Deputy Chief, Radio Communication Branch; J. J. Egli, Chief, Radio Relay & Microwave Section; and especially to the group who co-operated in the measurements, C. E. Sharp, L. R. Battersby, E. A. Conover, and, particularly, A. Meyerhoff, who also assisted in the preparation of the material.

Standards on Pulses: Definitions of Terms—Part I, 1951*

COMMITTEE PERSONNEL

Standards Committee, 1950–1951

J. G. BRAINERD, *Chairman*
L. G. CUMMING, *Vice-Chairman*
A. G. JENSEN, *Vice-Chairman*

M. W. Baldwin, Jr.
R. R. Batcher
H. G. Booker
F. T. Budelman
W. G. Cady
P. S. Carter
J. W. Forrester
A. G. Fox
R. A. Hackbusch
J. V. L. Hogan
J. E. Keister
E. A. Laport
Wayne Mason
R. A. Miller
L. S. Nergaard
A. F. Pomeroy
George Rappaport
H. E. Roys
P. C. Sandretto
E. S. Seeley
R. F. Shea
J. R. Steen
Henry Tanck
Bertram Trevor
W. N. Tuttle
L. C. Van Atta
K. S. Van Dyke
D. E. Watts
Ernst Weber
L. E. Whittemore

Definitions Co-ordinating Subcommittee

A. G. JENSEN, *Chairman*
M. W. Baldwin, Jr.
P. S. Carter
E. A. Laport

Task Group on Pulse Definitions

C. J. HIRSCH, *Chairman*

R. H. Daugherty, Jr.
Harold Goldberg
W. M. Goodall
W. H. Huggins
Nathaniel Rochester
W. G. Tuller
C. M. Wheeler
W. T. Wintringham

I. INTRODUCTION

THE MEANINGS of commonly used terms in pulse work have often been a matter of disagreement. The IRE Standards Committee, faced with the fact that different technical committees proposed different definitions for the same term, and wishing to try to introduce uniformity where little has existed, set up a special task group with wide representation of special interests to propose standard definitions of terms concerned with pulses. Months of work by the task group and intensive critical review by the Standards Committee has led to results the first half of which are given below. These are necessarily compromises. The Standards Committee urges IRE members (a) to try to use the terms according to the definitions below, so that reasonable uniformity may be achieved, and (b) to take into account that in this particularly controversial region many compromises have been necessary so that favorite meanings and uses may appear not to have been considered, whereas in actuality it is unlikely that the very thorough review of the field has failed to unearth them for the Committee's consideration. The present set of definitions has been judged

* Reprints of this Standard, **51 IRE 20 S 1,** may be purchased while available from The Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y., at $0.50 per copy. A 20 per cent discount will be allowed for 100 or more copies mailed to one address.

sufficiently important to print at this time; it is hoped that the second half will be ready for printing within nine months.

Since many pulse shapes are possible, and a clear concept of the ones under discussion is desirable, it may be helpful to use drawings of pulse shapes, pulse times, magnitudes, durations, and the like, to show how these quantities apply.

In these definitions, linear superposition of pulses and possibly other waveforms is understood. Since it is possible to generate pulses whose characteristics may not seem to be adequately covered by the definition, it has been assumed that complex pulses can be analyzed in terms of more fundamental pulses and waveforms somewhat as a complex periodic wave can be considered as the sum of a fundamental and harmonics.

II. DEFINITIONS

Average Absolute Pulse Amplitude. The average of the absolute value of the instantaneous amplitude taken over the pulse duration.

Note—By "absolute value" is meant the arithmetic value regardless of algebraic sign.

Average Pulse Amplitude. The average of the instantaneous amplitude taken over the pulse duration.

Crest Factor of a Pulse. The ratio of the peak-pulse amplitude to the rms pulse amplitude.

Leading Edge Pulse Time. The time at which the instantaneous amplitude first reaches a stated fraction of the peak pulse amplitude.

Mean Pulse Time. The arithmetic mean of the leading edge pulse time and the trailing edge pulse time.

Note—For some purposes the importance of a pulse is that it exists (or is large enough) at a particular instant of time. For such applications the important quantity is the *Mean Pulse Time.* The *Leading Edge Pulse Time* and *Trailing Edge Pulse Time* are significant primarily in that they may allow a certain tolerance in timing.

Peak Pulse Amplitude. The maximum absolute peak value of the pulse excluding those portions considered to be unwanted, such as spikes.

Note—Where such exclusions are made, it is desirable that the amplitude chosen be illustrated pictorially.

Pulse. A variation of a quantity whose value is normally constant; this variation is characterized by a rise and a decay, and has a finite duration.

Note 1—The word "pulse" normally refers to a variation in time; when the variation is in some other dimension, it shall be so specified, such as "space pulse."

Note 2—This definition is broad so that it covers almost any transient phenomenon. The only features common to all "pulses" are rise, finite duration, and decay. It is necessary that the rise, duration, and decay be of a quantity that is constant (not necessarily zero) for some time before the pulse and has the same constant value for some time afterwards. The quantity has a normally constant value and is perturbed during the pulse. No relative time scale can be assigned.

Pulse Amplitude. A general term indicating the magnitude of a pulse.

Note 1—For specific designation, adjectives such as average, instantaneous, peak, rms (effective), etc., should be used to indicate the particular meaning intended.

Note 2—Pulse Amplitude is measured with respect to the normally constant value unless otherwise stated.

Pulse Amplitude, Average. See *Average Pulse Amplitude.*

Pulse Amplitude, Average Absolute. See *Average Absolute Pulse Amplitude.*

Pulse-Amplitude Modulation (PAM). Amplitude modulation of a pulse carrier.

