USE OF THE DUAL CHANNEL SYNCHRONOUS DETECTOR TYPE DSD 02 AND SIGNAL ANALYZER TYPE 2033 FOR HIGH-RESOLUTION RADIO FIELD STRENGTH AND FREQUENCY MEASUREMENTS

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Received September 29, 1983

Presented by Dr. I. BOZSÓKI

Summary

Co-channel sound broadcasting transmissions have the same nominal frequency with a frequency offset tolerance of the order of some Hz. Consequently the spectra of different transmissions overlap and the selectivity of conventional measuring receivers is insufficient to separate them.

In this paper the theoretical background of dual-channel radio-frequency measurement based upon the orthogonal down conversion to about zero frequency is given together with information on its practical implementation.

Introduction

In the field of radio monitoring it is often necessary to measure a channel occupied by several co-channel signals. In general, however, the selectivity of radio-frequency measuring equipment does not allow the individual measurement of signals with very close frequency separation.

A possible way to increase the resolution is to convert down the intermediate-frequency output signal of the measuring receiver either by envelope or by synchronous detector, followed by low-frequency spectrum analysis for separating co-channel carrier [1]. In this way the field strengths and — by auxiliary methods — the directions of all co-channel carriers can be independently measured, but — as during the down conversion the spectrum is folded around the local oscillator frequency — only the absolute values of frequency differences can be determined.

This latter problem can be overcome by using the Dual Channel Synchronous Detector, in which the local oscillator paths are fed with signals of identical frequency with a certain phase offset.

The magnitude spectra of downconverted signals are the same, nevertheless the phase spectra differ depending on whether the frequency of incoming signal was higher or lower than the local oscillator frequency.

Consequently the true frequencies of downconverted carriers can be obtained based on their phases in the resulting spectra.

In this paper the theoretical background of dual-channel radio-frequency measurement is given together with information on its practical implementation to form a high-resolution monitoring system based on the Dual Channel Synchronous Detector and Signal Analyzer type 2033.

Principle of dual-channel frequency measurement

The basic idea of the high-resolution radio-frequency field strength measurement is to use a signal analyzer for the evaluation of downconverted radio-frequency channel. The process of downconversion necessarily means the fold of spectrum around the local oscillator frequency as shown in Fig. 1. In the downconverted signal only positive frequencies exist, i.e. the original frequency cannot be simply reconstructed from the measured baseband and local oscillator frequencies.

The boundaries of the radio-frequency spectrum to be analyzed are set by the bandwidth of signal analyzer.

The result is that a part of spectrum, twice wider than the bandwidth of signal analyzer, can be evaluated at a time, at the price of obtaining absolute values of frequencies.

If the true frequencies on both sides of local oscillator frequency are needed, any of the single sideband detection techniques — well known in the field of radiocommunication — may be used.

All of the conventional single-sideband detection methods use, however, some kind of analog filtering, in the form of sideband filter or single or multiple-path phase shifters, to suppress the unwanted sideband. Obviously the analog filtering cannot provide the cut-off performance which could meet the high resolution of an FFT signal analyzer.

In the particular case of identifying carrier signals, however, it is quite unnecessary to suppress all spectral components in one side of the local oscillator frequency, only the sign of the frequency of downconverted signal is important instead.

The sign of frequency can be obtained by using a dual-channel downconverter having local oscillator signals of the same frequency with a definite phase offset.

