Introduction to "Synchronous Communications"

A Classic Paper by John P. Costas

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Invited Paper

The paper "Synchronous Communications," originally published in this journal in December 1956 by John P. Costas, has had a profound effect on modern digital communications. At the time of its publication, virtually all communications were analog in nature and, in fact, the stated goal of the paper was to demonstrate an amplitude-modulated (AM) system that could provide significantly improved performance for analog signaling and to dispel the notion that single sideband (SSB) had inherent performance advantages over properly constructed AM signaling systems.

At the time of writing this paper in December 1956, John Costas (Fig. 1) had been with the General Electric Company since 1951. He was serving as a consulting engineer in the Henry Military Electronic Equipment Department of the Defense Electronics Division, located in Syracuse, NY. John was born in Wabash, IN, and had previously attended Purdue University and received his B.S. degree in electrical engineering in 1944. He then served with the U.S. Navy as a radar officer during which time he also attended both the Harvard University and Massachusetts Institute of Technology (MIT) Radar Schools. In 1946, he returned to Purdue, earned his M.E.E. degree in 1947, and subsequently was awarded his Doctor of Science degree from MIT in 1951. Later in his career, John was formally recognized for his professional contributions when he became an IEEE Fellow in 1965 for his "contributions to communications theory and techniques."

Fig. 1. John Costas.

This paper is particularly significant because it was the first to demonstrate that carrier phase could be reliably recovered from the received signal using a structure that has come to be known as the Costas Loop. In its initial configuration, it resolved the received double sideband and suppressed the AM carrier signal into in-phase and quadrature components. These were then used to derive frequency and phase-control signals for the local oscillator, which in turn provided synchronous or coherent demodulation. The advantages cited at the time of publication of the 1956 paper included improved SNR performance and improved interference suppression properties of the synchronous receiver.

What was not foreseen in 1956 was the profound effect that this receiver structure would have on the design of digital communications receivers. Since the early 1970s, there

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has been phenomenal growth in modem technology. Today, achieving 56 kb/s on the switched telephone network is commonplace. Almost all such high-rate modems utilize a variation of quadrature amplitude modulation (QAM) and employ quadrature demodulation techniques. This is almost invariably accomplished using a quadrature loop structure that is related to the basic loop depicted in the 1956 paper.

There have been numerous quadrature carrier recovery loops developed, and they are all related to the original structure. The variations include remodulation loops and decision aided loops. In addition, there have been extensions to structures that jointly estimate carrier phase and recover symbol timing. Much of this work is summarized in the excellent tutorial paper of Franks [1].

In addition, there has been work done to develop a unified analytical model and analyses for generalized quadrature carrier recovery loop structures [2] for phase-shift keyed signals. These structures have varying nonlinearities in the quadrature arms of the loop, but the overall structure is easily recognized as having the basic form due to the work of Costas.

Further generalization of the quadrature loop structure has been made to demodulate QAM signals [3]. Here, the basic loop structure incorporates data filters and decision devices in the quadrature arms of the loop, but again the basic structure can easily be seen to be that of the 1956 paper. There have been many other papers published since that have produced generalizations of the quadrature loop for various scenarios. The number of such papers is much too great to mention in this brief introduction. The three papers listed merely provide examples of the many developments in quadrature loops for synchronization that have occurred since the publication of the 1956 paper by Costas.

This year is the 50th anniversary of the founding of the IEEE Communications Society. It seems fitting that the by now classic paper by Costas that first described the use of a quadrature loop for coherent demodulation should be republished. I trust that you will enjoy reading it and seeing first-hand the insights that led to the development of such loops.

REFERENCES

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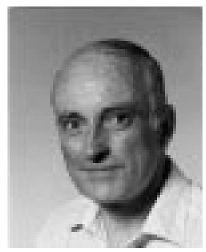

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