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51-channel analyzer for spectrum sampling

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G. 51-CHANNEL ANALYZER FOR SPECTRUM SAMPLING

The general specifications for the 51-channel spectrograph under construction are summarized in Fig. I-9, I-10, and I-11. A few modifications have recently been made in the plan for the particular combinations of bandwidths and frequency spacings of the filters. The group A of the filters comprises 10 filters spaced 100 c/s apart covering the frequency range 0-900 c/s. They may be used as a supplement to the main filter bank, group B, which covers a frequency range from 1000 c/s upward. The lowest of these filters, No. 11, has a constant center frequency of 1000 c/s, independently of the particular combination selected. The center frequency of the highest filter, No. 51, varies with the spacing, Δf, between successive filters. Group B of the filter bank is normally fed from a frequency transposition stage adding 1000 c/s to the incoming speech band. When used together with group A it is connected directly without this frequency translation.

The degree of overlap, defined as the ratio $B/\Delta f$ of filter bandwidth B to the spacing measure Δf is maximally 10, i.e., in combination 3, and minimally 1.25, i.e., in combinations 4 and 7. The overlap factor is 5 for combinations 2, 6, and 9, and 2.5 for combinations 1, 5, and 8. Besides these nine linear combinations there are two combinations of group B providing equal spacings on a technical mel scale.(1)

$$tm = \frac{1000 \log(1+f/1000)}{\log 2} \qquad \text{(technical mel)}$$

The value $\Delta tm = 80$ has been selected. The total range of 3200 tm corresponds to 8200 c/s. Position 10 has constant bandwidth of 250 c/s and position 11 has constant width of tm = 300 which is 250 c/s at f = 100 c/s and 1850 c/s at f = 8200 c/s.

A reduction of the speed of the tape-recorder at the input of the filter band by a factor of 2 may be used for increasing the effective spacing and width data of the filters by the same factor. By this trick it is possible to vary the properties of the filter bank beyond the 11 combinations of Fig. I-10. The associated stretching of the time scale is a means

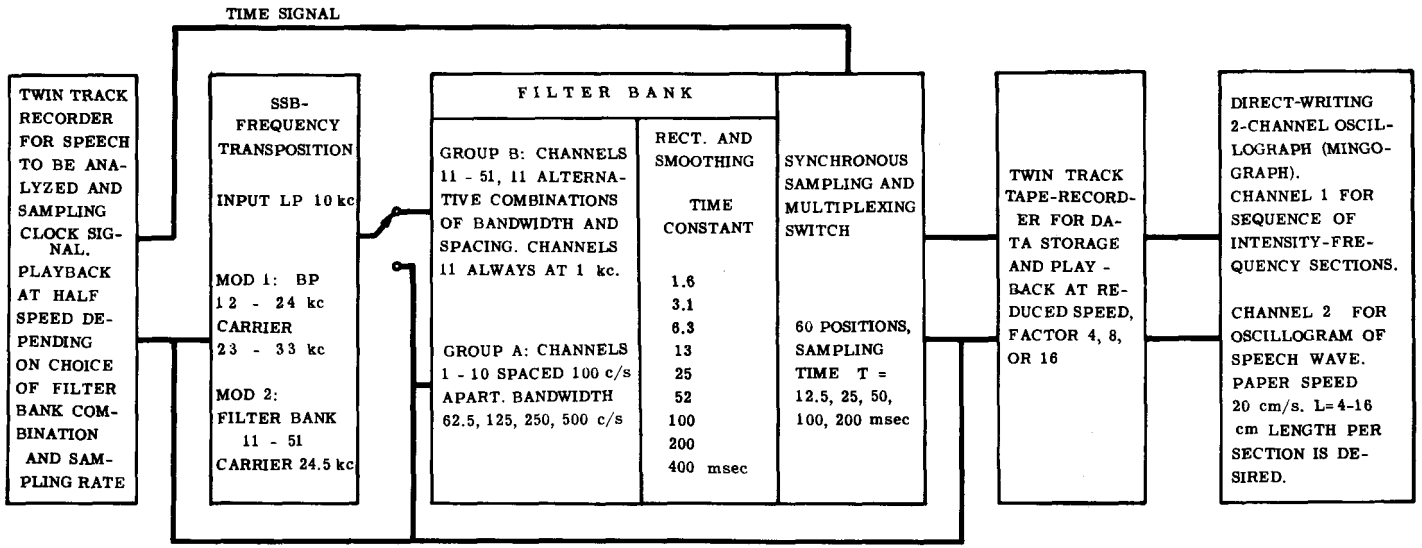
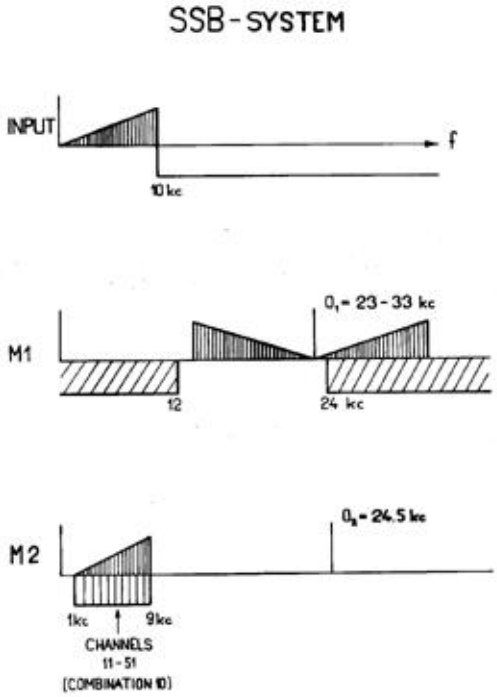


Fig. I-9 Block diagram of the 51-channel spectrum analyzer and associated equipment for the recording of successive frequency, time-synchronous spectral sections.



