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Jasper et al.

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[54] **PEAK TO AVERAGE POWER RATIO REDUCTION METHODOLOGY FOR QAM COMMUNICATIONS SYSTEMS**

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[73] Assignee: **Motorola, Inc.**, Schaumburg, Ill.

[21] Appl. No.: **786,681**

[22] Filed: **Nov. 1, 1991**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 536,825, Jun. 12, 1990.

[51] **Int. Cl.**[6] **H04L 27/04**

[52] **U.S. Cl.** **375/59**; 332/103

[58] **Field of Search** 375/38, 39, 42, 59, 375/60; 370/9, 10, 12, 18, 19, 20; 332/103, 144

[56] **References Cited**

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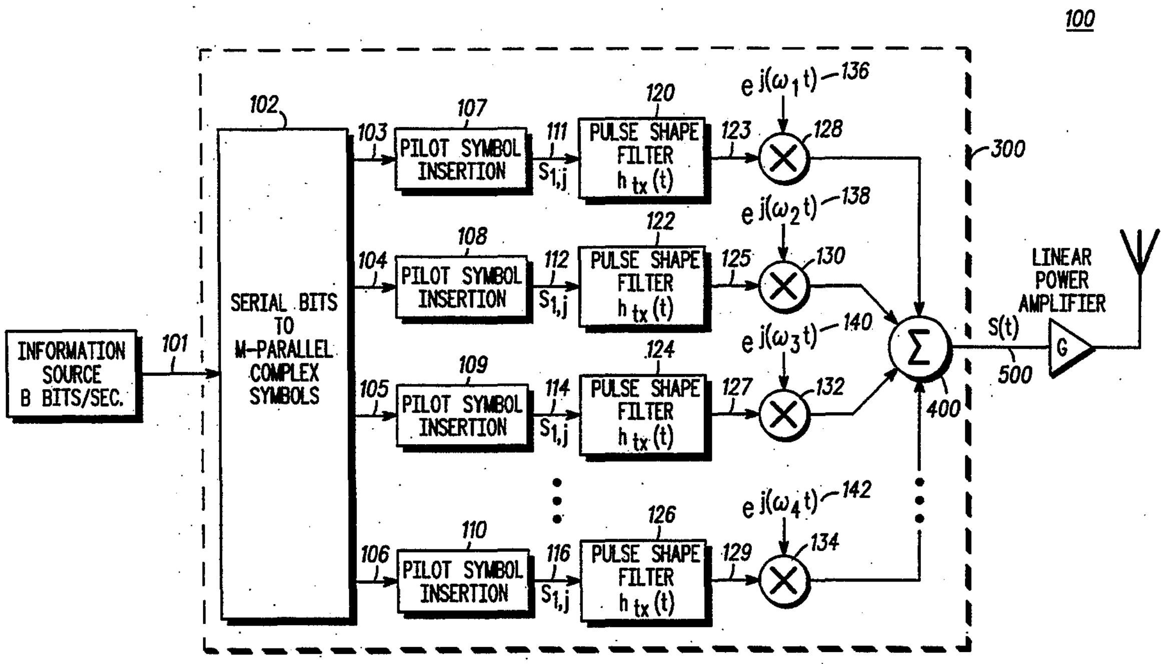
Primary Examiner—Stephen Chin

Attorney, Agent, or Firm—Joseph P. Krause

[57] **ABSTRACT**

The ratio of peak power level to average power level in a power amplifier used in a QAM communication system transmitter can be reduced by preselecting magnitudes and phase angles of complex-valued pilot symbols used in multi-channel, N-level QAM.

