CHAPTER 8

Study of Harmonic Outputs of 20 Mc/s Harmonic Generator

In this chapter, the variation in amplitude of the harmonic current as one proceeds to higher orders has been studied. An interesting observation is the inhibition of certain high order harmonics. They are either completely absent or present in very feeble amplitude. This has been explained theoretically.

8.1 Study of the Variation of Harmoni Harmonic Frequency

Reference to Sec. 6.1 (see page study of the variation involves the de of

(a) the voltage gain (K_n) of th harmonic frequencies,

(b) the output voltage (V_{on}) of frequencies and

(c) the 'g_m' of the multiplier the current and potentials, as were ob as a multiplier.

The experimental procedure followed an study these parameters are the same as In what follows, only the results of t parameters will be given.

NOTE : Since the harmonics upto the o the measurements of 'K_n' and 'V_{on}' harmonic of the 15th order.

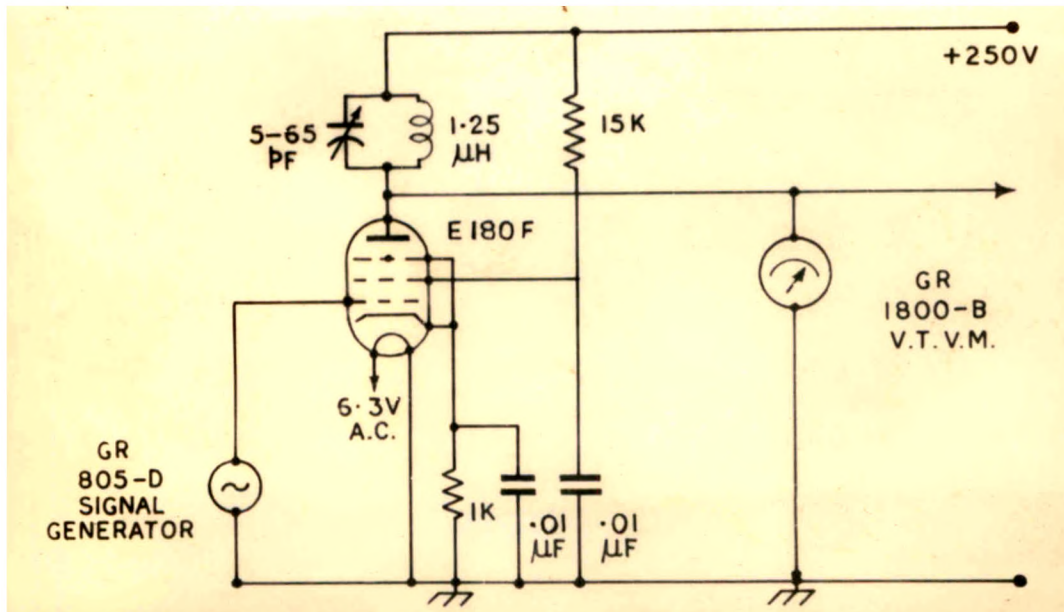


Fig.8.1 Schematic diagram of the E180F tube connected as an RF amplifier.

Measurement of K_n at Harmonic Frequencies

Table 8.1

Resonance frequency f_{rn} (Mc/s)	Condenser (C)+ dial setting corresponding to frequency f_{rn} (Arbitrary units)	Nominal value of condenser connected in parallel with 'C' to cover f_{rn} ($\mu\mu$F)	Total* value of 'C' needed to tune to f_{rn} (L = 1.25 μH) ($\mu\mu$F)	Voltage gain** K_n
6	47.8	530	540	30.1
8	35.1	290	307	40.5
10	52.3	162	197.5	51.0
12	76.7	80	139	59.0
14	66.2	47	101	62.5
16	96.7	-	75	64.5
18	70.0	-	59.5	64.9
20	50.2	-	48	65.0
22	35.7	-	41.6	65.0
24	25.1	-	34.7	64.7
26	17.0	-	29.1	62.5
28	10.2	-	24.8	62.0
30	4.2	-	21.2	61.5

+ 'C' is variable from 5 to 65 pF; see ~~page~~ Fig.7.1.

* The values were measured on a Q-meter

** This was determined by the circuit arrangement illustrated schematically in Fig. 8.1.

Measurement of V_{on} at Harmonic Frequencies

In making this measurement, the limiter tube was removed from the circuit of Fig.7.1. The rest of the circuit components were kept intact. Harmonic generator was thus driven with pulses of the type generated with R_1 = 50 K (see Table 7.1) in the driver-pulse-shaping network. 2 Mc/s input to this network was maintained constant throughout at 30-Volts (RMS). Harmonics of the 2 Mc/s frequency were measured by the method illustrated on page 105.

