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United States Patent [19]

Schmidl et al.

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- [54] **TIMING AND FREQUENCY SYNCHRONIZATION OF OFDM SIGNALS**
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both of Stanford, Calif.
- [73] Assignee: **Stanford University,** Stanford, Calif.
- [21] Appl. No.: **666,237**
- [22] Filed: **Jun. 20, 1996**
- [51] Int. Cl.⁶ **H04L 7/00**
- [52] U.S. Cl. **375/355; 375/354**
- [58] Field of Search **375/354, 355;**
370/206, 208

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Assistant Examiner—Mohammad Ghayow
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[57] ABSTRACT

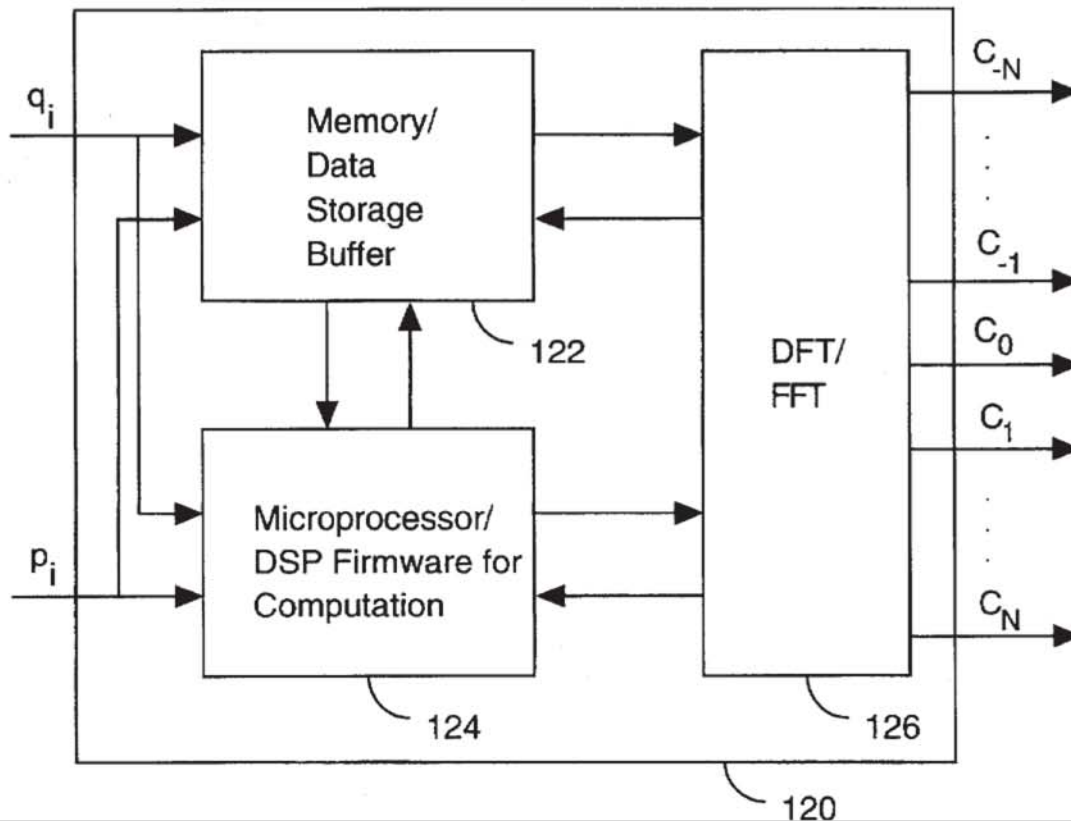
A method and apparatus achieves rapid timing synchronization, carrier frequency synchronization, and sampling rate synchronization of a receiver to an orthogonal frequency division multiplexed (OFDM) signal. The method uses two OFDM training symbols to obtain full synchronization in less than two data frames. A first OFDM training symbol has only even-numbered sub-carriers, and substantially no odd-numbered sub-carriers, an arrangement that results in half-symbol symmetry. A second OFDM training symbol has even-numbered sub-carriers differentially modulated relative to those of the first OFDM training symbol by a predetermined sequence. Synchronization is achieved by computing metrics which utilize the unique properties of these two OFDM training symbols. Timing synchronization is determined by computing a timing metric which recognizes the half-symbol symmetry of the first OFDM training symbol. Carrier frequency offset estimation is performed in using the timing metric as well as a carrier frequency offset metric which peaks at the correct value of carrier frequency offset. Sampling rate offset estimation is performed by evaluating the slope of the locus of points of phase rotation due to sampling rate offset as a function of sub-carrier frequency number.

