THE INSTITUTION OF ELECTRICAL ENGINEERS

Colloquium on

APPLICATIONS OF ACTIVE, DIGITAL AND PASSIVE FILTERS

Tuesday 14 January 1975 at 10.30 a.m.

PROGRAMME

Hours	Author(s)	Title	Contribution No.
10.00	COFFEE		
10.30	Dr D J Goodman	Digital encoding applications of digital filters	1
11.00	M N Y Shum	The design and implementation of a digital adaptive equalizer	2
11.30	L D J Eggermont	Efficient multiplication in digital filters	3
12.00	Professor A G J Holt J Attikiouzel & R Bennett	Design technique for digital non-recursive filters with complec coefficients	4
12.30	LUNCH		
14.30	Dr W Saraga	Channel bark filtering - a survey	5
15.00	A J L Muir	Design of a dissipation compensated M.C.F. for use in a data transmission system	6
15.30	Dr A C Davies	Delta-modulation filters	7
16.00	M J Gingell	Sequence Asymetric polyphase networks: application to F D M	8
16.30	TEA		

SEQUENCE ASYMMETRIC POLYPHASE NETWORKS: APPLICATION TO FDM

M.J. Gingell

The frequency translation of twelve audio speech channels into a basic group (60 - 108kHz) has traditionally been achieved by modulating each channel followed by selection of the required sideband with a bandpass filter. The choice of frequency of the number of stages of modulation depend on the filter type chosen. For example, in the United Kingdom where a considerable investment in crystal technology exists, a single modulation process is used. This is the simplest method but requires highly stable filters.

Of the alternative methods which avoid band pass filters the most popular is quadrature modulation. A phase shift network splits the audio signal to be modulated into two paths so that they are approximately 90 degrees out of phase. Applying each signal path to its respective modulator with carriers 90^{o} apart and adding the resultant products gives a controlled cancellation of one sideband. The 90^{o} phase spitting is achieved by taking the difference between two large phase shifts from two different networks and is in consequence extremely sensitive to component tolerances. This paper describes an alternative method where the phase splitting is achieved with a single "polyphase" network which is much less sensitive to component tolerances.

Principle

A polyphase filter network is used to achieve phase splitting by sequence selection. Each phase or path of the network is physically identical to its neighbours but by the way the phases are interconnected the filter can discriminate between positive and negative sequence input signals without distorting their symmetry. A single phase input signal is applied which may be considered as being the superposition of two symmetrical polyphase signals, one of positive and one of negative sequence. This input signal is applied to the filter which is designed to pass the positive sequence signals and attenuate negative sequence signals. When the output of the filter is connected to modulators with carriers of $\mathrm{Sin}f_c$, $\mathrm{Cos}f_c$, $-\mathrm{Sin}f_c$, $-\mathrm{Cos}f_c$ and the resultant products summed, lower and upper sidebands are produced by the positive and negative sequence signals respectively. The unwanted sideband is therefore suppressed by the negative frequency response of the polyphase filter with respect to the wanted sideband which is due to the positive frequency response. A fuller explanation and proof is given in reference 1.

Practical Application to FDM

For translation into a 12 channel group each voice channel which extends from 250 to 3400 Hz must be modulated with its respective carrier of 64, 68, ... 108kHz with a passband ripple of less than 0.2dB and a stopband suppression of 60dB rejecting the unwanted upper sideband by this amount from carrier plus 600Hz to carrier plus 3400Hz. A six section polyphase network is required, each section consisting of 4 matched resistors and 4 matched capacitors. The network is extremely tolerant of the relative impedance levels between sections - so much so that it possible to choose any

M.J. Gingell is with Standard Telecommunications Laboratories, Harlow, Essex.

convenient values to suit available components providing the general rule is observed of placing the sections in ascending order of impedance level. Only the component match within a section is critical getting more so proceeding from input to output. For example a tolerance of ± 2½% on the first section graded to ± .3% on the final section would be adequate for 60dB sideband suppression with a production yield of 90%.

For 60dB suppression an accuracy of about 0.1% amplitude and 0.1° in phase is required from the modulators. This is achievable with modulators using field effect transistors as series on off switches controlled from a digital divider which gives precise timing and hence phase accuracy. Since the FDM group band is less than one octave wide the higher order modulation products can be eliminated with a group filter common to all channels after combining. Exactly the same scheme can be used in reverse for demodulation although great care is necessary to prevent channel intermodulation in the input stage and the modulators.

Performance

Complete FDM channels have been constructed and achieve 60dB sideband suppression without difficulty. Because of component tolerances and modulator imperfections the peaks of attenuation in the stopband become rounded and shifted in frequency although the minima remain largely unaffected.

A Monte-Carlo analysis was carried out to determine the likely performance with ± .3% tolerance on all components on three different networks:

a) A passive R-C phase splitter.

b) A passive L-C phase splitter.

c) A six section RC polyphase filter.

Each network was designed from the same initial transfer function to give 70dB sideband suppression over the same frequency range. For the R-C phase splitter only 3% of networks gave a stopband of not less than 60dB over the full frequency range while for the LC phase splitter the corresponding figure was 19%. For the polyphase filter 87% exceed 60dB at all points and in fact this figure is affected very little if the tolerances in the earlier sections are relaxed.

From the results of both experimental work and computer analysis polyphase filters prove to be more economic because of the easier component tolerances required to meet a given application. Although the total component count is higher only a match between each set of 4 identical resistors and each set of 4 capacitors is needed. If the network is made using one of the modern film technologies the matched sets of components should track together with age and temperature thus maintaining the performance.

Reference

1. M.J. Gingell: "Single Sideband Modulation using Sequence Asymmetric Polyphase Networks": Electrical Communication, Volume 48, Number 1 and 2, 1973, pp 21-25.