A Simple Technique for the Generation of Short Rectangular RF Pulses from a CW Source*

A gated traveling wave amplifier or klystron amplifier can be used to produce pulses from an essentially CW source. In the case of the TWT amplifier, rise times as short as a few millimicroseconds have been observed.[1] This communication points out how millimicrosecond RF pulses have been produced using an inexpensive mercury contact switch installed in the center conductor of a coaxial line. The first use of a mercury contact switch for discharging a transmission line to generate rectangular dc pulses was reported by Garwin.[2] Such pulsers based on this switch are now commercially available. With an appropriate transmission line configuration using the switch in the center conductor, RF pulses can be generated from a CW source. With reference to Fig. 1, the switching element from a Western Electric 276 mercury contact relay was removed and installed in the $\frac{3}{8}$-inch center conductor of a 50-Ω rigid transmission line. The active element of the switch is caused to move from one set of contacts to the other by a 60 cycle magnetic field. Fig. 2 shows the complete assembly. Reading from the bottom up, we have, first, the switch assembly, with a solenoid for actuating it, connected to an RF generator; then a section of variable length line so that a current maximum of the standing wave pattern may be placed at the switch contacts; then a section of line with a side arm T for the output signal; above this is a variable short.

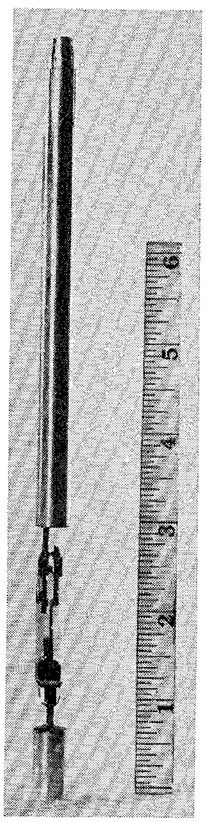

Fig. 1—Mercury contact relay element in center conductor of 50-Ω coaxial line.

The pulser operates as follows: with a CW generator connected at the switch end and the switch contactor at rest (either open or closed), the variable short is placed so that a minimum signal is detected at the side arm of the T. When the switch contact changes position, an abrupt change in RF takes place (completed in approximately 1n μsec). This steep wavefront propagates to the T where it divides, one half the transmitted power going each way and some being reflected from the T; that portion of the wave reflected from the short returns to the side arm and nullifies the signal there in a time equal to the round trip path from the side arm to short and back divided by the velocity of propagation in the line. Further reflections take place but gating of an oscilloscope beam can be used to remove them from the picture. This device has been successfully operated at 3000 Mc. At this frequency, the open circuit impedance of the switch is approximately 50-Ω capacitive reactance; so about $\frac{1}{2}$ of the generator voltage ($\frac{1}{4}$ of its available power) goes into the pulse immediately after the switch. With 50-Ω line used throughout, only $\frac{4}{9}$ of this power appears at the output; that is, the output pulse power (peak or average) is $\frac{1}{9}$ of the available generator power. This situation could be improved by using lower impedance line or an especially designed switch. At the time these tests were performed, the observed output pulse (envelope) width was limited by the amplifiers in a Tektronix 517 oscilloscope. This produced a pulse about 14n μsec wide.

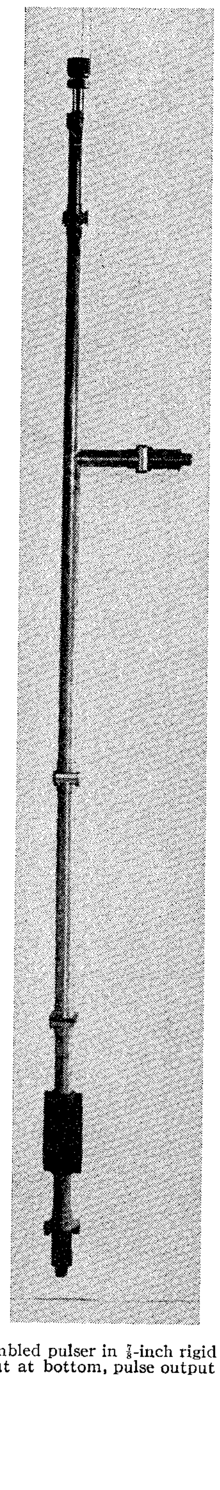

Fig. 2—Assembled pulser in $\frac{3}{8}$-inch rigid 50-Ω coaxial lnei CW input at bottom, pulse output at side arm.