Results

Table 8.2

Multiplier output at harmonic frequencies

Dial setting* of the variable-condenser 'C' (Arbitrary units)	Nominal value of condenser connected in parallel with 'C' ($\mu\mu$F)	Harmonic frequency+ 'f_{rn}' (Mc/s)	Harmonic output 'V_{on}' (Volts)$_{peak}$
47.8	530	6	42.56
35.8	290	8	53.70
53.5	162	10	57.48
77.7	80	12	56.42
67.0	47	14	49.60
96.7	-	16	39.87
69.9	-	18	31.04
50.2	-	20	22.13
35.5	-	22	14.85
24.9	-	24	9.61
16.9	-	26	5.71
10.2	-	28	( )**
4.2	-	30	4.35

* These correspond to the settings of the dial, readjusted to make the plate tank (or the output circuit) resonant at approximately the previously calibrated positions (see Table 8.1) of 'C'.

\+ Estimated from Table 8.1.

** Output circuit could not be tuned to 28 Mc/s.

Miscellaneous Measurements

The following data of the multiplier, as found necessary, was collected as a part of the above measurements.

(1) Multiplier plate current pulse amplitude	=	47.4 mA*
(2) Multiplier plate current pulse duration	=	0.07 μsec**
(3) Multiplier average cathode current	=	5.28 mA+
(4) Multiplier average screen current	=	1.2 mA
(5) Multiplier average plate current	=	4.1 mA
(6) Multiplier average screen voltage	=	232 Volts
(7) Multiplier plate or screen supply	=	250 Volts

*, ** These were evaluated from the oscillogram of the plate-current-pulse waveform. The latter was recorded across 500 Ω plate resistance with type 543-A Tektronix Oscilloscope.

+ This was calculated from the voltage developed across 1 KΩ resistance in the cathode lead of E180F tube (see Fig.7.1).

Calculations of g_m, Z_{Ln} and I_{on}

Transconductance 'g_m' of the multiplier tube, in the above operating conditions, was determined by the method outlined on page 108 . Its value at the plate current of 4 mA was found to be 6.9 mA/v.

Z_{Ln} , the multiplier-output impedance at harmonic frequencies was evaluated from Eq.(6.2) using the value of 'g_m' determined above and the results of Table 8.1. The results are

shown in Table 8.3.

Table 8.3

Z_{Ln} as a function of f_{rn}

f_{rn} (Mc/s)	Z_{Ln} (KΩ)
6	4.36
8	5.87
10	7.39
12	8.55
14	9.06
16	9.35
18	9.41
20	9.42
22	9.42
24	9.38
26	9.06
28	8.98
30	8.91

The values of I_{on}, the harmonic current, as evaluated from the results of Tables 8.2 and 8.3, are presented in Table 8.4.

Table 8.4

Multiplier output current at harmonic frequencies.

f_{rn} (Mc/s)	I_{on} $(mA)_{peak}$
6	9.76
8	9.15
10	7.78
12	6.60
14	5.48
16	4.26
18	3.30
20	2.35
22	1.58
24	1.02
26	0.63
28	( )*
30	0.49

* Plate tank could not be tuned to 28 Mc/s.

The most interesting outcome of the foregoing study is the total inhibition of the 14th harmonic from the results of Table 8.4. This is a useful byproduct of this study. During the course of experiment, it turned out that the generator-output circuit could not be tuned to the 14th harmonic but it did so at harmonics one higher and lower in rank than this.

This led to the systematic search for some other cases of the missing of harmonics using R_1 as 10K, 20K and 30K respectively. The experimental procedure adopted in each case was the same as the one illustrated above. The results obtained are summarised in Table 8.5.

Table 8.5.

Multiplier harmonic output at four different pulse drives

Order of the Harmonic (n) / R_1	Harmonic Currents $(mA)_{peak}$		
	10 KΩ	20 KΩ	30 KΩ
Driver pulse amplitude	10.5 V	7.75 V	6.25 V
Average plate current in the multiplier tube	7.3 mA	5.6 mA	4.8 mA
Tube Transconductance at these plate currents	9.4 mA/V	8.6 mA/V	7.0 mA/V
3	22.09	15.33	10.84
4	18.90	14.01	10.02
5	16.37	12.06	8.74
6	12.77	9.69	7.37
7	9.59	7.85	6.01
8	6.57	5.83	4.58
9	4.06	4.09	3.35
10	2.09	2.62	2.28
11	( )+	1.48	1.46
12	1.36	( )+	0.85
13	1.70	0.90	( )*
14	1.82	0.96	0.64
15	1.71	1.03	0.64

+ Tuning was feeble for this harmonic. The vacuum-tube-voltmeter shunted across the multiplier output circuit just managed to indicate its presence.

* Output circuit could not be tuned to 26 Mc/s.

8.2 Discussion of Results

From Tables 8.4 and 8.5, it is seen that complete suppression of harmonics in the range 11 to 14 is practical in this multiplier, by suitable adjustments of the value of R_1 in the driving network. The typical values are 10K, 20K, 30K and 50K respectively. Suppression of the harmonics lower in rank than 11 was not practical, as it involved prohibitive currents to flow through the multiplier tube. These and the other characteristics of the multiplier outputs are accounted for as follows.

