GENERAL RADIO COMPANY

engineering department

INSTRUMENT NOTES

IN-105 JULY, 1965

THE FREQUENCY SPECTRUM OF A TONE BURST

The advantages and disadvantages of pulses and of continuous tones as test signals are well known. A relatively new type of test signal – the tone burst – is winning increasing acceptance because its characteristics lie between those of pulses and continuous tones. In evaluating the tone burst, it is useful to compare its spectrum with those of a pulse and of a continuous tone.

Characteristics of a spectrum of a tone burst.

1. Components at 1,2,3, etc. times the repetition rate of the burst.
2. Maximum amplitude at the frequency of the sinusoidal part, f.
3. Zeros in the envelope (missing components) at intervals of f/(no. of cycles in burst) about f.
4. "Bandwidth" of spectrum is inversly proportional to numbers of cycles in the burst.
5. Phase coherence is required to produce consistent spectra for bursts with few cycles in burst.

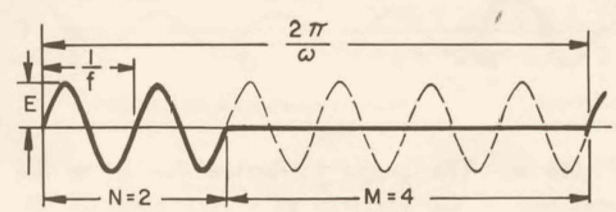

Figure 1. Sine-wave tone burst of two cycles on, four cycles off. Frequency spectrum is given by:

$$\epsilon(t) = \sum_{n=1}^{\infty} a_n \sin n\omega t$$

A sinusoidal tone burst signal is shown in Figure 1. It is formed by essentially "turning on and off" (gating) a sinusoidal signal. We are concerned with tone bursts which are on and off for whole numbers of cycles.

The Fourier frequency spectrum of a tone burst consists of discrete components at the burst repetition frequency and its harmonics, as follows:

$$e(t) = \sum_{n=1}^{\infty} a_n \left\{ \begin{matrix} \sin \\ \cos \end{matrix} \right\} n\omega t$$

where, $e(t)$ = tone-burst signal voltage

a_n = amplitude of the nth harmonic

n = harmonic number

ω = 2π x repetition frequency of the tone burst $= \frac{2\pi}{N+M} f$

N = number of cycles in the burst

M = number of cycles between bursts

f = frequency of the sinusoidal signal in the burst

The sine series is used for a sine tone burst (see Figure 1) and the cosine series for cosine tone bursts (see Figure 2).

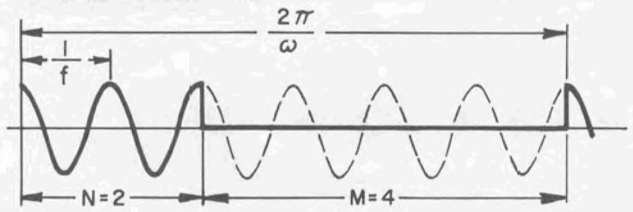

Figure 2. Cosine-wave tone burst of two cycles on, four cycles off. Frequency spectrum is given by:

$$\epsilon(t) = \sum_{n=1}^{\infty} a_n \cos n\omega t$$

The amplitude of the harmonic component, a_n, is given by the following equation:

$$a_n = E \frac{N}{N+M} \left(\frac{\sin x}{x} \mp \frac{\sin y}{y} \right)$$

where, E = amplitude of the sinusoidal signal

$$x = N\left(\frac{n}{N+M} - 1 \right)\pi$$

$$y = N\left(\frac{n}{N+M} + 1 \right)\pi$$

This equation for the envelope of the spectrum can be considered in three parts:

$$a_n = E \frac{N}{N+M} \left(\frac{\sin x}{x} \mp \frac{\sin y}{y} \right)$$

scale factor main part phase correction

a. the scale factor, which is the product of the amplitude of the sinusoidal signal, E, times a duty-ratio factor, $\frac{N}{N+M}$. The duty-ratio factor approaches 0 for widely spaced, narrow bursts or 1 for closely spaced, wide bursts.

b. the main part of the spectrum (see Figure 3). This $\frac{\sin x}{x}$ function is centered at the sinusoidal frequency, f, and has zeros and nodes at intervals of f/N about f.

