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PHASE LOCK APPLICATIONS IN CATV SYSTEMS

I. Switzer, P. Eng.,
Chief Engineer,
Maclean-Hunter Cable TV Limited,
27 Fasken Drive,
Rexdale, Ontario.

PHASE LOCK APPLICATIONS IN CATV SYSTEMS

Phase locking techniques have been used for some time in a variety of communications applications. The term may be generally applied to locking the phase of one signal source to another. Such sources will then operate at the same frequency and their relative phase will remain constant or nearly so. The principle application in communications has been suppressed carrier communications systems, both wire and radio, and in the transmission of colour television. Colour television subcarriers are operated in a suppressed carrier mode. Each individual colour receiver has a local subcarrier oscillator which must be phase locked to the original colour subcarrier in order to permit the colour information to be demodulated. Similarly, other suppressed carrier communications systems require a locally generated carrier to permit the transmitted information to be demodulated. The local carrier is often generated by phase locking to a pilot signal of some kind.

Figure 1 shows a basic phase lock loop. A phase comparator compares the reference signal and the local carrier oscillator. The local carrier oscillator is a voltage controlled type whose output frequency can be controlled by a DC control voltage. The comparator produces an error signal which is used to control the voltage controlled oscillator (VCO). With a suitable error signal amplifier and VCO characteristics the feedback loop will keep the local carrier oscillator tightly locked in phase with the incoming reference signal. Phase lock loops of this kind have been studied in great detail and complete analyses of a number of forms of this basic phase lock loop are to be found in the electronic engineering literature.

CATV APPLICATIONS

One of the earliest phase locking applications in CATV is the Model 220 Phase Lock generator produced by Phasecom Engineering, of Anaheim, California. This phase lock generator is employed to produce an unmodulated carrier which is phase locked to a broadcast television channel. In areas of moderate to strong local signal, it is common practice to convert the local channel to a different channel for distribution. The local channel is often left vacant, but many CATV systems use this channel within the cable system for distribution of news or weather services or other closed circuit originations. Unless the modulator used for this origination is phase locked to the air signal there will usually be annoying "co-channel" beats in subscribers' receivers caused by the beat between the direct pick-up of the air channel and the cable channel. These two channels will generally be slightly different in frequency and will cause an annoying beat at interfering signal levels which are not strong enough to cause annoying or even visible "ghost" effects. Generally speaking, the "co-channel beat" is visible before the ghost. If the CCTV modulator is phase locked to the air signal there will be "co-channel beat". If the interference is strong enough there may still be a ghost visible on some subscribers' receivers. In exceptional cases there may be no co-channel beat but there may be interference to the sound carrier. It is not feasible to lock FM sound carriers.

Figure 2 shows the basic block diagram of the Phasecom Engineering Model 220 Phase Lock Generator. A tuned RF amplifier selects the desired off-air channel. The associated sound carrier and any adjacent carriers are rejected at this point. A phase comparator (balanced diode bridge) compares the incoming air signal and the signal from the internal VCXO (voltage controlled crystal oscillator) and produces an error signal which is amplified and then used to control the VCXO.

The purpose of the phase lock generator is to provide a local carrier which is phase locked to the air signal. This carrier then becomes the carrier for the CCTV modulator, replacing the modulator's internal crystal controlled carrier. The VCXO used is a precision crystal oscillator in a temperature controlled oven. It is controlled over a very narrow range--about plus or minus 2 KHz, slightly more than the frequency drift that TV stations are permitted by the FCC. Television broadcast stations must operate on assigned frequency with only 1 KHz ($\pm$) permitted. Restricting the "pull-in range" of the VCXO simplified its design and also prevents it from locking onto unwanted modulation sidebands. When no air signal is present to provide a reference lock, the VCXO will still be quite close to the desired output frequency.

Other techniques might be used to produce a local carrier which is an unmodulated form of the air carrier. Hard limiting might have been used to "strip" the modulation from the air carrier. Most limiters tend to convert the AM modulation to a small amount of phase modulation. This would be undesirable. A limiting technique would also have the disadvantage of not providing a carrier when the air channel was not broadcasting, or if the air channel was overmodulated.