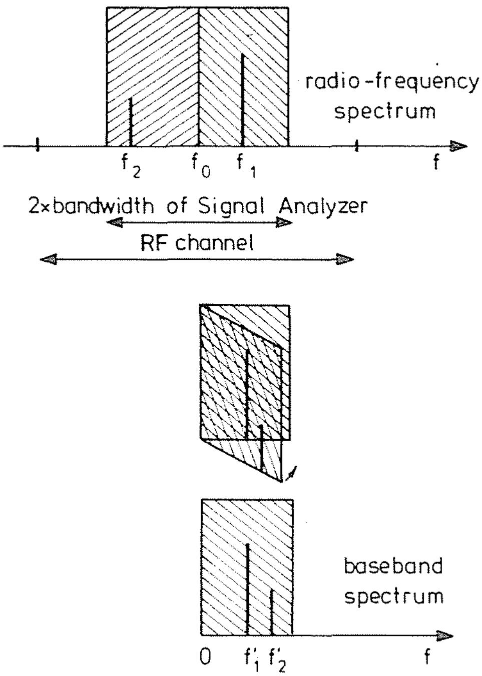

Fig. 1. Principle of high-resolution field strength measurement. The folding of spectrum during downconversion around the local oscillator frequency f_0. f_1 and f_2 denote the frequencies of co-channel carriers
($f'_1 = f_1 - f_0$ and $f'_2 = f_0 - f_2$)

The principle is shown in Fig. 2.

The two downconverter routes contain identical mixers fed by the same input and orthogonal local oscillator signals. The output signals also will be orthogonal.

It is important that at the first output (φ_1) the phase of signal does not depend on the sign of frequency difference (arc cos (φ) = arc cos $(-\varphi)$) but at the second output it does (arc sin $(\varphi) = -$arc sin $(-\varphi)$). As a result the sign of phase difference between the two output signals provides the sign of frequency difference between the incoming and the local oscillator frequency (sign $(\omega_1 - \omega_0)$ = sign $(\varphi_2 - \varphi_1)$).

Note that the result of above derivation does not depend on the initial phases of signals. Here, for the sake of simplicity, these values were choosen to be zero.

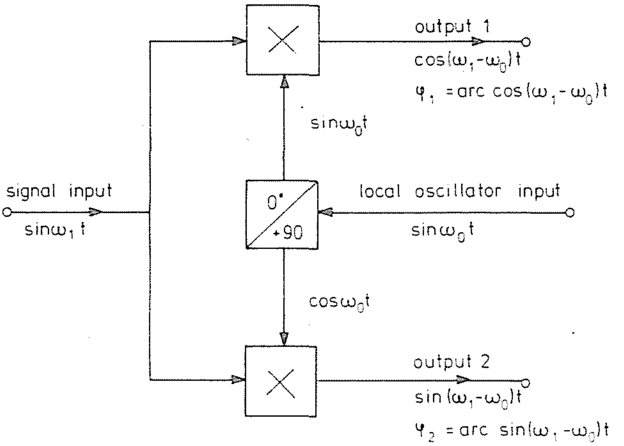

Fig. 2. Block diagram of dual-channel synchronous detector. Signals with unity amplitude for derivation of true frequencies are given at the main points

When using orthogonal local oscillator signals, the phase difference $(\varphi - \varphi_1)$ to be detected is + or -90 degrees, which gives the highest possible noise margin for identification.

Finally, taking the tuning frequency of measuring receiver into account, and provided the local oscillator frequency of synchronous detector equals the nominal intermediate frequency, the frequency of measured signal is given by:

$$f = f_t + k \cdot f_a$$

where f_t — tuning frequency of measuring receiver;

f_a — frequency of selected signal as measured in the downconverted spectrum by the signal analyzer;

k is $+1$ or -1 depending on the phase conditions as described in Fig. 2.

The phase difference between the output signals can be measured by the FFT analyzer using complex spectra. To obtain both phase values either single-channel or dual-channel signal analyzers may be used.

In the case of a single-channel signal analyzer the two outputs of the dual-channel synchronous detector should be connected to, and analyzed by, the signal analyzer one after the other. Note that the phase shift corresponding to the time interval between the two samples should be taken into account and the measured signal should have negligible frequency and phase fluctuations during the measuring time.

The use of synchronous detection offers some further important advantages:

— The inherently linear process eliminates all the systematic errors (error of measured levels, presence of higher order products) which appear when using envelope detectors.

— The screen of the Signal Analyzer provides a true panoramic facility for the measuring receiver even if the levels of co-channel signals cross each other due to fading. The level variations of all signals can be followed independently, which greatly helps manual direction finding.

Instrumentation and measurements

Figure 3 shows the typical interconnection of Dual Channel Synchronous Detector and Signal Analyzer Type 2033 with a measuring receiver and controller in an automated high-resolution monitoring set-up.