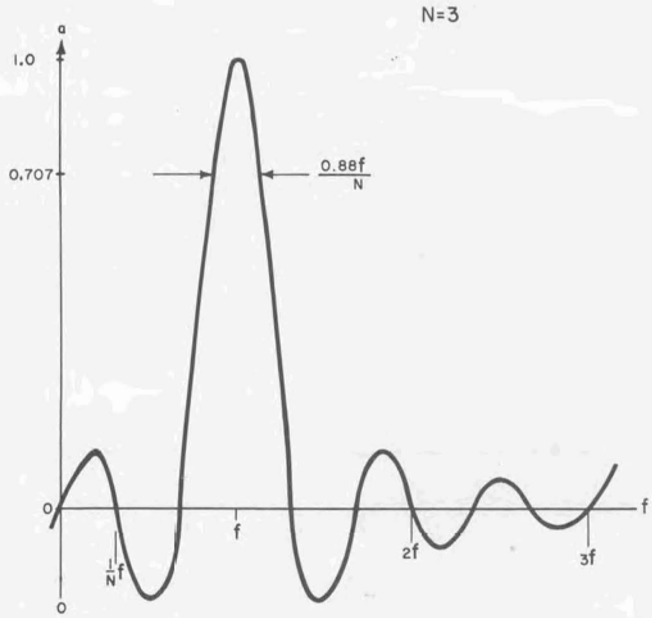

Figure 3. The main part of the envelope of the spectrum of a tone burst (N=3).

c. the phase correction (see Figure 4). This $\frac{\sin y}{y}$ function is subtracted for sine tone bursts or added for cosine tone bursts. The phase correction does not affect the maximum value or the frequency of the nodal values. It does, however, make the spectrum envelope asymmetrical about f (see Figure 5).

Figure 4. The phase correction portion of the envelope of the spectrum of a tone burst (N =3).

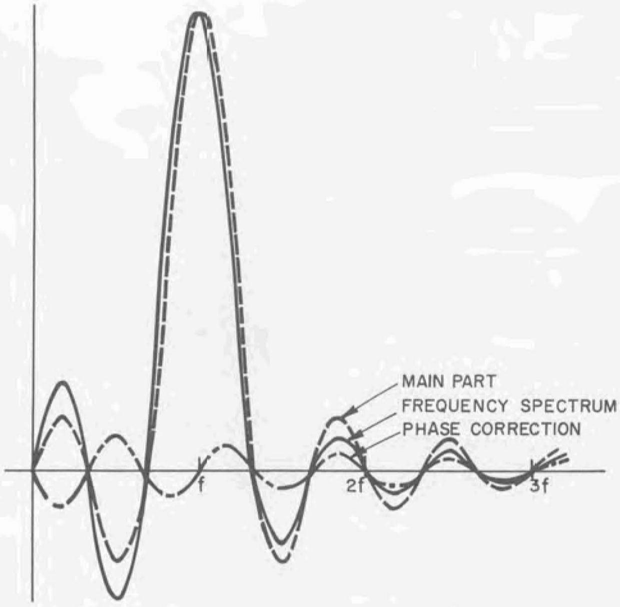

Figure 5a. Spectrum of a 3-cycle sine burst. Phase correction is subtracted from the main part.