Carriers could also be effectively phase locked by the use of very precise oscillators for both the air transmitter and the CCTV modulator. The use of high precision crystal oscillators or rubidium or caesium beam oscillators is becoming more common in broadcast stations but is far from universal. A similar high precision oscillator in the CCTV modulator would keep the locally generated carrier substantially in phase with the air signal for long periods of time. Such oscillators are extremely expensive ranging from $5,000 to $15,000, depending on the degree of precision required.

Phase lock generators, which Phasecom Engineering has produced so far have been for VHF use. Because the frequency lock-in range is quite small, they must be ordered with broadcast station offset in mind. One recently installed by our Company at North Bay, Ontario operates on channel 10- i.e. 193.240 MHz instead of the nominal channel 10 visual frequency of 193.250 MHz. There has been some consideration of using the phase lock generator at IF frequency (45.75 MHz). This would permit its use in IF type modulators and would also permit the construction of an IF phase locking generator that could then be applied to a number of different situations. Phase locking at IF would require precision down conversion since the "pull-in range" of the VCXO is so narrow. A down converter from channel 13 to IF normally operates with an L.O. at 257 MHz. A stability and precision of better than 1 KHz at this frequency requires an L.O. with about .0005% accuracy.

This would be an expensive L.O.--possible, but a bit expensive. Such a phase lock system would operate an IF modulator as in figure 3. In cases where IF type modulators are used, the scheme in figure 4 is recommended. In this case, the up-converter L.O. is not as critical, and the phase lock generator operates at the same frequency as the air channel visual transmitter.

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Phase lock techniques may also be used to reduce the risk of interference to direct local reception caused by signal leakage from the cable system. In the North Bay installation previously mentioned, the local air signal is not strong enough to cause serious beat and ghost problems and the system distributes sound programms only (no visual modulation) on its locally generator channel 10. The reason for the phase lock installation was reduction of the risk of c-channel interference, arising from system radiation interfering with direct local reception by non-subscribers. The system experienced a number of cases in which a subscriber and non-subscriber would have receivers back-to-back, separated only by a thin partition. A small amount of radiation from the subscriber's service drop and matching transformer leads would cause interference to the non-subscriber receiving the local station on rabbit ears on the other side of the partition. It was a case of marginal radiation causing interference to marginal direct reception. The phase lock system has completely cured this problem.

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Dual cable systems would seem to be natural applications for phase locking systems. The "co-channel beat" due to excessive cross-talk between cables is visible and annoying before the "ghost" becomes visible. Phase locking the channels in adjacent cables will eliminate the "co-channel beat" type of interference. Channels of the same "number" in each cable should be phase locked to each other. One channel would be designated as the reference channel and the same channel number in the other cable phase locked to it. For example channels in the "A" cable would be designated as the reference channels and the "B" cable channels phase locked to the "A" channels. Channel 2B would be locked to 2A, 3B to 3A, etc. In some instances both the A and B channels might be locked to an air channel.

Figure 5 shows one of several schemes that permit locking channels in adjacent cables of a dual cable system. In the example shown, 9A has been derived from a channel 9 transmitter at a moderate distance. Channel 9B is derived from a UHF station, channel 50. Heterodyne processors are shown in both channels for signal processing. The phase detector compares 9B to 9A and controls a VCXO which is incorporated into the channel 50 - 9 UHF converter. This VCXO varies the phase of the 9B signal to keep it locked to 9A. The phase lock loop can be expanded to include a number of different signal processing elements.

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Phase lock techniques can be used to eliminate third order intermodulation (triple beat) problems in CATV systems. Visual carriers in CATV systems are only nominally on specified channels. The actual visual carrier frequencies can be significantly different from the "true" visual carrier frequencies. Differences arise from the + and - 10 KHz offsets assigned to television broadcast channels, the + and - 1 KHz frequency tolerance allowed television broadcast channels, and the frequency errors arising from low tolerance oscillators in CATV channel conversion and channel originating equipment. The "triple beats" which arise as distortion products in CATV have frequencies which are the sums and differences of either three different visual carriers (aural carriers are neglected in this discussion because of their relatively low level) or the second harmonic of one carrier and the fundamental of a second carrier. If all the visual carriers in a contiguous set of carriers were separated by exactly the same frequency, the "triple beat" products would all be "zero" and would cause only very minor changes in level rather than visible interference beats. This technique is applicable to contiguous groups of channels, e.g. 2,3,4, or 7,8,9,10,11,12,13. It would also be applicable in cases where additional mid-band or superband channels are added to the high band group. These channel visual carrier frequencies could all be locked to a 6 MHz master oscillator which would set the frequency spacing between them. It is not important that the spacing be exactly 6 MHz, only that the spacing be exactly the same for all the channels.