Pulse Amplitude, Peak. See *Peak Pulse Amplitude.*

Pulse Amplitude, RMS (Effective). See *RMS (Effective) Pulse Amplitude.*

Pulse Bandwidth. The smallest continuous frequency interval outside of which the amplitude of the spectrum does not exceed a prescribed fraction of the amplitude at a specified frequency.

Caution—This definition permits the spectrum amplitude to be less than the prescribed amplitude within the interval.

Note 1—Unless otherwise stated, the specified frequency is that at which the spectrum has its maximum amplitude.

Note 2—This term should really be "Pulse Spectrum Bandwidth" because it is the spectrum and not the pulse itself that has a bandwidth. However, usage has caused the contraction and for that reason the term has been accepted.

Pulse Carrier. A pulse train used as a carrier.

Pulse Decay Time. The interval between the instants at which the instantaneous amplitude last reaches specified upper and lower limits, namely, 90 per cent and 10 per cent of the peak-pulse amplitude unless otherwise stated.

Pulse Duration. The time interval between the first and last instants at which the instantaneous amplitude reaches a stated fraction of the peak pulse amplitude.

Pulse-Duration Modulation (Pulse-Length Modulation) (Pulse-Width Modulation). A form of pulse-time modulation in which the duration of a pulse is varied.

Note—The terms "pulse-width modulation" and "pulse-length modulation" are also used to designate this system of modulation but the term "pulse-duration modulation" is preferred.

Pulse Duty Factor. The ratio of the average pulse duration to the average pulse spacing.

Note—This is equivalent to the product of the average pulse duration and the pulse repetition rate.

Pulse Frequency Spectrum. See *Pulse Spectrum.*

Pulse Interleaving. A process in which pulses from two or more sources are combined in time-division multiplex for transmission over a common path.

Pulse Interval. See *Pulse Spacing.*

Pulse-Interval Modulation. A form of pulse-time modulation in which the pulse spacing is varied.

Pulse-Length Modulation. See *Pulse-Duration Modulation.*

Pulse-Position Modulation (PPM). A form of pulse-time modulation in which the position in time of a pulse is varied.

Pulse, Radio-Frequency. See *Radio-Frequency Pulse.*

Pulse Regeneration. The process of restoring pulses to their original relative timings, forms, and/or magnitudes.

Note—In many devices, pulses may become distorted due to phase or amplitude distortion, limiting, or other processes. It is often desirable to restore the pulse to something resembling its original form before it has become so distorted that the original information which it contains is completely destroyed. This process is normally called pulse regeneration.

Pulse Repetition Frequency. The pulse repetition rate of a periodic pulse train.

Pulse Repetition Period. The reciprocal of the *Pulse Repetition Frequency.*

Pulse Repetition Rate. The average number of pulses per unit of time.

Pulse Rise Time. The interval between the instants at which the instantaneous amplitude first reaches specified lower and upper limits, namely, 10 per cent and 90 per cent of the peak-pulse amplitude unless otherwise stated.

Pulse Spacing (Pulse Interval). The interval between the corresponding pulse times of two consecutive pulses.

Note—The term "pulse interval" is deprecated because it may be taken to mean the duration of the pulse instead of the space or interval from one pulse to the next. Neither term means the space *between* pulses.

Pulse Spectrum (Pulse Frequency Spectrum). The frequency distribution of the sinusoidal components of the pulse in relative amplitude and in relative phase.

Note—The definition of this term was phrased to convey the idea that the spectrum is a complex (phasor) function of frequency and to express this function most nearly in a manner which corresponds to the method of measuring it (i.e., measuring amplitude and phase separately).

Pulse Spike. An unwanted pulse of relatively short duration superimposed on the main pulse.

Note—This term came into wide use in radar to define the first part of the pulse fed through a TR tube. This portion contains most of the pulse energy, has a duration about 10^{-3} that of the rest of the pulse, and an amplitude up to 10^{6} to 10^{9} times that of the rest of the pulse. Seen on a cathode-ray tube, it looks like a spike sticking up from the pulse. By extension, the term has come to be applied to any *unwanted* pulse of relatively short duration superimposed on the wanted pulse.

Pulse Time, Leading Edge. See *Leading Edge Pulse Time.*

Pulse Time, Mean. See *Mean Pulse Time.*

Pulse-Time Modulation. Modulation in which the time of occurrence of some characteristic of a pulse carrier is varied from the unmodulated value.

Note—This is a general term which includes several forms of modulation, such as pulse-duration, pulse-position, pulse-interval modulation.

Pulse Time, Trailing Edge. See *Trailing Edge Pulse Time.*

Pulse Train. A sequence of pulses.

Pulse, Unidirectional. See *Unidirectional Pulse.*

Pulse-Width Modulation. See *Pulse-Duration Modulation.*

RMS (Effective) Pulse Amplitude. The square root of the average of the square of the instantaneous amplitude taken over the pulse duration.

Radio-Frequency Pulse. A radio-frequency carrier amplitude-modulated by a pulse. The amplitude of the modulated carrier is zero before and after the pulse.

Note—Coherence of the carrier (with itself) is not implied.

Trailing Edge Pulse Time. The time at which the instantaneous amplitude last reaches a stated fraction of the peak pulse amplitude.

Unidirectional Pulse. A pulse in which pertinent departures from the normally constant value occur in one direction only.

Note—This is sometimes called "single-polarity" pulse, a term which is deprecated.