20 Claims, 3 Drawing Sheets



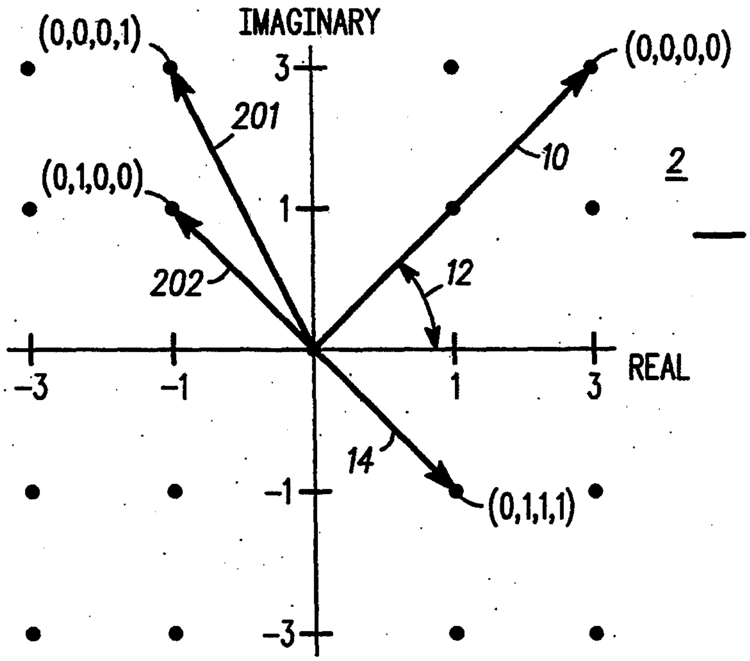


FIG. 1

— PRIOR ART —

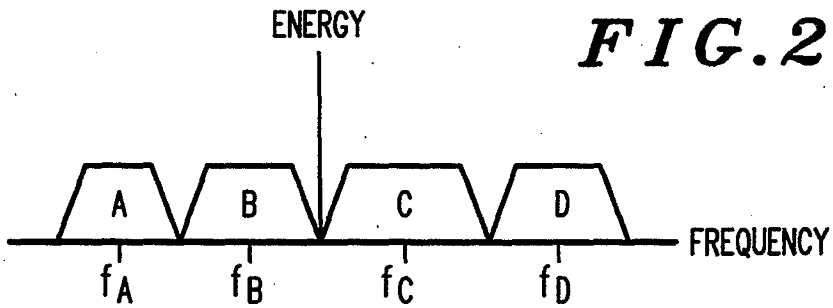


FIG. 2

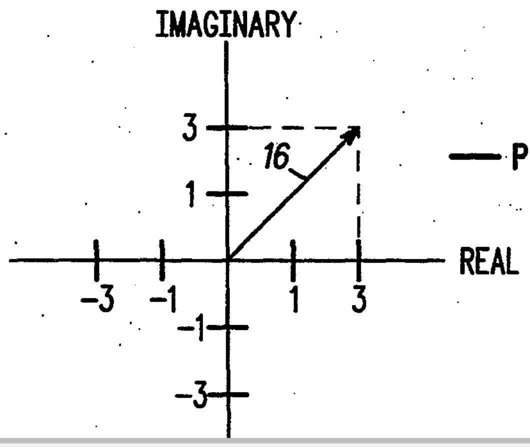
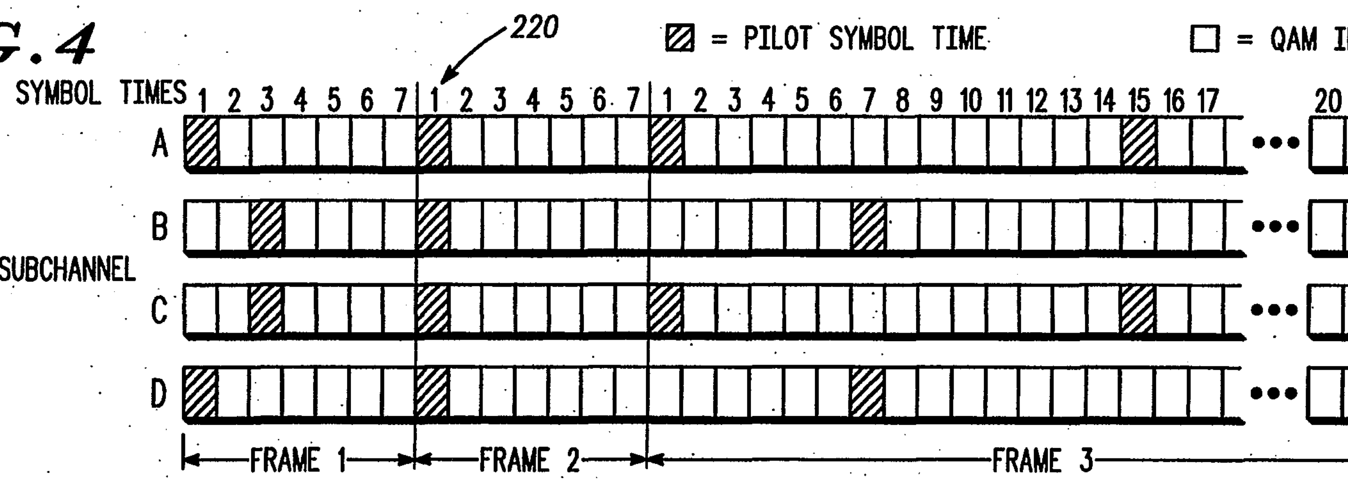