A number of techniques could be used to derive such a locked set of channels. One scheme is illustrated in figure 6. A master 6 MHz oscillator sets the spacing between channels. A comb generator generates multiples of the master 6 MHz oscillator. These are separated and amplified and mixed with the channel 7 visual oscillator (175.25 MHz). The resulting sum frequencies are filtered and amplified to become a master set of reference carriers which are all separated by the 6 MHz master oscillator frequency. This set of reference carriers can be used as the carrier oscillators for originating modulators or they can be used as references to which specially modified heterodyne processors could be locked. The modified heterodyne processors would use a VCXO as one of the local oscillators permitting the processor output frequency to be locked to the appropriate master reference carrier.

The value of such a system is not yet known, although its cost would be substantial (but probably well within the means of larger CATV systems). Triple beats are usually a lesser problem than cross modulation interference. It is probable that they accumulate in a system at a slower rate than cross modulation products. It is likely that a system that has cross modulation products held to a tolerable level will also have triple beats under control, but there may be cases in which triple beat is still a serious problem. Still, it would be nice to eliminate the triple beats completely.

Phase lock techniques can be used to generate the local carrier required in synchronous detector systems. A television demodulator marketed by Scientific Atlanta uses phase lock to develop a local carrier for synchronous detection.

The S-A demodulator uses an elaborate system to sample the television carrier during sync pulses when the carrier is at full amplitude, in a manner analogous to the phase lock system in colour television receivers which phase locks the locally generated colour subcarrier to the colour burst transmitted on each synchronizing pulse.

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Suppressed carrier techniques would considerably reduce the loading-induced distortion products in CATV systems. Suppressed carrier might be used for transportation trunks with carrier reinsertion before distribution. Alternately, suppressed carrier might be used throughout a system trunk system with carrier reinserted at bridging locations feeding the less critical parts of the distribution system. It might be possible to include carrier reinsertion in back-of-the-set or set-top multi-channel converters. Phase lock techniques locking to a carrier "burst" might be used or a pilot tone system might be considered.

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The author wishes to acknowledge the assistance of Mr. Arie Zimmerman, of Phasecom Engineering, for the information on the Phasecom Model 220 Phase Lock Generator and for the provision of practical phase lock hardware to test some of the applications which have been discussed.