The Synchronous Detector receives the intermediate-frequency output signal of measuring receiver which has been previously tuned to the channel to be analyzed.

The receiver should be in its linear mode of operation.

The receiver must be synthetiser tuned to ensure the required stability. Moreover the phase noise of its tuning system — that has no effect when an envelope detector is used, but can impair the performance of synchronous detection — should be low.

The Synchronous Detector contains band-pass filtering to reject hum and harmonics of receiver output. The bandwidth allows the measurement of a total radio-frequency channel in one receiver setting. The extremely linear

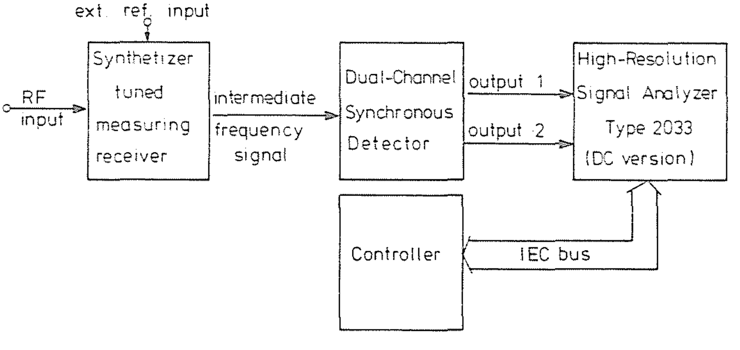

Fig. 3. Typical instrumentation set-up showing the interconnection of Dual Channel Synchronous Detector and High-Resolution Signal Analyzer with the measuring receiver and controller

balanced mixers are fed with local oscillator signals from a crystal controlled synthetizer.

The Dual Channel Synchronous Detector can be used with practically any of high-performance measuring receivers, since the nominal input level and the local oscillator frequency can be changed if required.

The outputs of Synchronous Detector are connected to the Direct and Preamplifier Inputs of Signal Analyzer Type 2033. The switch-over of inputs can be performed at the proper time by the controller via the IEC bus.

Spectra obtained from the Signal Analyzer are evaluated by the Controller. In this system the use of a controller together with an appropriate software is essential, since the phase information of spectra may be retrieved from the Signal Analyzer through its digital outputs alone.

The software available for the Dual Channel Synchronous Detector searches for, and identifies the stable sinusoid signals (originating from carriers of AM broadcasting transmitters first of all in the LF and MF bands), determines their field strengths and true frequencies.

Figures 4 and 5 show an example of measuring result hardcopies.

The tuning step of synthetizer-tuned measuring receiver — in the frequency band of our scope — is generally not higher than 100 Hz, consequently the frequency of spectral components to be measured by the Signal Analyzer needs not exceed 50 Hz. The Signal Analyzer with its zoom facility provides a 4000 line resolution still improved in the subsequent spectrum evaluation by software means by a factor of at least 10. It results in a resolution of measured frequencies in the entire radio-frequency band to be about 1 mHz.

The high resolution may require the use of external frequency reference for the instruments to improve the absolute accuracy of measurements. The Synchronous Detector has an external reference input for standard frequencies most common in measuring receivers.

Since the frequencies to be measured by the signal Analyzer are generally by 3 to 5 orders of magnitude lower than those appearing in the receiver and Synchronous Detector, the accuracy of internal reference of Signal Analyzer is adequate even for precise measurements.

Conclusions

The Dual-Channel Synchronous Detector together with its associated software, the Brüel and Kjaer Signal Analyzer Type 2033, an appropriate measuring receiver and IEC bus controller, offer high-resolution radio field strength and frequency measurements as well as high-performance monitoring.

