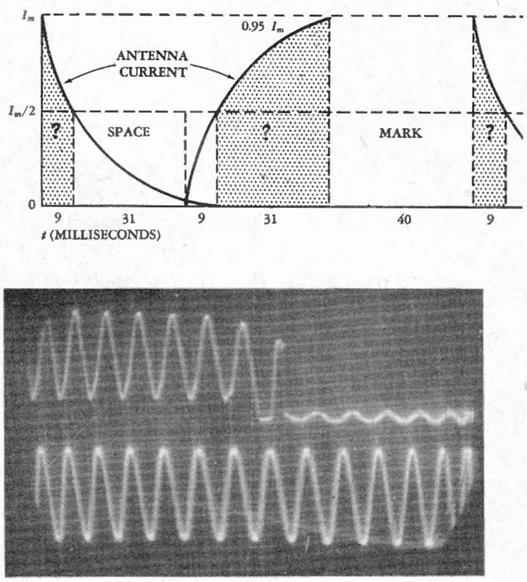
nel notes:

high-speed keying of vlf radio circuits

a



b

FIGURE 1—(a) Time variation of antenna current for 50 per cent ON-OFF keying, indicating energy storage in the antenna circuit. (b) Oscillograms of keying current (upper trace) and constant-amplitude antenna voltage (lower trace) for frequency-shift keying. Mark-to-space transition occurs within one r-f cycle.

The reliability of low and very low frequencies has long been utilized by the Navy to maintain continuous contact with ships at sea through scheduled Fox broadcasts. Effective as these broadcasts have been, they have suffered the restrictions of the low transmission speeds inherent in conventional LF and VLF on–off keying. A solution to the problem of increasing transmission speeds to permit automatic keying seems to lie in a unique frequency-shift keying method developed by the U. S. Navy Electronics Laboratory.

On-off keying at LF and VLF is necessarily slow because, in antennas such as those used at many existing Navy LF and VLF shore installations, the ratio of the energy radiated to energy stored is very small. The energy stored in a VLF antenna system can be several hundred times that which is being radiated. When the key is opened, the energy which has been stored in the antenna system continues to be radiated until it is gradually dissipated by radiation and circuit losses. When the key is closed, the antenna circuit starts storing energy again while the antenna current is gradually built up to the level where power is radiated at a rate equal to that supplied by the transmitter.

In receiving on-off keyed transmissions, it is necessary to distinguish with reasonable certainty two amplitudes, one representing mark and the other space. Assuming a given noise level, the power for mark must be approximately 6 db over that for space to fulfill this requirement. The intervals required for the antenna power to build up and decay during on-off keying are shown in figure 1A. Between each space and mark there is a "region of uncertainty" during which a mark cannot be reasonably distinguished from a space. A maximum limiting keying speed will be reached above which the region of uncertainty becomes too large a fraction of the total keying period. Calculations made for one VLF shore station indicate that at 15 kc the maximum keying speed will be limited by a mark or space time duration of about 40 milliseconds, allowing equal times for mark, space, and uncertainty. Ascribing one-half the uncertainty to mark and one-half to space, the dot length of 60 milliseconds is then equivalent to a keying speed of about 18 (Morse) words per minute. The build-up and decay times thus determine the permissible keying speed of the antenna circuit.

By the frequency-shift keying method developed at NEL, power level is not varied. Instead, the reactance of the antenna circuit is varied in synchronism with the frequency-shift modulation of the carrier frequency. In tests made with an experimental 100-watt transmitter keyed by this method, successful tranmission of 60-wpm teletype was realized, and two-condition speech transmission was accomplished under conditions of negligible noise.

Subsequently, a 10-kw frequency-shift keyed transmitter and antenna modulating equipment (operating at 28.5 kc with 100 cps shift) were used in conjunction with the low frequency antenna at NCS, Chollas Heights, California. Successful 60-wpm printing telegraph transmissions were made using this transmitter. Radio San Francisco (approximately 500 miles away) reported S5, R5. Signals were entirely suitable for frequency-shift keyed teleprinter operation.

Development has been underway to apply high-speed keying to the Chollas Heights transmitter. The maximum keying rate so far achieved with this method is 460 wpm (see fig. 2). Thus, it is possible to predict performance for such applications as time-division teletype multiplex.

Adaptation of existing LF and VLF shore stations for the proposed method of frequency-shift keying will be economical. Traffic handling capabilities can be at least tripled, while the cost of the modulator should approximate not more than ten per cent of the cost of the transmitter. Standard Navy RBA receivers and AN/URA–8A converter equipment can be used with modification for high-speed Morse and teletype reception.

When Navy LF and VLF shore stations can be adapted to high-speed frequency-shift keying, less time will be required for transmission and reception of Fox schedules, and automatically keyed transmission and teletype reception will greatly reduce operator error and fatigue.

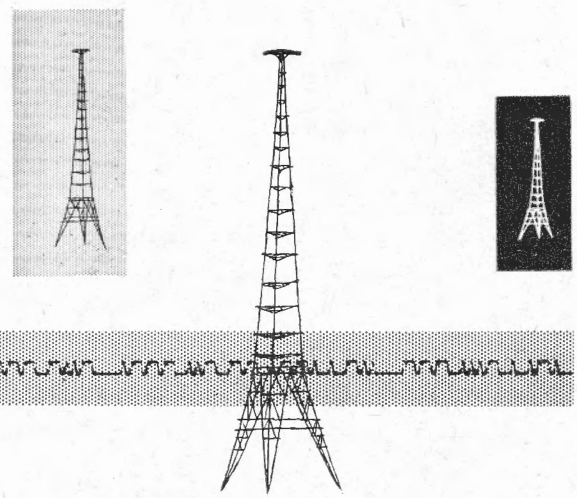


FIGURE 2—Sample of Morse tape signal received at a speed of 460 words per minute. Transmission made at 28.5 kc with a power of 10 kw.

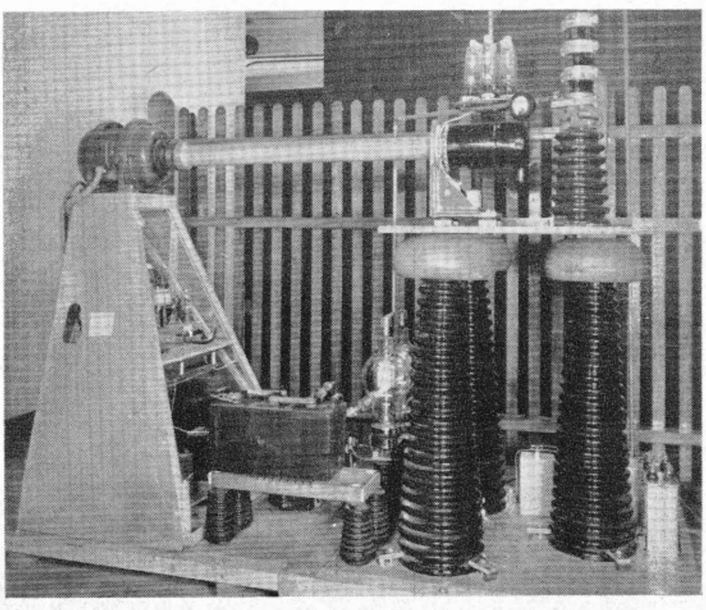


FIGURE 3—Antenna keyer unit of 10-kw transmitter used in frequency-shift keying experiments at NCS, Chollas Heights, California.