheme should be compared with make-and-break transmission at twice the power, because of the 100% duty cycle of two-tone versus the approximately 50% duty cycle of make-and-break. Carson indeed suggested that an advantage might be had by transmitting the message twice so as to use the same power as the FSK proposal. I'm not clear whether he meant to transmit two copies on two different frequencies, or on the same frequency at two different times. He does note that the FSK transmission involves twice the receiver bandwidth of the single-channel transmission.

It seems to me that Carson's critique of Armstrong's proposal needs to be tempered by instrumental considerations. Copying Morse code signals by ear makes use of the operator's training and the marvelously complex human auditory system to separate the signal from the noise. Copying with an ink recorder bypasses all that with a fairly simple electronic circuit, but still preserves some of the analog nature of the signal. Operator skills still come into play, in a reduced way. For reception by automatic printer the incoming signal must operate a relay, which eliminates all human ability from the process and substitutes simple electronics. FSK may be a greater help in this situation that is apparent from theoretical considerations of signal to noise ratio. The relay transitions in one direction when the marking channel signal exceeds the spacing channel signal, and in the opposite direction when the opposite signal conditions are true. With make-and-break keying the relay has to be biased somewhere between the noise level and the expected signal level.

It seems unlikely that Schmitt and Armstrong were aware of each other's work. The main point of Schwartz's article is that Armstrong went on to employ a limiter; and by that means the noise-reduction ability of FM was realized.

Gilbert Vernam of AT&T received patent 1,622,297 Radioprinting telegraph system Filed Dec. 29, 1924 - Issued March 29, 1927

The radio receiver is shown only as a block. An A.C. power supply is shown; and the printer is shown as having an A.C. motor. Like Brady, he suggests "there may be a demand for a radio printer service in which the news matter would be broadcast from a central transmitting station to the newspapers subscribing for such service." Make-and-break operation is used. The detector tube operates a polar relay which drives the printer magnets - a polar printer magnet is shown. An extra winding of the polar relay is connected to the secondary of a "kick" transformer, the primary of which is in series with the operate winding of the polar relay. This is intended to insure quick operation of the polar relay.

Frederick G. Hallden received patent no. 1,864,303 assigned to Postal Telegraph for Radio Printing Telegraph System Filed April 27, 1928 - Issued June 21, 1932.

The radio equipment is shown only in block form. The essence of the invention is to transmit each character three times, from a rotary distributor having three sets of segments. A character received the same all three times will be printed. If the character is not received the same all three times only the marking pulses which agree will appear in the printed character. "It is well known that static can only cause marking pulses..." which shows that he is talking about make-and-break keying; for with FSK static would affect marks and spaces more or less equally. A lot of relays are used at both transmitter and receiver.

Austin Bailey and T. A. McCann of AT&T contributed a paper to Bell System Technical Journal vol. 10, October 1931, p. 601, "Application of Printing Telegraph to Long-Wave Radio Circuits." This was a paper presented at the 6th annual convention of Institute of Radio Engineers. Notes the need for better signal-to-noise ratio for printing telegraphy compared with aural Morse operation. It cites advantage of two-tone operation over single-tone. As with the Schmitt patent, two-tone operation is analogous to polar operation of a wire circuit in preventing bias resulting from varying signal strength. Discusses experiments conducted on a 60KHz carrier circuit between New York and London, using a power of 50KW. Directive antenna systems helped to combat noise. Further tests were conducted in 1930 between Rocky Point, Long Island, and Rochester, NY, a distance of 286 miles. Power was 700 watts.

I have a picture of the Morkrum plant site, 1400 Wrightwood Ave., Chicago, when part of it was a vacant lot. This shows some antennas being erected for radioteletype tests with Lake Geneva, Wisconsin. The word from Walt Zenner, by way of Bob Reek, is that there were radio experiments between the Morkrum plant and Sterling Morton's home in the western suburbs of Chicago. Also that when Walt arrived at Teletype, Schmitt was the plant engineer, responsible for utilities and the like. Nothing came of his radio work. I presume that when Teletype was an independent company it was scrambling for business wherever it could be found. After the purchase by AT&T it was viewed as an equipment manufacturer; matters involving transmission were on AT&T and later Bell Labs' turf.

It was reported in Telegraph and Telephone Age, October 1, 1932 that RCA Communications Inc. was using radioteletype between San Francisco and Hawaii, with plans to extend the use of RTTY in the immediate future. A paper by Moore of RCA [Accuracy and Speed on Short-Wave Teleprinter Services; John B. Moore; Proceedings of the National Electronics Conference, Chicago, 1953, pp 927-934] confirms the use of radioteletype on the San Francisco to Hawaii Circuit and notes that it was not possible to use radioteletype on the Atlantic circuits at that time. Morse operation was faster, up to 300 words per minute versus 60. Time- division multiplex was employed starting about 1935 to allow teleprinter operation to compete with Morse. An error-detecting code was developed and used from 1939 until 1947. Post World War II a system called ARQ (automatic request for retransmission) was developed, based on the error detecting code. With this system a receiving station detecting an error in incoming traffic signals the sending station to retransmit the text that was received in error. Systems based on this principle continue in use today: for example the SITOR system used in marine communications. With microcomputers it is extremely simple to implement such a system.