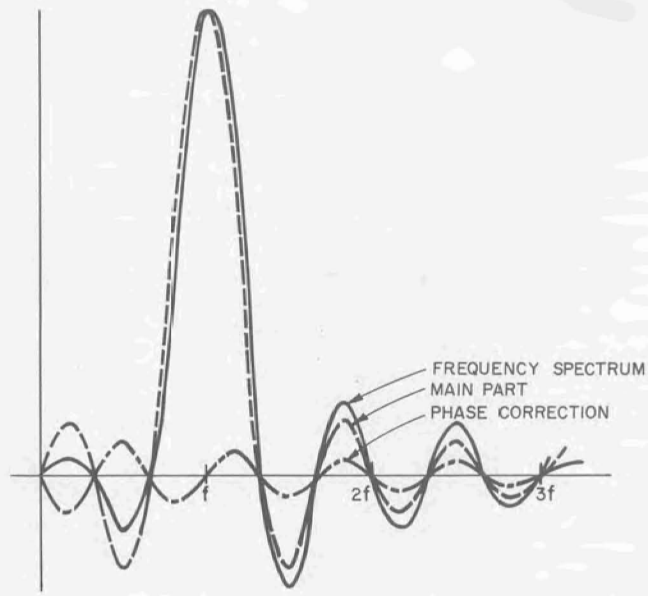

Figure 5b. Spectrum of a 3-cycle cosine burst. Phase correction is added to the main part.

As the number of cycles in the burst, N, changes, the frequency spectrum of the burst changes Figure 6 shows the frequency content for bursts of a signal with frequency, f, for several values of N. The functions for $N = 3$ are also shown in Figures 3 and 4.

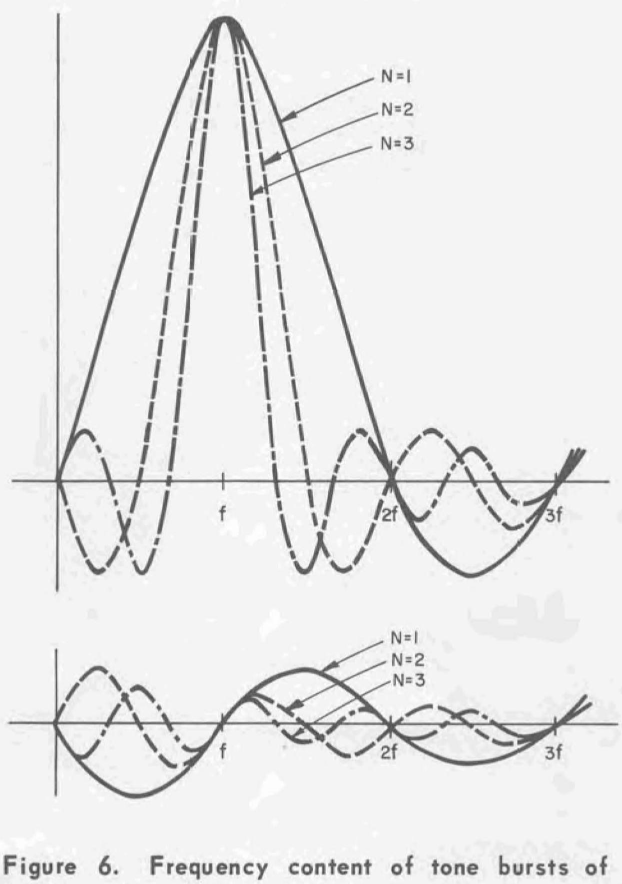

Figure 6. Frequency content of tone bursts of 1,2,3, and 4 cycles of a signal of frequency, f.

The 3-dB bandwidth of the main lobe of the envelope is $\frac{0.88f}{N}$ (see Figure 3). The amplitude of the Fourier component nearest this 3-dB point changes as the phase of the tone burst changes from sine to cosine. The magnitude of this phase correction is inversely proportional to the number of cycles in the burst. Thus, for a burst of many cycles, the amplitude change in the Fourier component at the 3-dB point is very small as the phase of the tone burst is changed. (Note that in Figure 6 the amplitude of the phase correction is much greater for a 1-cycle burst than for a 3-cycle burst).