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26 Claims, 15 Drawing Sheets



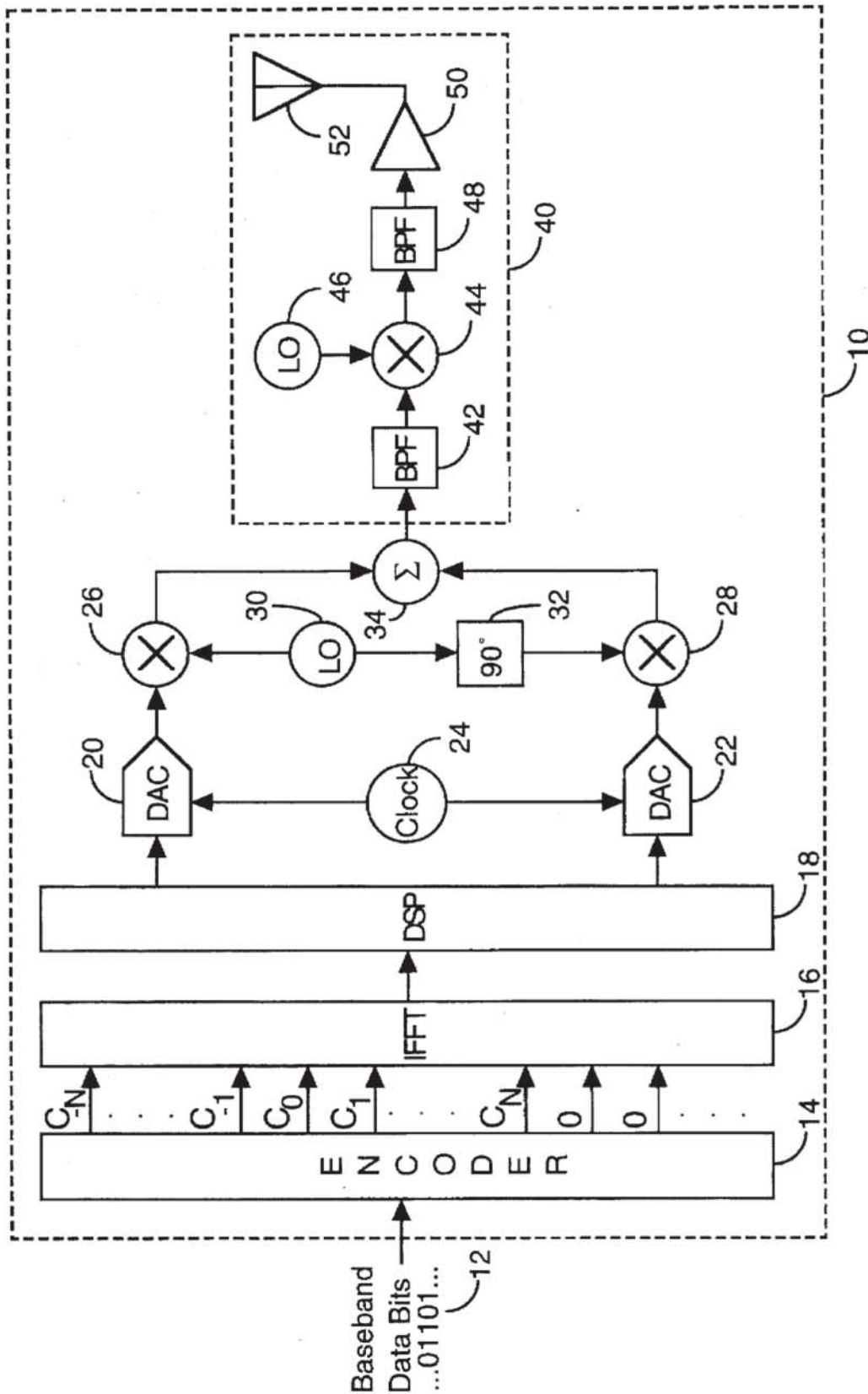