CHANNELS 11 - 51

SPACING Δ f	12.5	25	50	100	200 c/s	80 tm
RANGE W_3	0.5	1	2	4	8 kc/s	
B = BANDWIDTH						
31 c/s	1	4				
62	2					
125	3		5	7		
250			6	8		10
500				9		
300 tm						11

THE UNIT tm (TECHNICAL MEL) = $\frac{1000 \cdot \log (1 + f/1000)}{\log 2}$

WHERE f = FREQUENCY IN c/s

Fig. 1-10 SSB-modulation system for filter bank group B of the 51-channel spectrum analyzer and tabulation of the 11 available filter combinations in terms of frequency spacing and bandwidth.

TYPICAL OPERATION

VARIABLE	HARMONIC ANALYSIS		FORMANT ANALYSIS		WIDE RANGE ANALYSIS	
GROUP A UTILIZED	NO		YES	NO	NO	
GROUP B CONNECTION	SSB		DIRECT	SSB	SSB	
GROUP B COMBINATION	1		9		10	11
S_1 = INPUT TAPE SPEED	1/2	1	1		1	
B = FILTER BANDWIDTH	31 kc		500 c/s		250 c/s	300 tm
B_e = EFFECTIVE BANDWIDTH	62 c/s	31 c/s	500 c/s		250 c/s	300 tm
Δf = FREQUENCY SPACING	12.5 c/s		100 c/s		80 tm	
Δf_e = EFFECTIVE FREQUENCY SPACING	25 c/s	12.5 c/s	100 c/s		80 tm	
W_B = RANGE OF GROUP B	500 c/s		4000 c/s		8000 c/s	
W_A = RANGE OF GROUP A			1000 c/s			
W_E = EFFECTIVE ($W_B + W_A$)	1000 c/s	500 c/s	5000 c/s	4000 c/s	8000 c/s	
τ = SMOOTHING TIME CONST.	50 msec	25 msec	25 msec		25 msec	
τ_e = EFF. SMOOTHING TIME CONST.	25 msec		25 msec		25 msec	
T = SWITCH PERIOD	50 msec	25 msec	25 msec		25 msec	
T_e = EFF. SAMPLING PERIOD	25 msec		25 msec		25 msec	
S_2 = OUTPUT SPEED REDUCTION	4	8	16		16	
L = PAPER LENGTH PER SAMPLE	4 cm		16 cm		16 cm	
COMMENTS			USE COMBINATION 8 OR 7 IN CASE OF LOW F_0		300 tm = 230 c/s AT 100 c/s 1900 c/s AT 8000 c/s	

Fig. I-11 Typical choice of operational characteristics for producing a sequence of frequency-intensity sections with the 51-channel spectrum analyzer.

of increasing the number of spectrum samples per second at a constant sampling rate of the switch unit. As an example it may be seen from Fig. I-10 and I-11 that the filter-spacing of 100 c/s and bandwidths of 250 c/s may be obtained either with combination 8 and the normal tape-recorder speed or with combination 5 and a speed reduction by a factor 2. Combinations 1, 2, and 4 are primarily intended for harmonic analysis whereas combinations 3, 5, 6, 7, 8, 9 are primarily intended for "broad-band" or "formant" analysis. Some of the latter will be useful in the simulation of various formant-tracking schemes.

The output from the electronic switch is the time-division multiplexed data of the rectified and smoothed outputs of the filter banks. Smoothing time constants are variable from 2.5 - 320 msec. The switch period includes 9 empty time positions besides those of the 51 channels and these may be used for the synchronous sampling of other speech parameters of interest. One application would be to check the function of a pitch frequency tracker or of a formant tracker against the short time spectrum and oscillographic display. A constant reference to be recorded on a separate channel of the oscillograph is simply the speech wave time-function. In case our direct-writing ink-jet recorder, the Mingograph, is used for the final data display it will be necessary to slow down the data flow by means of storage in a twin track tape-recorder and playback at reduced speed. This is the proposed normal practice which has the advantage of immediate accessibility of records and that large size spectrum section diagrams and time-synchronous oscillograms may be printed on light-weight, cheap paper. An alternative or rather supplementary method of spectrum portrayal would be to produce time-frequency-intensity spectrograms from a cathode ray tube.

The work is progressing on the design of a prototype for the individual channels of the analyzer. The band-pass filters contain three resonant circuits in cascade and are designed for minimum overshot characteristics. The smoothing filters are 18 dB/octave active RC-filters, also of minimum overshot type.

(1) Fant, G.: "Acoustic analysis and synthesis of speech with applications to Swedish", Ericsson Technics 15, No. 1, 3-108 (1959).