Table 1 gives the total change in amplitude of the component nearest the 3-dB envelope amplitude point as the phase of the tone burst changes from sine to cosine. If the phase of the tone burst is shifted midway between sine and cosine (45°), the phase correction will no longer disturb the symmetry of the envelope about f.

Table 1

N	1	2	3	4	8	16	32
Change	50%	20%	15%	9%	5%	2%	1%

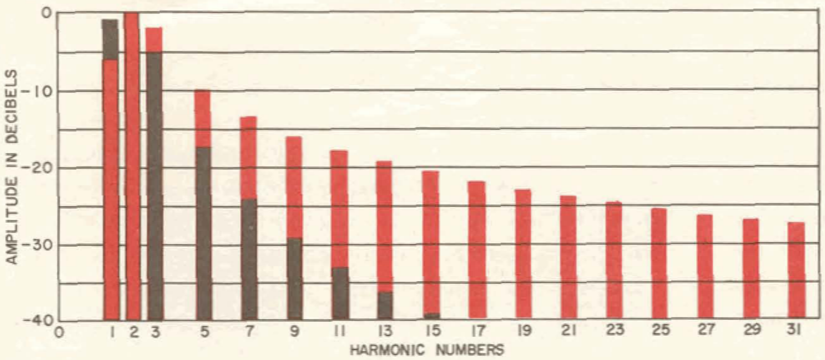

Figure 7. Amplitude of the first 31 Fourier harmonics of a one-cycle on, one-cycle off tone burst. Switching at zero crossings (sine burst) in black; switching at peak points (cosine burst) in red.

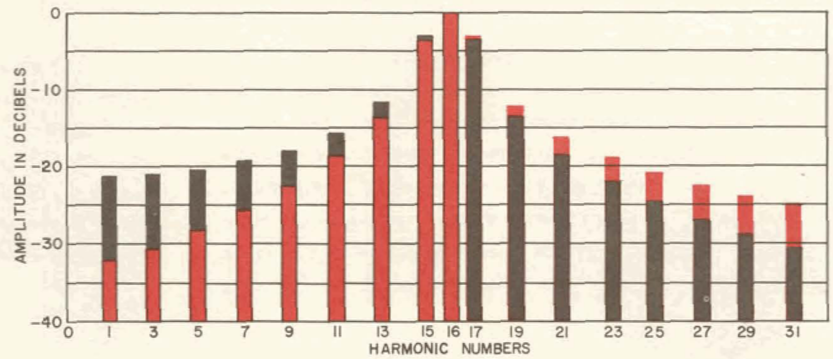

Figure 8. Amplitude of the first 31 Fourier harmonics of an 8-cycle on, 8-cycle off tone burst. Switching at zero crossings (sine burst) in black; switching at peak points (cosine bursts) in red.

The presence of the phase correction requires that the tone bursts be phase coherent in order to produce consistent test results. If the tone burst is incoherent, the signal will drift between sine and cosine tone bursts, and the phase correction will cause a corresponding drift in the spectrum. That is, an incoherent burst of three cycles has the same energy in each burst but the frequency distribution of that energy drifts as the start and stop points change in phase relative to the sinusoidal signal.

Figure 9 compares the waveforms and frequency spectra of pulse, tone-burst, and continuous-tone signals. Only the envelope of the spectra are plotted.