FIG. 1 (Prior Art)

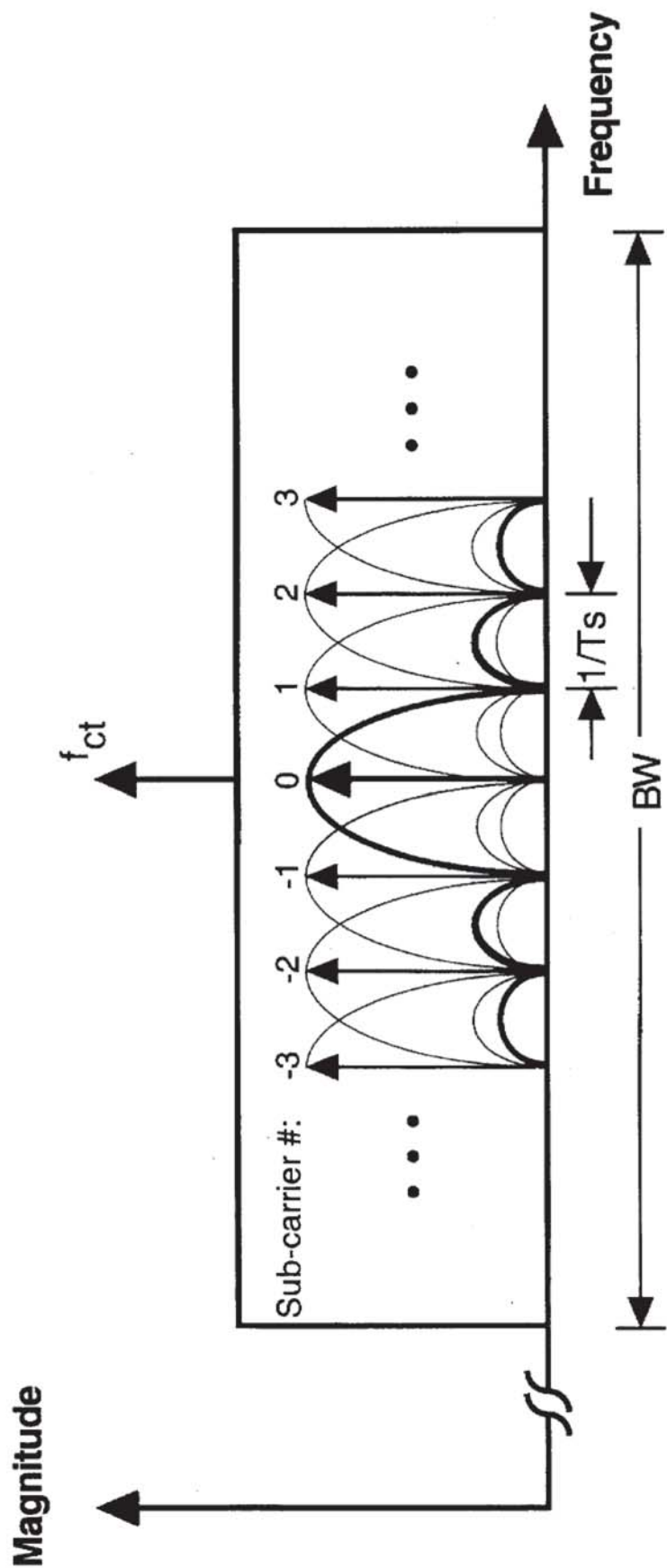


FIG. 2 (Prior Art)