FIG. 3

— PRIOR ART —

FIG. 4



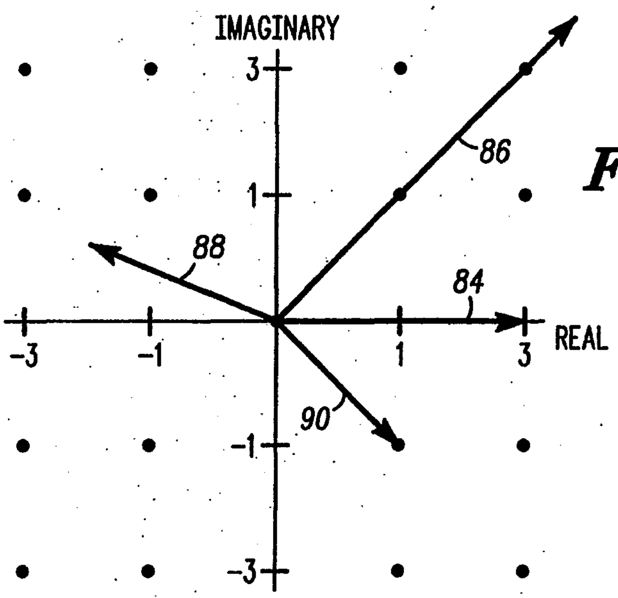
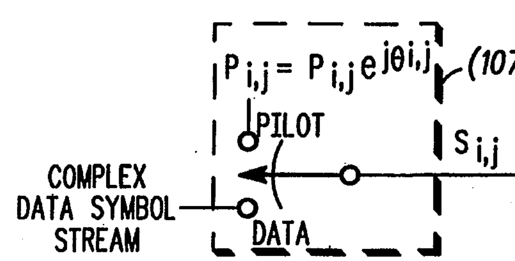
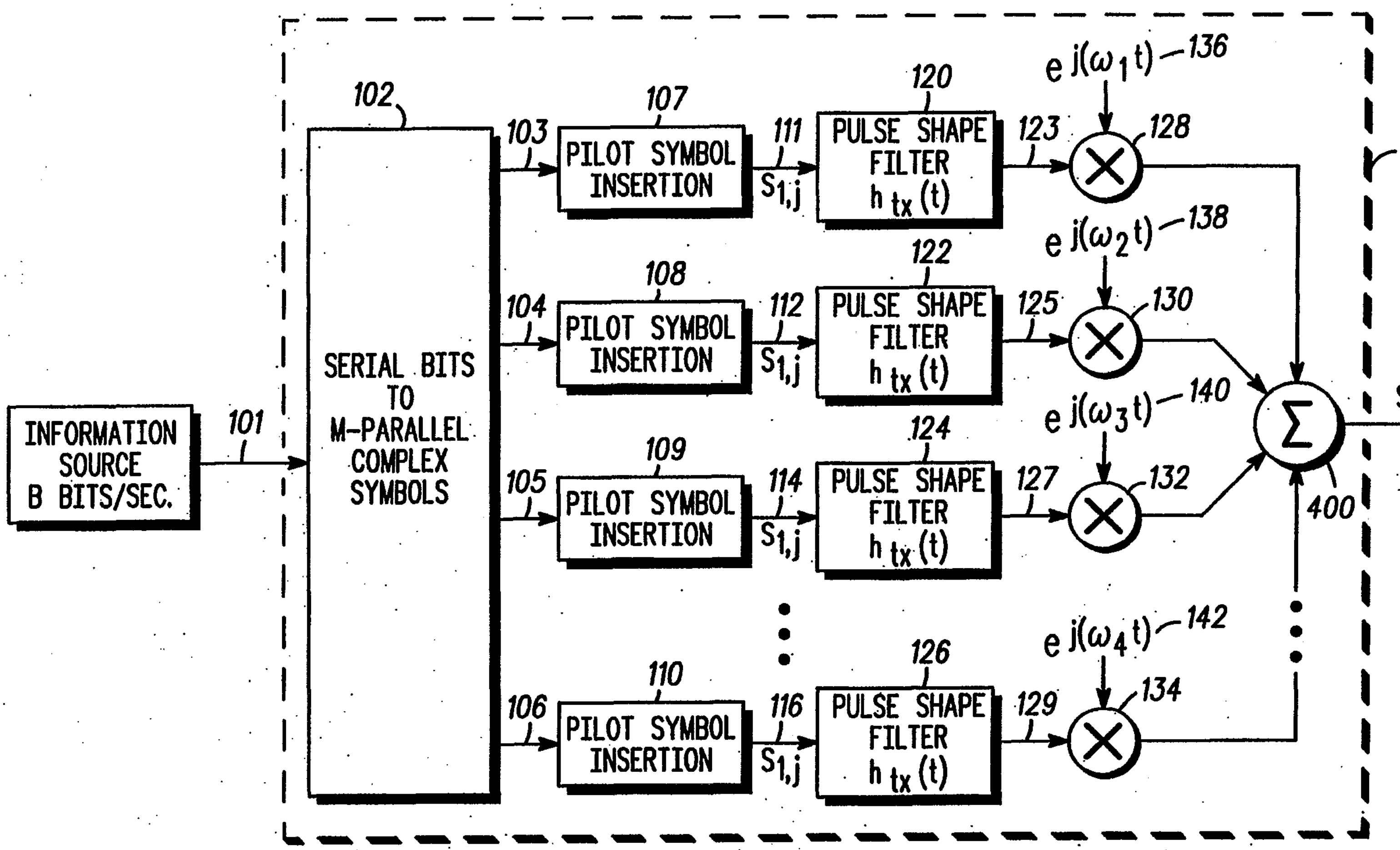