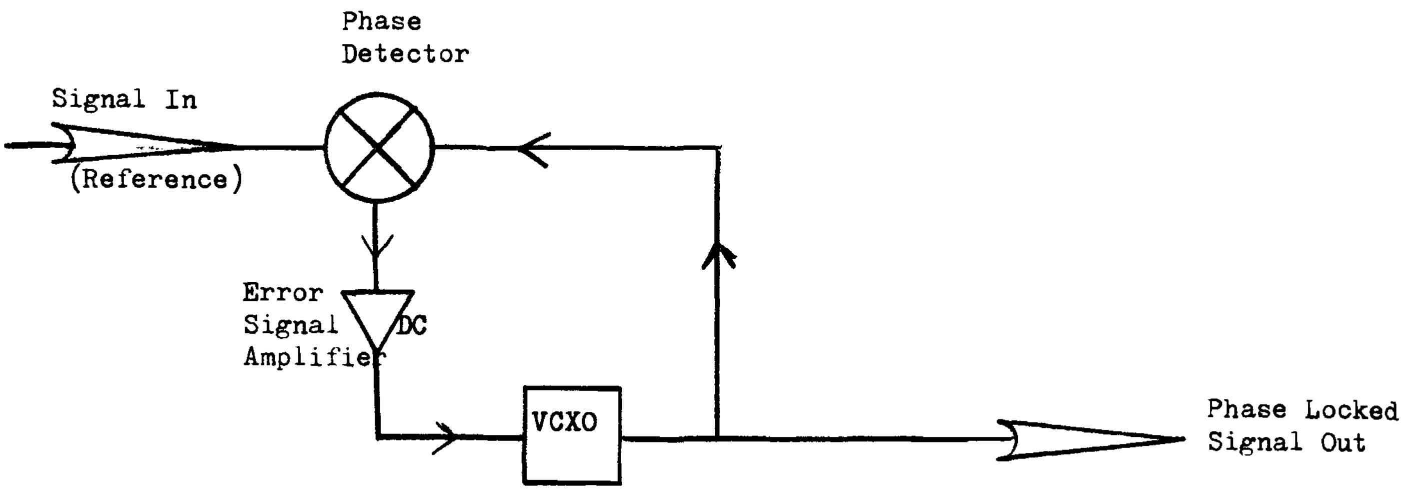

Figure 1
Basic Phase Lock Loop

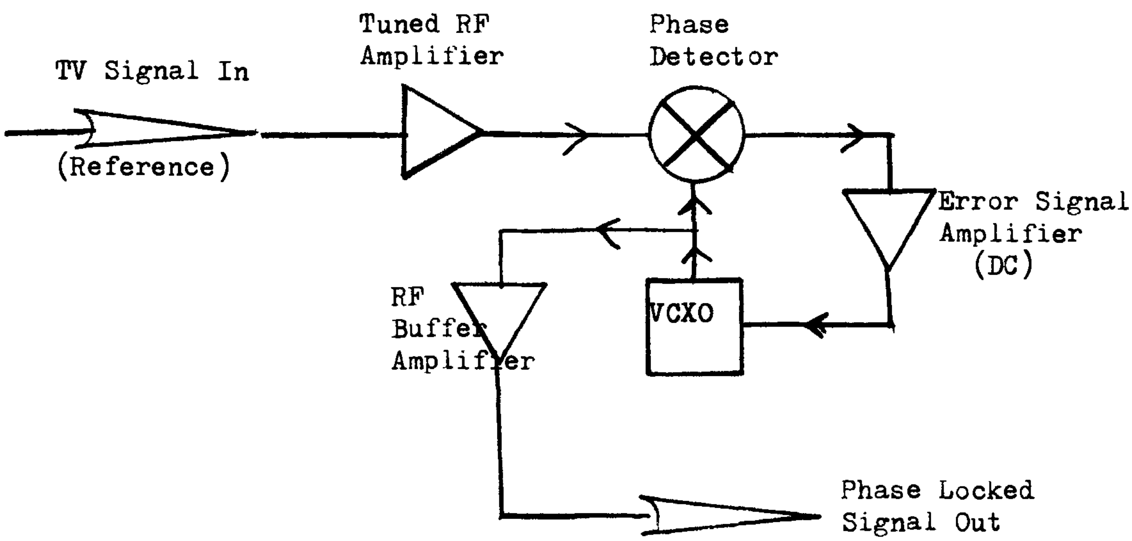

Figure 2
Basic Block Diagram