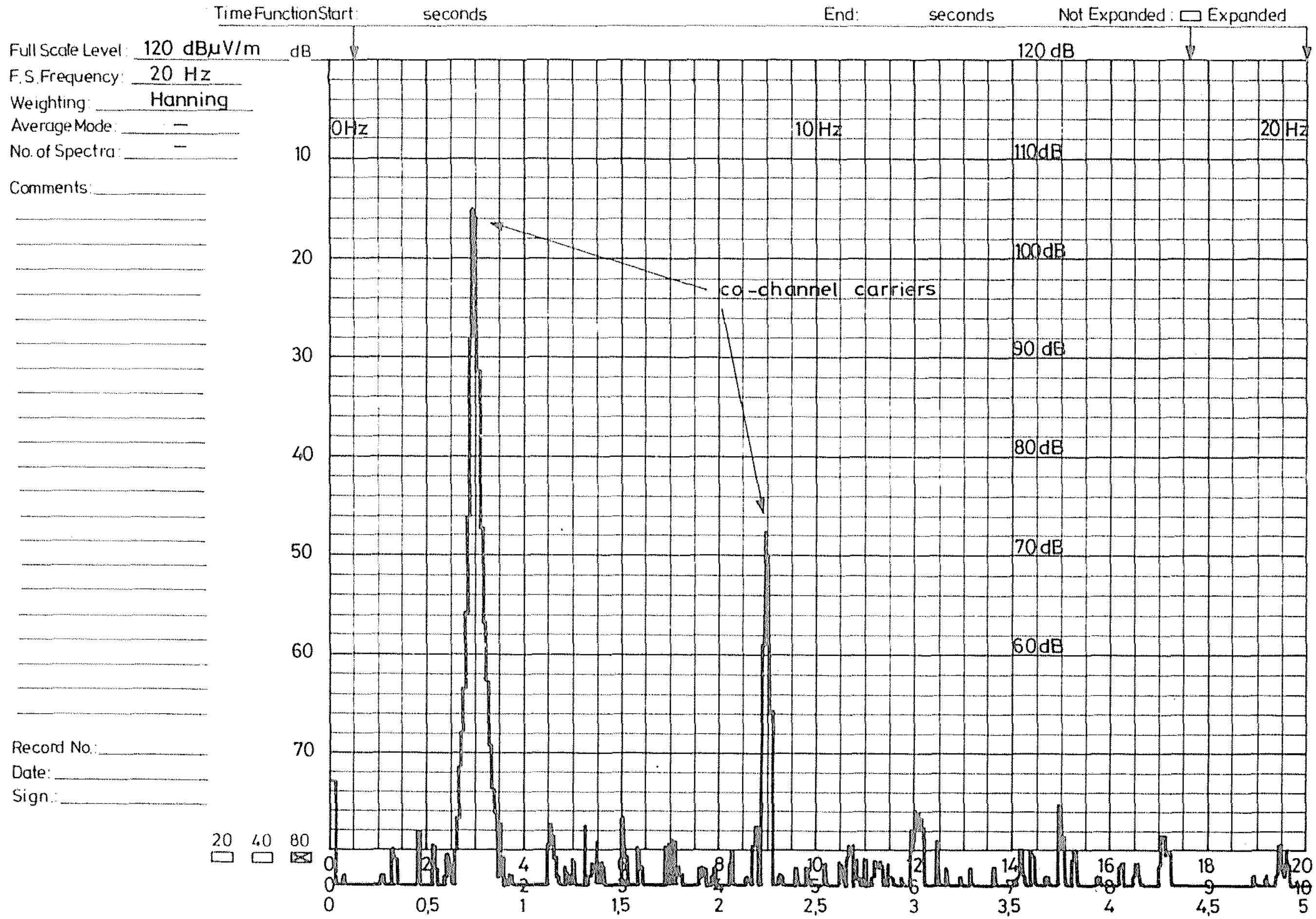

Fig. 4. Spectrum of a channel occupied by co-channel carriers

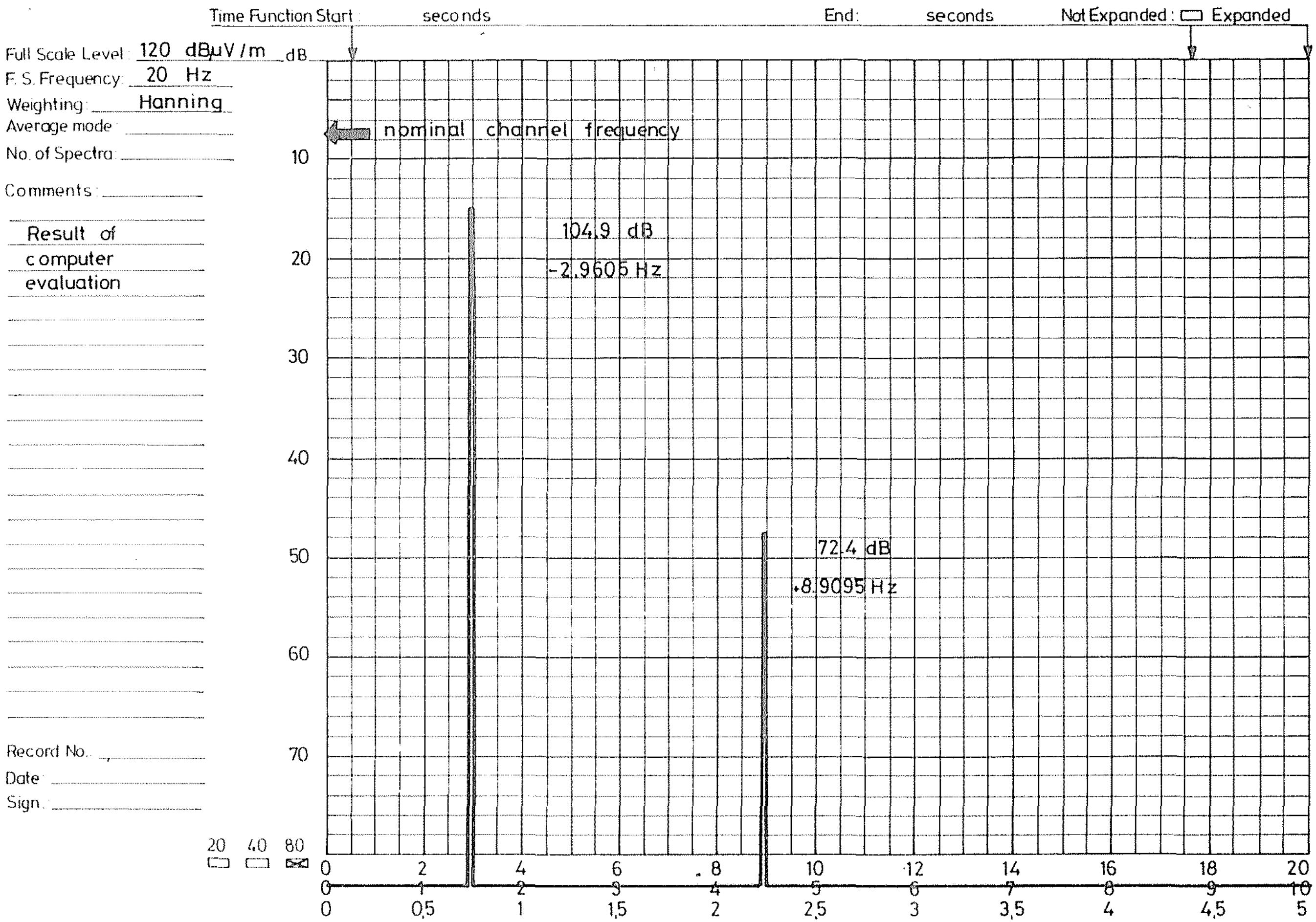

Fig. 5. Result of computer evaluation of spectrum shown in Fig. 4

The system provides the true frequencies of measured signals, and an equivalent selectivity which is far better than that obtained by conventional methods. Owing to the good linearity of the system, individual measurements of co-channel carriers of stable AM signals are possible.

The measurement is based upon the orthogonal downconversion of intermediate-frequency output of measuring receiver to about zero frequency.

On the baseband signals FFT analysis is performed. In the spectra peaks corresponding to carriers may be separated from stochastical spectra by virtue of the narrow analysis bandwidth.

The difference of phases related to the selected peaks shows if the original frequency was lower or higher than the local oscillator frequency of the synchronous detector. A controller is needed to evaluate spectra, to have access to the necessary phase information and to control the operation of equipment.

Owing to its automatic operation, high frequency resolution and dynamic range, the system may be well used at monitoring and measuring stations.

References

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