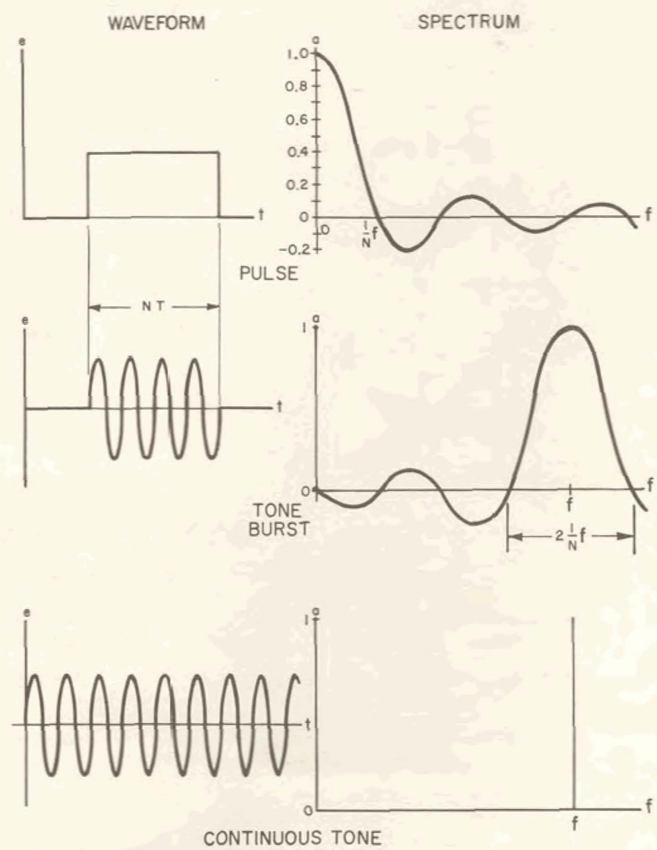

Figure 9. Comparison of waveform and spectrum envelopes for pulse, tone burst, and continuous tone signals.

The spectrum for the pulse is given by:

$$e(t) = E \left\{ k + \frac{2}{\pi} \sum_{n=1}^{\infty} \left[\frac{1}{n} \sin (n k \pi) \cdot \cos n \omega t \right] \right.$$

where, E = amplitude of the pulse

k = duty ratio of the pulse

ω = 2π x repetition rate

In the example shown in Figure 9, both the tone burst and the pulse have durations of NT seconds, and hence zeros and nodes occur at intervals of $1/NT$ or f/N cycles about f. Both, then, have the same shape frequency distribution of energy. However, the tone-burst spectrum envelope is centered about the frequency of the sinusoidal signal, f, whereas the peak response of the pulse envelope always occurs at dc, or 0 frequency. The pulse may or may not have a dc component. However, the component nearest dc (at the rep rate) is the highest in amplitude.

The sine wave shown in Figure 9 has the same frequency, f, as the sinusoidal signal in the tone burst, and hence has its spectrum centered at f. The absolute invariance of the continuous sine wave results in a line envelope of only one frequency component. The narrow-band properties of this continuous tone may be a disadvantage in some applications. It is usually necessary to make some variation in the sine wave, as frequency sweeping, in order to make it useful.

As shown in Figure 9, the tone-burst spectrum has the bandwidth properties of a pulse yet the spectrum can be tuned to center at any test frequency just as a continuous tone can. The bandwidth of the tone burst can be adjusted from very wide, impluse-type signals (1-cycle burst) to very narrow (burst of many cycles). To produce consistent spectra, the bursts must be phase coherent.

The frequency spectrum as well as the waveform indicate that the tone burst combines some of the useful features of the pulse and the continuous sinusoidal tone. The tone burst can therefore be used in many areas where the other two signals are used and the burst can be particularly effective where the application lies in the wide midground between pulse and sinewave testing.

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Type 1396-A TONE-BURST GENERATOR

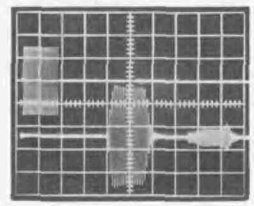
FEATURES:

- Functions as a phase-coherent gate for any input waveform. Alternately passes and blocks a selected number of cycles of any input frequency from dc to 500 kc/s.
- Number of cycles in each burst and interval between bursts are individually adjustable.
- Starting and stopping point of the burst is adjustable.

