AN IMPROVED FREQUENCY MEASURING TECHNIQUE FOR CATV

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NEED FOR FREQUENCY MEASUREMENTS

Most specifications currently in force or proposed for CATV make some reference to the frequency accuracy and stability of the TV carriers in cable television systems. The specifications usually require carrier frequency accuracies approaching those applied to television broadcast transmitters, particularly in the case of adjacent channel operations.

Television channels processed through doub conversion, heterodyne processors using the same local oscillator for down and up conversion are not changed in frequency. Neither the visual carrier frequency nor the visual-aural intercarrier spacing is changed by such processing. Any frequency errors observed in such a case must have occurred in the broadcasting station.

Television channels converted from one channel to another, either by single or multiple conversion processes or by demodulation and remodulation are subject to possible frequency errors arising the processing system. Intercarrier spacing is usually not affected unless audio is reduced to baseband and remodulated for cable system use.

A convenient and accurate method of measuring carrier frequencies in cable systems has been developed and is described:-

ACCURACY REQUIRED

Broadcast standards for frequency accuracy are +- 1 KHz for both visual carrier and intercarrier. The universal use of intercarrier sound systems in television receivers makes the intercarrier spacing a more important parameter than the aural carrier frequency itself. It is desirable to have an accuracy of at least +- 100 Hz in a measuring system to check carriers specified to +- 1 KHz. This desired 100 Hz tolerance in measurement implies an accuracy of 5 parts in 10^7 or .00005% at 200 MHz. Such accuracies can only be conveniently obtained with digital frequency counter techniques.

VISUAL CARRIER MEASUREMENTS

Digital frequency counters operate by counting the number of cycles of carrier which pass through a gate in a precisely controlled period of time. The gate time is controlled by a counter derived from a "clock" within the instrument. This clock is a precision oscillator whose stablility and accuracy set the precision attainable with the instrument. Very low cost instruments use the power line frequency as a "clock". Better class instruments use temperature compensated or oven-housed crystals as the "clock". The "clock" can be periodically calibrated by comparison with more precise frequency standards. Most digital frequency counters have an upper counting limit of from 10 to 50 MHz. This operating range can be extended by the use of digital pre-scalers or heterodyne converters. Pre-scalers divide the incoming frequency, usually by multiples of ten, reducing the frequency to a range which the counter will handle. Heterodyne converters "translate" the incoming frequency into a range which the counter will handle using local oscillators derived from the counter's own clock.

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Pre-scalers are currently available to handle inputs up to 500 MHz. Heterodyne techniques may be used up to microwave frequencies (tens of GHz). A frequency counter with 1 in 10^7 accuracy and with a 500 MHz range (usually achieved by built-in pre-scaler) is very suitable for CATV use.

Waveform input requirements for frequency counter instruments are quite critical. Higher frequency instruments usually have 50 ohm inputs and require about 100 millivolts of signal. The input signal must be relatively free of non-harmonically related spurious components. Since the counter operates by individually sensing and counting each cycle of carrier there must be enough of each cycle present to trigger the counter circuitry. Trigger sensitivity varies considerably from one model of instrument to another but very few counters will trigger on the highly modulated (80 - 90%) AM television visual carriers. Even if the desired carrier is separated from all the unwanted carriers present (associated aural carrier and other TV channels in the system) the high degree of amplitude modulation prevents proper operation of most digital frequency counters. This paper describes a method of separating the desired visual carrier from the unwanted carriers and reducing the amplitude modulation to a level which most counters will accept.

The desired visual carriers could be separated for counting by using a suitable band pass filter or by using a tunable band pass filter. We find it convenient to use a tunable television demodulator for this purpose, using the selectivity of the demodulator IF section to reject all unwanted carriers. Unwanted amplitude modulation is then removed by a limiter stage. The "limited" IF carrier is then translated back to the original input frequency using a mixer and the local oscillator from the tuner. This is merely double heterodyne conversion using the same local oscillator for both down and up conversions with a limiter stage inserted in the visual carrier IF. The output frequency is the same as the input but unwanted carriers have been removed and the amplitude modulation has been reduced to a level which most frequency counters will accept.

DETAILED DESCRIPTION

A practical prototype of a frequency measurement system of this type has been in use on Maclean-Hunter systems for some time. Figure 1 is a block diagram of the instrument. A Jerrold Model TD demodulator is used as the tuner and IF system. Other demodulators or television receivers can be adapted for this purpose. The TD demodulator has the local oscillator available at a suitable level from a connector right on the tuner. Sufficient local oscillator signal can usually be derived from the tuner by coupling through a small capacitor. The loading caused by the up-converter mixer causes the local oscillator to shift by only 15 KHz. Since the accuracy and stability of the local oscillator does not affect the output frequency, this is not important. The limiter stage which has been added is fed from the IF test point on the demodulator. It is a Motorola MC1330P integrated circuit, which is designed for use as a low level video detector in television receivers. It also has a limiter section designed to feed AFT circuitry in TV receivers. This output level is adequate for feeding the double balanced mixer which serves as an up-converter. A co-axial switch and two band pass filters are provided to reject the unwanted mixer images. The amplifier board from a small MATV type amplifier was used to amplify the output to about 500 millivolts for driving the digital frequency counter.

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Effectiveness of the limiter was tested by modulating the TV carrier with a 15.75 KHz square wave. Figure 2 shows the modulation envelope of a TV carrier and its associated frequency spectrum. Modulation was set to about 80%. The first modulation side bands are about 7 db below carrier. Figure 3 shows the same carrier after limiting. The modulation envelope shows very little modulation. The associated frequency spectrum shows that modulation sidebands have been reduced by 17 db. The frequency counter accepted the limited carrier without any triggering problems. The 80% modulated carrier would not trigger our frequency counters and pre-scalers properly.