Phasecom Model 220 Phase Lock Generator

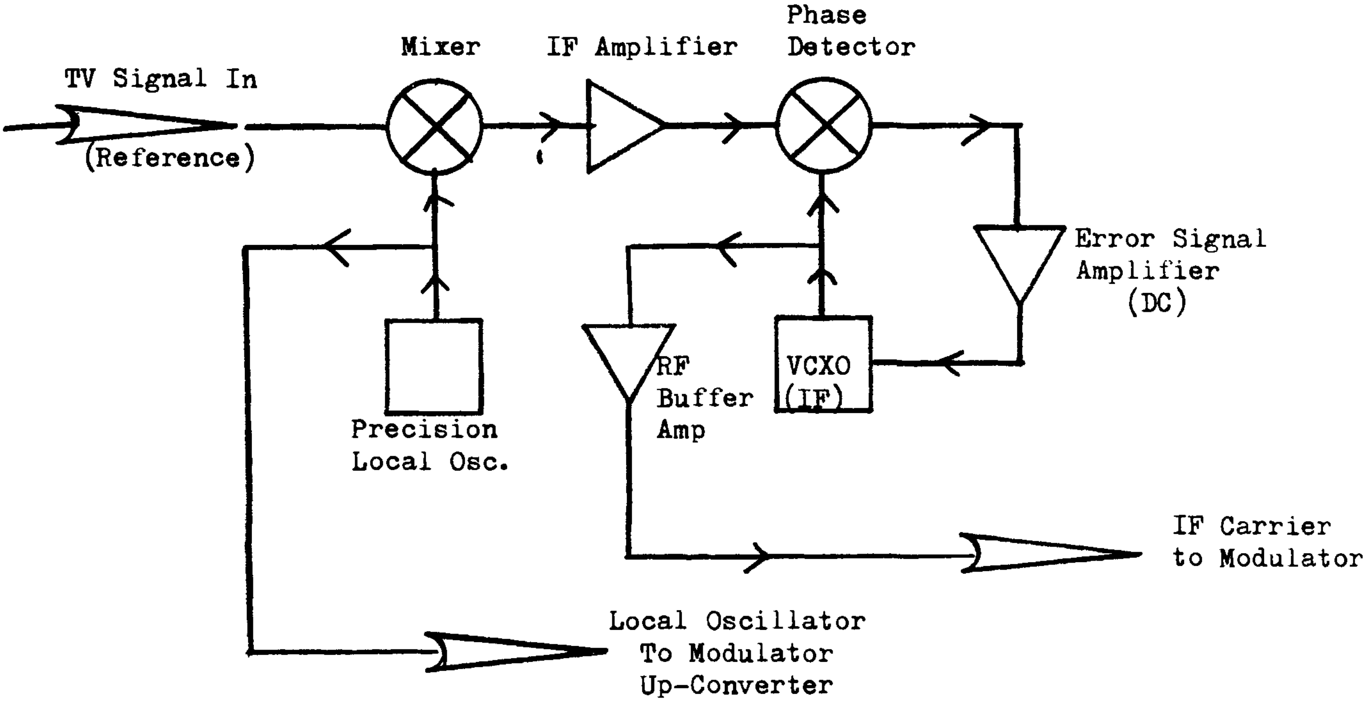

Figure 3

Phase Lock Operating at IF Frequency