USES: The TYPE 1396-A Tone-Burst Generator is the first commercial instrument of its kind; it provides an instrumentation bridge for the gap between continuous-wave testing and step-function, or pulse, testing. It is ideally suited for applications such as the test and calibration of sonar transducers and amplifiers, the measurement of distortion and transient response of amplifiers and loudspeakers, and routine testing of filters and ac meters. Still other uses are found in the measurement of room acoustics and automatic-gain-control circuits, in the synthesis of time ticks on standard-time radio transmissions, and in psychoacoustic instrumentation.

DESCRIPTION: A binary scaler is used to establish both the number of cycles in a burst and the time duration between bursts. Separate front-panel controls select the number of cycles of the timing-input signal during which the gate will be opened and closed. Additional features of the Tone-Burst Generator are a switch that holds the gate open for preliminary alignment of external equipment (if necessary); trigger controls, which allow control of the relative phase of the gate and input signal; the ability to use separate input signals for the gate timing and gated signals; and a timed mode for extremely long periods between bursts.

SONAR TEST TANK SIGNALS



Typical waveform produced by the Type 1396-A/Type 1308-A combination with a 15-kc signal turned on for 16 cycles and off for one-half second. Upper trace shows input to sonar projector; lower trace shows output from projector and subsequent echo return from wall of test tank.

The Tone-Burst Generator is also useful with pulse and aperiodic signals. If pulses are applied to its input, the TYPE 1396-A performs as a word generator or a frequency divider.

SPECIFICATIONS

SIGNAL INPUT (signal to be gated)
Frequency Range: dc to 500 kc/s.
Maximum Voltage Level: ±7 V (5 V, rms).
Input Impedance: Approximately 10 kΩ.

TIMING SIGNAL (signal that controls gate timing)
Frequency Range: dc to 500 kc/s.
Maximum Voltage Level: ±10 V.
Minimum Voltage Level: 1 V, p-to-p.
Input Impedance: Approximately 7 kΩ.
Triggering: Slope selectable, trigger level adjustable from −7 to +7 V.

GATE TIMING: Gate-open and -closed intervals can be independently set to 2, 4, 8, 16, 32, 64, or 128 cycles (periods) of timing signal. By means of a MINUS ONE switch, intervals can be set to 1, 3, 7, 15, 31, 63, or 127 cycles. The gate-closed intervals can also be timed in increments of one period of timing signal from 1 ms to 10 s. Fixed timing errors are less than 0.5 μs.

GATED SIGNAL OUTPUT
Gate-Open Output: Maximum signal level is ±7 V. Total distortion is less than −60 dB (compared to maximum level) at 1 kc/s and 10 kc/s.
Gate-Closed Output: Less than 140 mV, p-to-p, (−40 dB) with maximum signal input.
Pedestal Output (dc potential difference between open- and closed-gate output): Can be nulled from front panel. Less than 50-mV change with line voltage.
Switching Transients: Less than 140 mV, p-to-p, (−40 dB compared to maximum signal input), with 120-pF load.
Output Impedance: 600 Ω.
Gating Voltage Output (signal for triggering oscilloscope): Rectangular waveform of approximately +12 V at 10-kΩ source when the gate is closed and approximately −12 V at 20 kΩ when the gate is open.

GENERAL
Ambient Operating Temperature: 0 to 50°C (32° to 122°F).
Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 c/s, 15 W, approximately.
Accessories Supplied: TYPE CAP-22 Power Cord.
Accessories Required: External source for any desired frequency range between 0 and 500 kc/s.
Accessories Available: Relay-rack adaptor set (panel height 5¼ in).

MECHANICAL DATA Convertible-Bench Cabinet.

Width		*Height*		*Depth*		*Net Wt*		*Ship Wt*	
in	*mm*	*in*	*mm*	*in*	*mm*	*lb*	*kg*	*lb*	*kg*
8	205	5⅞	150	7½	195	6½	3	9	4.1

See also *General Radio Experimenter*, May 1964.

Catalog No.	*Description*	*Price*
1396-9701	**Type 1396-A Tone-Burst Generator**	**$490.00**
0480-9638	**Type 480-P308 Relay-Rack Adaptor Set**	**7.00**