Moore goes on to note the increased need for record communication by radio during World War II, met by frequency-division multiplexing over single sideband radiotelephone circuits, and the development of frequency shift keying. RCA developed a two-channel time-division multiplex that was more tolerant of signal distortion than a single-channel teleprinter.

Press Wireless, Inc. was also active in exploiting frequency shift keying for teleprinter operation over radio. A paper [Frequency Shift Radiotelegraph and Teletype System; Robert M. Sprague; Electronics, Nov. 1944, pp. 126-131] notes that company's use of FM for facsimile transmission followed by the use of FSK for telegraph transmission. This article shows that a limiter-discriminator scheme was in use. Hence performance in the presence of noise and interference is governed by FM principles rather than by those of limiterless two-tone systems. He notes the adoption of 850 Hz as the standard for frequency shift, saying that gives the best compromise between signal-to-noise ratio and bandwidth. There is some discussion of the bandwidth requirement of make-and-break keying, which is considerably greater than than the theoretical requirement because of squaring of the waveform in the transmitter. I suspect that such a wide shift as 850 Hz was also helpful in coping with frequency drift of transmitters and receivers in that era. This conjecture is supported by their use of A-C coupling between the discriminator and the loop keyer, with a threshold correcting circuit in between.

Probably the best known RTTY equipment of World War II is the AN/FGC-1 diversity FSK converter and its companion AN/FRR-3 diversity receiver. These units were manufactured by Western Electric using typical telephone style construction, apparatus mounted on flat plates, each unit occupying a 7-foot rack cabinet. Hence the units are largely for fixed-station use and on fixed frequencies. The Navy had some RTTY demodulators operating at the receiver intermediate frequency rather than at audio frequency.

Use of RTTY in amateur radio seems to have begin in the late 1940s in the New York City area. The reason seems to have been a confluence of amateurs having knowledge of military radioteletype during World War II and the availability of teleprinters. The New York Police Department had a network of Model 12 machines, which they had to replace because maintenance parts were no longer available. News wire services were replacing their Model 12 machines for the same reason. Amateurs were able to acquire these antiquated machines. They were put into operation on 2 meters using AFSK. The main reason was that FSK was not authorized for amateurs on the HF bands. A secondary reason was that the Model 12 was a prodigious generator of RF noise that made HF reception extremely difficult. Amateurs trying to operate Model 12 machines on HF resorted to measures such as vacuum tube keying of the code magnets and the governed motors.

For some reason, in spite of the huge amounts of radio equipment sold as war surplus, there was hardly any Teletype equipment. Perhaps the U.S. military needed to retain all its teleprinters as it phased out Morse operaton; perhaps foreign governments outbid the surplus dealers; perhaps the surplus dealers just didn't imagine any market for Teletype equipment. The New York hams did have access to a trickle of Western Union surplus, little of which was readily usable.

The New York area operators tended to run high power on VHF. Perhaps there was some scatter propagation augmenting line-of-sight. John Williams W2BFD designed an AFSK converter that was duplicated by a number of the New York hams. Another feature of the New York area operation was timed autostart. Stations would arrange to have their equipment turned on for a few minutes at the beginning of certain hours, under control of clocks. During that time they could receive messages unattended.

There was some experimentation on HF using make-and-break keying. FSK was allowed only on the 11-meter band until 1953, when privileges were extended to the CW-only portions of all the HF bands. Shift of 850 Hz and speed of 45.45 baud were required by the FCC rules.

Amateur RTTY suffered indifference, if not hostility, from ARRL. One reason was the bandwidth occupied if FSK were to be used. Why occupy nearly a kilohertz (using the required 850 Hz frequency shift) to transmit at 60 wpm when CW could operate almost as fast (assuming a skilled and talented operator) in a lot less bandwidth? The CW operators didn't appreciate having their band segments occupied by the relatively wide RTTY signals. Another reason I think was that ARRL discouraged the use of any technology that the amateur could not build himself; that certainly included a teleprinter. In the same vein ARRL tended to ignore military surplus equipment. There was the official QST advertising policy that everything offered had to be new manufacture, not used or surplus. This situation did not change until RTTY achieved a considerable degree of popularity and ARRL-member hams began to demand more coverage in QST. (And perhaps until some of the older ARRL officials had retired.)

In the absence of much information in the ARRL official journal QST, most of the published information available to amateurs came through other channels.