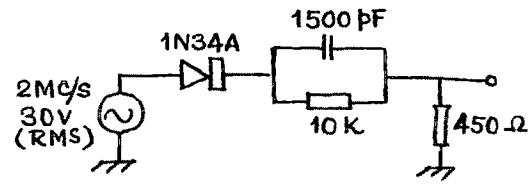
Close examination of Table 1.1 shows that in the case of Isosceles-Triangular pulse waveform, the absence of harmonic numbers 11, 12, 13 and 14 occurs for pulses with (d/T) ratio of (1/5.5), (1/6.0), (1/6.5) and (1/7.0) respectively. Now, the waveshape of the currents observed, was already shown (see Fig.7.4) to be nearly Isosceles Triangular. Evidently, the reason for the absence of harmonic numbers 11, 12, 13 and 14, as observed, must then be attributed to the aforesaid plate currents as having the (d/T) ratio nearly of (1/5.5), (1/6.0), (1/6.5) and (1/7.0) respectively. This is seen clearly from the results of Table 8.6.

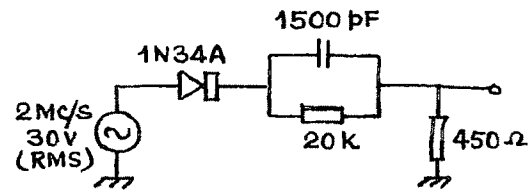
Ta

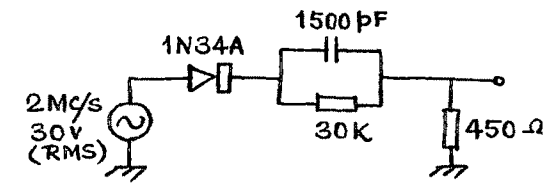
Plate current pulse

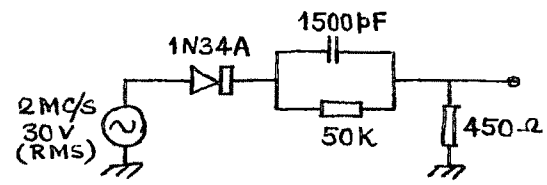
multiplier (Fig. 7.

Configuration
of the
Driver Network









+ Plate current pulse am
oscillograms of the pl
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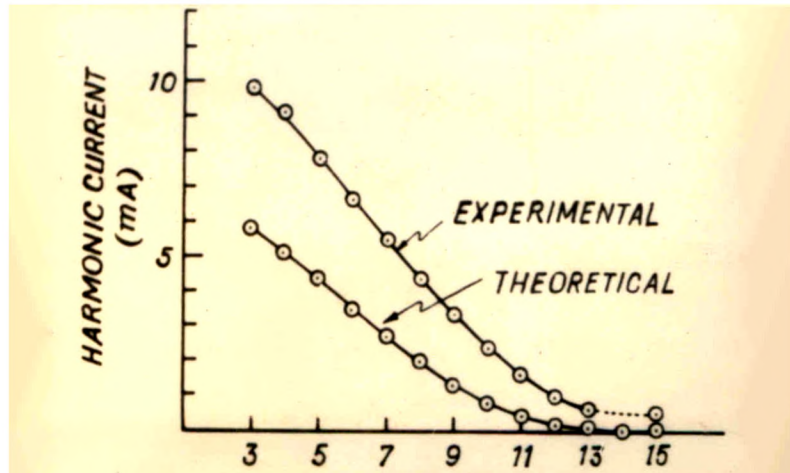
Numerical results of Tab

nearly tally with their



ig.8.2 Theoretically computed (a) and experimentally observed (b) plots of the multiplier harmonic current as a functi of the harmonic number.

The additional proof of the waveshape of the multiplier-plate current as being nearly Isosceles Triangular is provided by the ~~near~~ close agreement between the two plots of Fig. 8.2 - one based on the results of Table 8.4 and the other evaluated from the Fourier analysis of the theoretical Isosceles-Triangular-current pulse waveform, with pulses of amplitude 47.4 mA and (α/T) ratio (1/7) [Compare experimental data on page 135] .

8.3 Concluding Remarks

(1) The waveshape of the multiplier-plate current is almost Isosceles Triangular as is indicated by the ~~near~~ close agreement between the experimental and the theoretically computed curves of Fig. 8.2.

(2) Complete suppression of any one of the 11, 12, 13 and 14th harmonics was practical in this multiplier because of the accidental coincidence between the observed and required pulse shape and (α/T) ratio of the current pulses.

(3) Since the (α/T) ratio of the current pulses do not differ very much from one another, the use of a variable resistance, preferably a helipot, in the place of R_1, might help precise suppression of any one of the aforesaid harmonics.