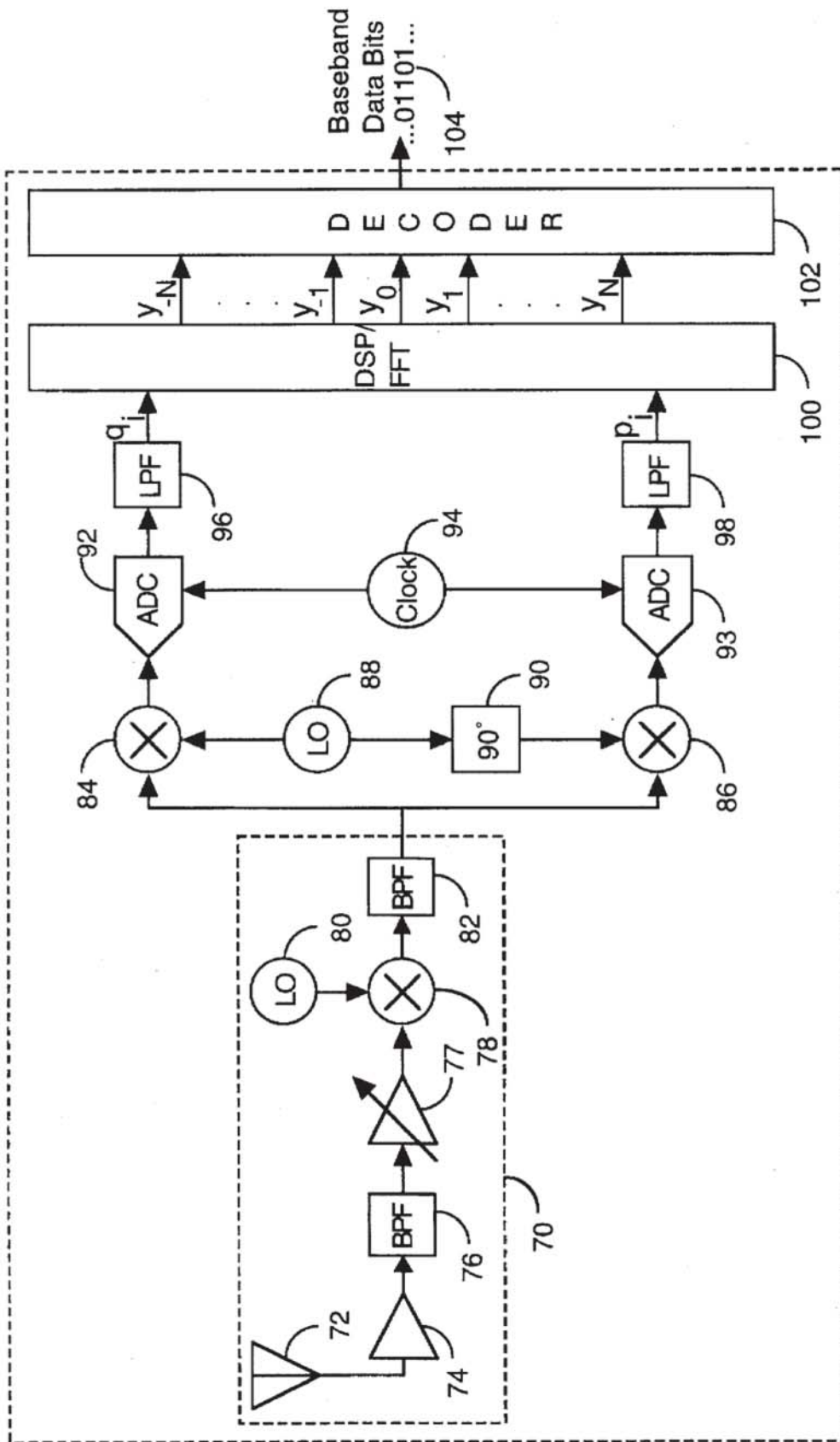


FIG. 3 (Prior Art)