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* Received September 20, 1963. This work was performed with joint armed services support while the author was at Harvard University, Cambridge, Mass.

[1] A. C. Beck, "Waveguide investigation with millimicrosecond pulses," *Bell Sys. Tech. J.*, vol. 35, pp. 35–65; January, 1956.

[2] R. L. Garwin, "A pulse generator for the millimicrosecond range," *Rev. Sci. Instr.*, vol. 21, pp. 903–904; November, 1950.

Propagation on Modulated Corrugated Rods*

In reviewing the literature on the subject of modulated surface wave antennas, we came across the paper "Propagation on Modulated Corrugated Rods" by C. C. Wang and E. T. Kornhauser[1] in which the authors study, both theoretically and experimentally, slow-wave propagation on modulated corrugated rod structures excited in the circularly symmetric TM mode.

We have noticed that the experimental results reported do not verify the presence of stop bands expected in the dispersion curves of slow-wave structures of this type and predicted by the approximate theory developed by Wang and Kornhauser.[1]

The reason for this discrepancy seems to lie in the inadequacy of the theoretical analysis based on a quasi-stationary treatment employed by Wang and Kornhauser.[1] In this analysis, the axial propagation wavenumber on the modulated corrugated structure is taken locally as that of an unmodulated structure corresponding to the local geometry.

As a consequence, with the assumed periodic modulation, a Hill's equation (4)[1] results. This type of equation automatically predicts stop bands at the values of the

* Received October 21, 1963.

[1] C. C. Wang and E. T. Kornhauser, "Propagation on modulated corrugated rods," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. 10, pp. 161–165; May, 1962.

axial propagation constant (β) corresponding to (Floquet Index)

$$\beta d = n\pi \quad n = 0, \pm 1, \pm 2, \pm 3, \cdots,$$

d being the spatial period of modulation.

The absence of stop bands is explained with reference to Oliner and Hessel,[2] Hessel[3] and Blank.[4]

One finds that, in order for a surface wave to propagate on a modulated cylindrical structure, all space harmonics have to decay in the radial direction towards infinity. This requirement results in the following necessary condition for the existence of a surface wave:

$$d < \lambda/2$$

where d is again the spatial period of modulation and λ the free space wavelength at the operating frequency. If $d > \lambda/2$, the wave propagating along the cylindrical structure is no longer a surface wave but a leaky wave.[2] In the leaky wave region, in contrast to the surface wave region, the dispersion curves in general do not possess stop bands.[5]

From the data and dimensions supplied,[1] it is evident that both structures A and B employed in the measurements were operating in the leaky wave region over the entire range of test frequencies. The axial period of modulation for structure A was $1.2'' = 3.048$ cm while the operating frequency range was from $f = 8.3$–9.7 kMc or $\lambda = 3.6118$ cm to 3.0905 cm. Hence, in the entire frequency range under test for the structure A, $d > \lambda/2$, violating the necessary condition for surface-wave propagation. For the structure B, $d = 1.8''$ which is even larger than that of A.

The measured guide wavelength was presumably that of the slow-wave fundamental space harmonic ($n = 0$), while the fast-wave higher space harmonics were not detected. The attenuation constant α was evidently small enough so that within the length of the structure the field decay was not markedly noticeable.

The stop bands are expected to show up somewhere in the range $\lambda > 2.4''$ (6.1 cm) in which a surface wave could propagate.

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[2] A. A. Oliner and A. Hessel, "Guided waves on sinusoidally modulated Reactance surfaces," IRE Trans. on Antennas and Propagation, vol. 7, pp. S201–S208; December, 1959.

[3] A. Hessel, "Guiding and Scattering by Sinusoidally Modulated Reactance Surfaces," Polytech. Inst. of Brooklyn, N. Y., Research Rept. PIB-825-60; 1960.

[4] S. J. Blank, "Guided Waves on Reactance Modulated Cylindrical Surfaces," Grumman Aircraft Corp., Bethpage, L. I., N. Y., ADR 03-03-63.2; May, 1963.

[5] A. Hessel and A. A. Oliner, "Mode-Coupling Regions in the Dispersion Curves of Modulated Slow-Wave Antennas," Antennas and Propagation Internat'l. Symp., Boulder, Colo., pp. 104–108; July, 1963.