- The publications of Amateur Radio Teletype Society, also known as V.H.F. Teletype Society, of the New York area.
- RTTY, the journal of the Southern California RTTY Society.
- A RTTY column in the magazine CQ, first written by Wayne Green W2NSD. Wayne was also for a time editor of the ARTS bulletin. Later he became editor of CQ and the RTTY column was taken over by Byron Kretzman W2JTP.

The ARTS publications came out rather irregularly and seemed to just fade away as time went on. RTTY ran from 1953 through 1966 as a labor of love of Merrill Swan W6AEE. Then it was sold to a more commercial publisher and continued into the late 1990s under various publishers. By then there were other digital modes in use; and RTTY operation was usually fully electronic rather than using a mechanical teleprinter. RTTY articles in CQ continued until 1965 or so. QST began giving major emphasis to RTTY about that time as a result of demands from the membership.

There was also personal contact, through organizations and one-on-one meetings, of RTTY-savvy amateurs with those wishing to get started. Nearly every large population center had an RTTY society in its area.

As noted earlier, the first teleprinters used by amateurs were primarily the obsolete Model 12 machines, and an assortment of other oddities. The communication companies had a policy of destroying any machines surplus to their needs, to prevent their being used in competition with their charged-for services. Amateur organizations entered into protracted negotiations with AT&T and its subsidiaries and eventually achieved agreements that surplus machines could be sold to amateurs. These sales all required that the buyer sign a waiver of any non-amateur use for the machine. In the mid 1950s the telephone companies began releasing quite a few Model 26 machines. These were page machines originally used in Bell's TWX service. They were made in the late 1930s in an attempt to have a lower-cost light-duty machine that could replace the heavy-duty Model 15 in TWX service. The expected economies were not achieved; so after World War II AT&T decided that Teletype could quit supporting them with maintenance parts and that they would be phased out of service. A trickle of Model 15 machines came into amateur hands as well. Well-heeled amateurs could obtain the latest Model 28 machines, the new Bell System and industry standard, principally for individuals who refurbished them from junked equipment. One prominent refurbisher was Ray Morrison, W9GRW. Later there was Model 28 equipment being surplused by the telephone companies, probably as a result of the transition to ASCII equipment.

The standard commercial and military method of generating FSK signals through the 1940s and 1950s was to use a 200 KHz L-C oscillator with reactance tube modulation to vary the frequency. The desired output frequency was obtained by heterodying a crystal oscillator with the 200 KHz oscillator, and in some cases by frequency multiplication from a lower frequency. This method of modulation was fairly linear, so the equipment could be used for

FM facsimile transmissions as well as for FSK. Amateurs used a much simpler arrangement, a diode which could be biased on or off to switch a slight reactance into a variable frequency or crystal oscillator to shift its frequency. Varying the bias allowed varying the shift, albeit not linearly.

The standard commercial, military and amateur method of receiving FSK signals through the early 1960s was the FM limiter-discriminator circuit, followed by a trigger circuit to provide solid mark and space signals to the teleprinter or other equipment. Unfortunately the usual amateur designs were somewhat faulty, based on some misunderstandings of filtering. Don Wiggins W4EHU, a professor at University of Florida, attempted to set things right with articles in RTTY in 1960 and 1963. He explained why any narrow filtering needed to go ahead of the limiter, and why the discriminator should be linear far beyond the mark and space frequencies. Sprague had stated this principle in his 1944 article but did not explain the reasoning behind it.

Some Post Office workers in England published a paper in 1957 on non-FM detection of FSK signals, treating mark and space as a frequency diversity pair of on-off keyed signals. In a sense this was a reversion to the early ideas of Armstrong and Schmitt, but with more involved ways of combining the two signals. An amateur terminal unit without a limiter had been described by Gates in RTTY in 1954, but had attracted little attention. The idea hit the amateur community in full force about 1963. Thereafter it found its way into FSK converters designed mostly by amateurs but marketed to commercial and government customers.

FSK RTTY was still in use by a lot of non-amateur services in the 1950s-1960s. With amateur equipment and a general-coverage receiver one could copy news wire service material and some unencrypted military and commercial traffic. With the advent of satellites and fiber optic cables this gradually dried up. About all that is left today is some meterological traffic and broadcasts from North Korea.

As electronic technology has advanced so spectacularly in recent years the mechanical teleprinters have fallen by the wayside, except for nostalgia reasons. First we had active filters and video terminals based on personal computers. Then came digital signal processing on specialized DSP engines; and then personal computers became powerful enough to do digital signal processing without extra hardware on the side. New modulation methods are continually being invented, all offering some improvement over two-tone FSK. Baudot RTTY continues to be used in amateur radio, but only in two niches: contesting and DX (distant station) chasing. For other purposes the newer modulation methods generally offer much better performance than RTTY.

Disclaimer: The above is not the result of an exhaustive search of patents and literature pertaining to radioteletype. Rather it is material I ran across while searching for other things. The above should be considered a work-in-progress. J.H.