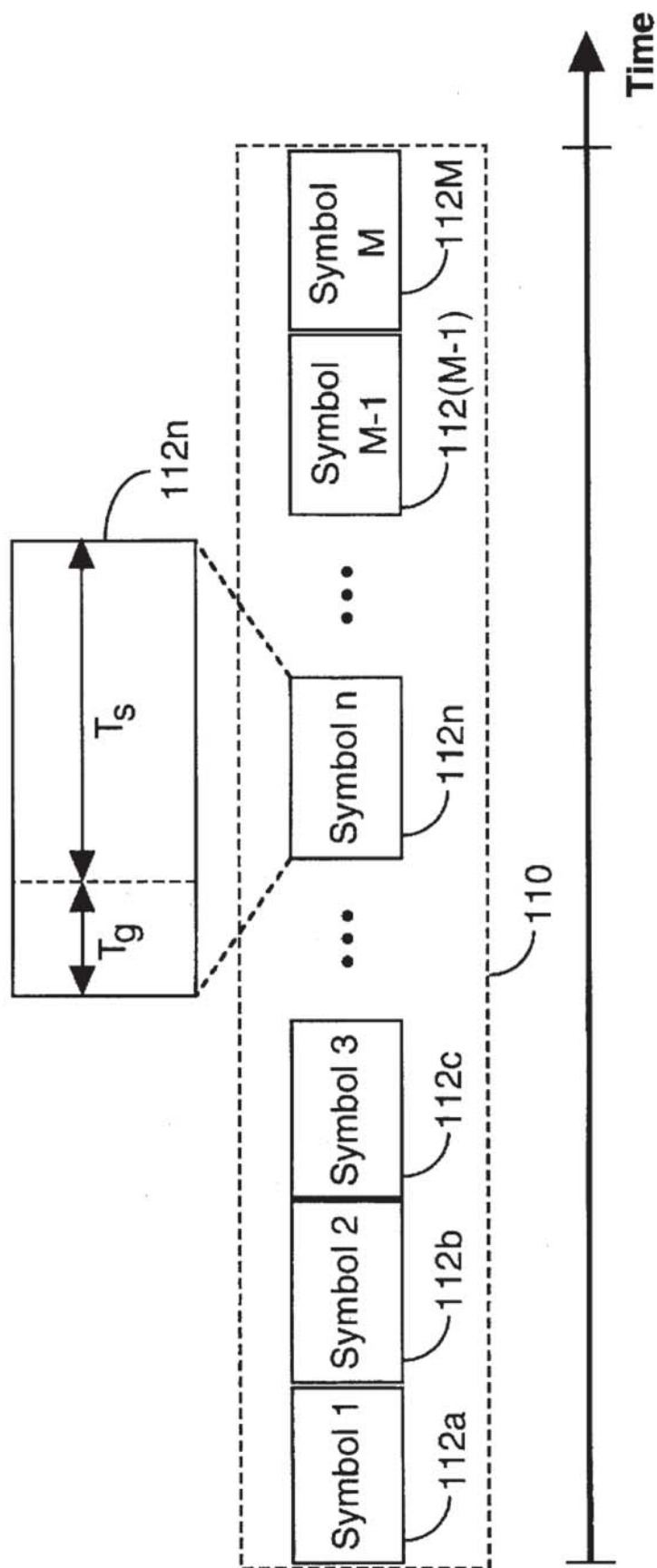


FIG. 4 (Prior Art)

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