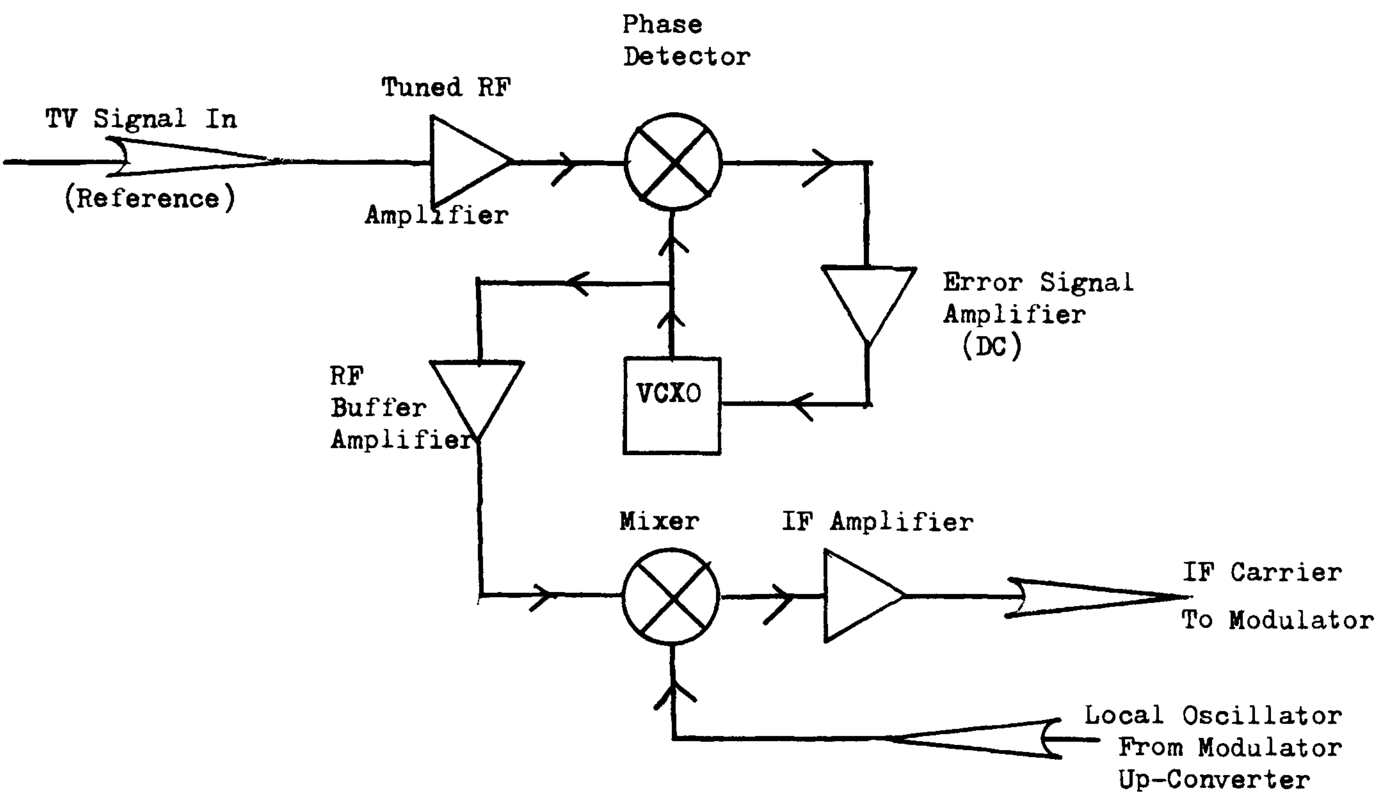

Figure 4

Phase Lock System for IF Modulator

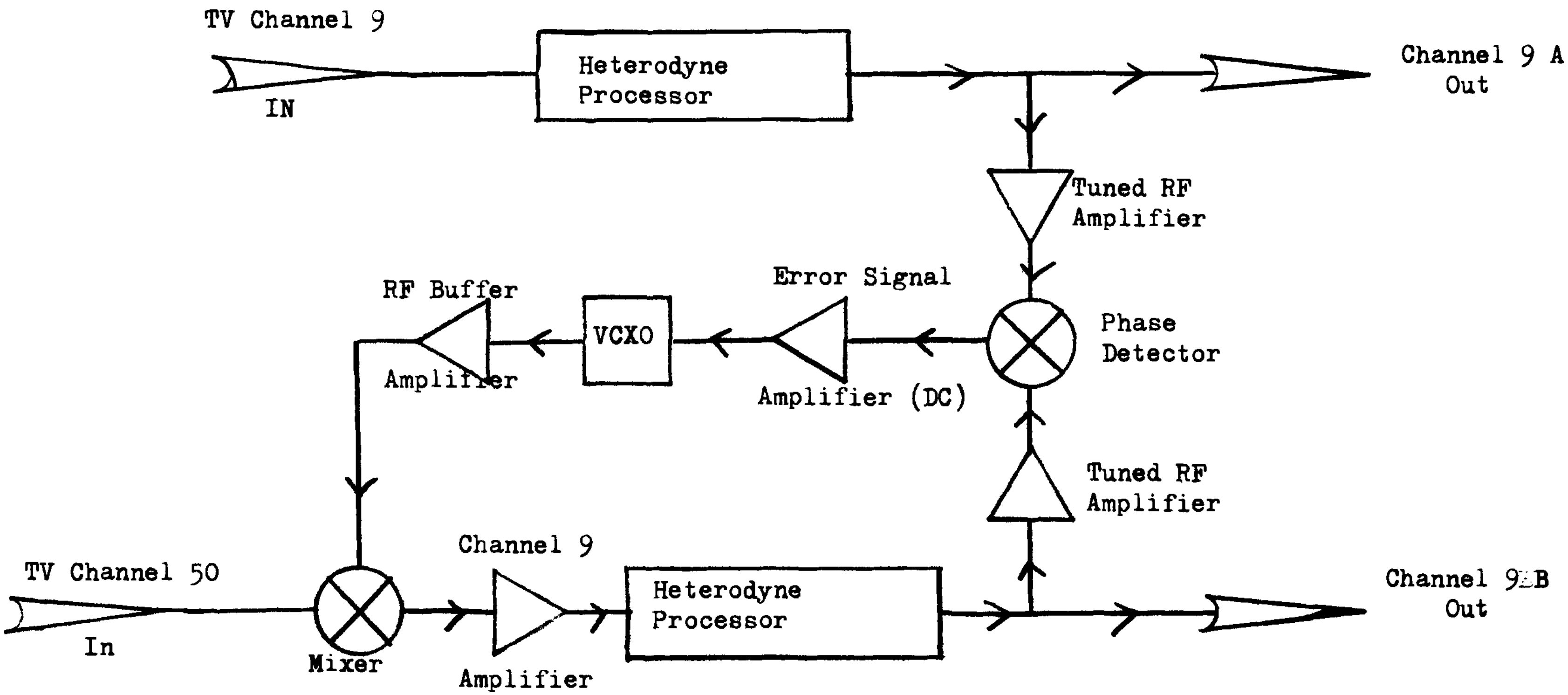

Figure 5