FIG. 6

FIG. 5B




INFORMATION SOURCE B BITS/SEC.
101
102
SERIAL BITS TO M-PARALLEL COMPLEX SYMBOLS
103
104
105
106
107
108
109
110
PILOT SYMBOL INSERTION
PILOT SYMBOL INSERTION
PILOT SYMBOL INSERTION
PILOT SYMBOL INSERTION
111
112
114
116
S1,j
S1,j
S1,j
S1,j
120
122
124
126
PULSE SHAPE FILTER h tx (t)
PULSE SHAPE FILTER h tx (t)
PULSE SHAPE FILTER h tx (t)
PULSE SHAPE FILTER h tx (t)
123
125
127
129
e j(ω1 t)
136
e j(ω2 t)
138
e j(ω3 t)
140
e j(ω4 t)
142
128
130
132
134
Σ
400

4

PEAK TO AVERAGE POWER RATIO REDUCTION METHODOLOGY FOR QAM COMMUNICATIONS SYSTEMS

This is a continuation-in-part of Ser. No. 07/536,825, filed Jun. 12, 1990.

FIELD OF THE INVENTION

This invention relates to communications systems. More particularly this invention relates to methods for improving the peak power to average power ratio in a linear modulation communications system particularly a QAM communications system.

BACKGROUND OF THE INVENTION

Various communication systems are known in the art. Pursuant to many such systems, an information signal is modulated on to a carrier signal and transmitted from a first location to a second location. At the second location, the information signal is demodulated and recovered.