Dual Cable Phase Lock Application

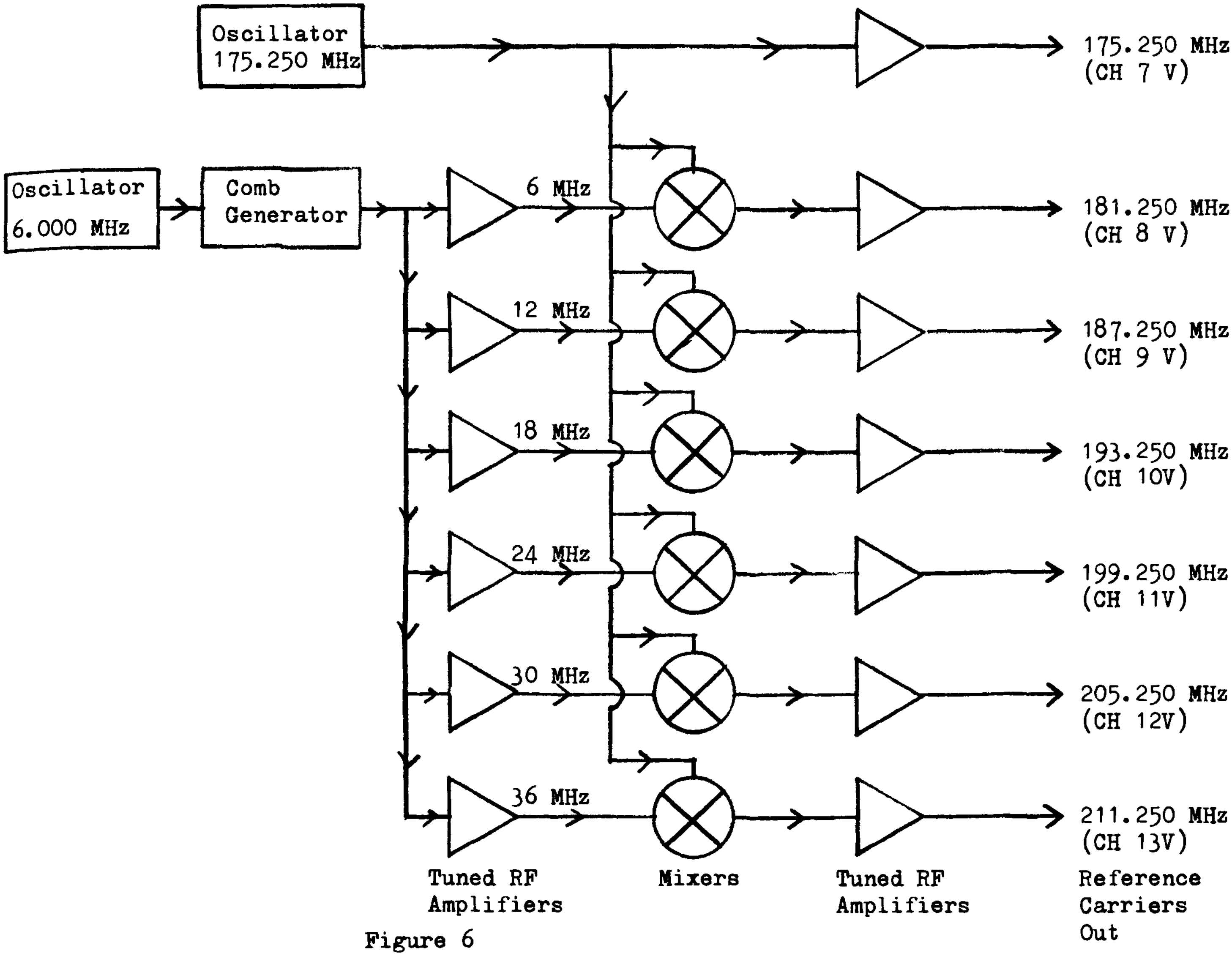

Figure 6

Block Diagram - Visual Reference Carriers locked to Common 6 MHz Spacing