Typically, the communication path used by such a system has various limitations, such as bandwidth. As a result, there are upper practical limitations that restrict the quantity of information that can be supported by the communication path over a given period of time. Various modulation schemes have been proposed that effectively increase the information handling capacity of the communication path as measured against other modulation techniques. Sixteen-point quadrature amplitude modulation (QAM) provides a constellation of modulation values (distinguished from one another by each having a different combination of phase and amplitude) wherein each constellation point represents a plurality of information bits.

By virtue of their changing amplitude from QAM-symbol time-to-QAM-symbol time, QAM symbols in a QAM communication system require linear power amplification to be able to accurately distinguish one QAM symbol at one amplitude level and another QAM symbol at some other power level. In a radio communications system, QAM symbols require a very linear amplification prior to broadcasting them on an antenna. In QAM systems, non-linear amplification of QAM symbols in a QAM signal, (which QAM signal is typically considered to be a pulse-shape filtered and frequency up-converted stream of QAM symbols), in a radio transmitter can make coherent demodulation impossible. Another more common problem with using non-linear amplifiers with QAM modulation is the frequency splatter caused by non-linear amplification of a signal. For this reason, linear power amplifiers are required in QAM radio transmitters, which power amplifiers increase in cost, size, and complexity as their output power level and/or linearity increase.

A problem in the design of a linear power amplifier is providing the ability of an amplifier to accommodate widely fluctuating input power levels while producing at its output a faithful reproduction of the input signal. While an amplifier can be readily designed to have a linear power amplification of a relatively constant-amplitude input signal, designing an amplifier that can accommodate a peak power level that might, at any given time, exceed the average power level by several decibels (db) can significantly increase the cost and size of the amplifier.

In QAM communications systems, the ratio of the peak power level to average power level of a QAM symbol stream will usually continuously vary by virtue of the fact that the data represented by the QAM symbols itself varies randomly. Accordingly, power amplifiers for QAM communications systems must be capable of handling a significant peak to average power level ratio and, accordingly, any reduction in the peak to average power ratio eases the requirements of a QAM power amplifier.

Some prior art, single channel QAM systems are frequently transmitted on a communications channel, such as a radio frequency channel, in conjunction with a pilot component. Such pilot components, by constructively or destructively adding with other QAM symbols can at times aggravate the the peak to average power level ratio requirements of a QAM power amplifier, thereby further aggravating the requirements of such an amplifier.

Any methodology by which the ratio of peak power amplitude to average power amplitude is reduced would therefore simplify and reduce the amplifier cost associated with a QAM system and would be an improvement over the prior art.

SUMMARY OF THE INVENTION

In a multi-subchannel, N-level QAM communication system using complex-valued pilot symbols, there is provided herein a method of reducing the ratio of peak to average power by pre-selecting amplitude and/or phase angles for the embedded, complex-valued, pilot symbols added to QAM information symbols, so as to minimize the peak to average power ratio of a composite QAM signal that is transmitted on a communications channel. Such pre-selected pilot symbols include complex-valued symbols that are not part of the well-known constellation of values used in an N-level QAM system, such as the 16 constellation points used in a 16 QAM system. In fact, using the method herein, in a multi-channel, N-level QAM system wherein, over some length of time during which several QAM symbol frames can occur, in addition to have different valued time-coincident pilots in several subchannels, the pilot values in one or more subchannel can also change over this length time. Stated alternatively, pilot values can change both over time and over subchannels to reduce the peak to average power ratio in the composite signal. Frequently at least one pilot symbol will be selected to be off the constellation of values in order to maximally reduce the peak to average power level in the composite signal of a QAM system, which composite signal is comprised of the combination or summation of a plurality of N-level QAM subchannels, which subchannels are in-turn comprised of complex-valued QAM information symbols combined with the complex-valued preselected pilot symbols. In a multi-channel, N-level QAM system, by proper selection of these preselected pilot signals, which are combined with the QAM information symbols (which QAM information symbols include the information of interest to be transmitted) the combined QAM symbols and the preselected pilot can have a substantially lowered peak power level to average power level ratio, compared to prior art systems that use only one or more QAM constellation points for pilot symbols.

In most application of the method herein, and in the embodiment of a QAM transmitter disclosed herein, at least one pilot symbol that is to be combined with a

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