IMPROVEMENTS PLANNED

Some minor modifications are planned. A small "split-band" amplifier will take the place of the switch and band-pass filters. The present "bread-board" arrangement will be miniaturized and built into one of our TD demodulators.

We plan to experiment with a phase-lock loop in the IF which would replace the limiter stage. This would assure that we have a continuous signal available at all times without concern for limiter threshold levels. The present system will not count an overmodulated carrier properly. This may be considered advantageous because we have often detected overmodulated carriers in this way. It is inconvenient if one nevertheless wishes to make a frequency measurement on the overmodulated carrier.

COUNTER ACCURACY

Measurements made in this way are no more accurate than the clock in the frequency counter. We use a frequency standard system which is locked to Loran C transmissions. The Loran C receiver in our laboratory produces a 1 MHz signal which is phase-locked to the pulsed 100 KHz transmissions from the North Atlantic Loran C chain. The Loran C chain is controlled by a caesium beam atomic frequency standard. The Loran C transmission effectively transfers this standard to our laboratory with very little loss in accuracy. This Loran C clock is used to drive the counters in our laboratory and to calibrate counters before use in the field. Similar systems are available which lock to NBS 60 KHz transmissions.

INTERCARRIER MEASUREMENTS

Intercarrier measurements are relatively easy to make, using the same demodulator employed for the visual carrier measurements. Many demodulators have an intercarrier output available at a level suitable for direct counting by a digital frequency counter. Such an output may be easily derived from receivers or demodulators which do not originally have a 4.5 MHz intercarrier output available. The only problem encountered is the frequency modulated nature of this intercarrier sound signal. If the aural modulation can be stopped for the period of the measurement, there is no problem and the intercarrier frequency can be read by normal digital counter technique. If the carrier is modulated (FM), we can only expect to read the average carrier frequency since the counter will actually count the number of aural carrier cycles (actually intercarrier) during a fixed gate time. If the modulation is symetrical around the normal carrier frequency, and if we use a sufficiently long gate time, we will get an accurate measurement of intercarrier frequency. We have found that a 10 second gate time gives good results. With some counters this requires a pre-scaling of the intercarrier to a frequency range in which the counter uses a 10 second gating time.

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The required gating time may be estimated by considering the normal frequency deviation used in TV aural carriers and the lowest modulating frequency likely to be used. Maximum deviation is ordinarily 25 KHz and the lowest modulating frequency is likely to be about 100 Hz. If we considered a "worst case" of square wave modulation by a maximum level 100 Hz square wave, the carrier could be at the deviation extremes for one half of each square wave (.005 seconds). The worst case in gating timing would be a situation in which the gate passed one more swing to one direction than it did to the other. With a square wave modulation to maximum deviation, this would pass about $4.5 \times 10^6 \text{ X } 5 \times 10^{-3} = 2.25 \times 10^4$ more (or fewer) cycles than the centre frequency. This 2.25×10^4 is a worst case error and is independent of the gating time. For this error to be less than 100 Hz in a 4.5 MHz measurement, it must amount to less than about 2 cycles in every 10^4 cycles counted. The total number of cycles counted should, therefore, be more than $2.25 \times 10^4 \text{ X } 2 \text{ X } 10^4 = 4.5 \times 10^8$ cycles. A 100 second gating time would pass this many cycles of a nominal 4.5 MHz carrier and guarantee the desired accuracy. This calculation has been based on worst case extremes and we have found that a 10 second gating time gives very acceptable results.

SUMMARY

A simple double conversion technique permits separation and limiting of television visual carriers so that they can be reliably measured with a digital frequency counter. The double conversion system uses readily available components and can be bread-boarded in a few hours. Frequency counters operating in the desired range of carrier frequencies are essential for practical measurements. Intercarrier measurements are easily made with the same equipment using the 4.5 MHz intercarrier output from the demodulator. A 10 second gating time is usually adequate to average the frequency swings caused by the FM modulation of the aural carrier.

July, 1971

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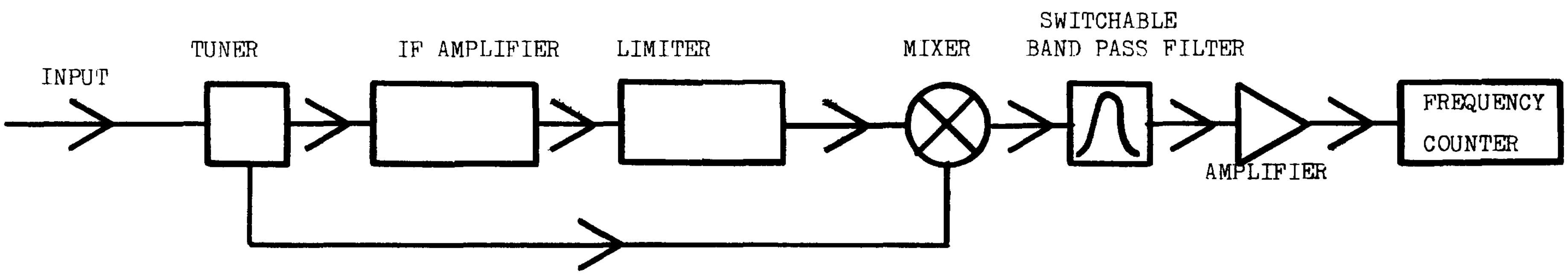
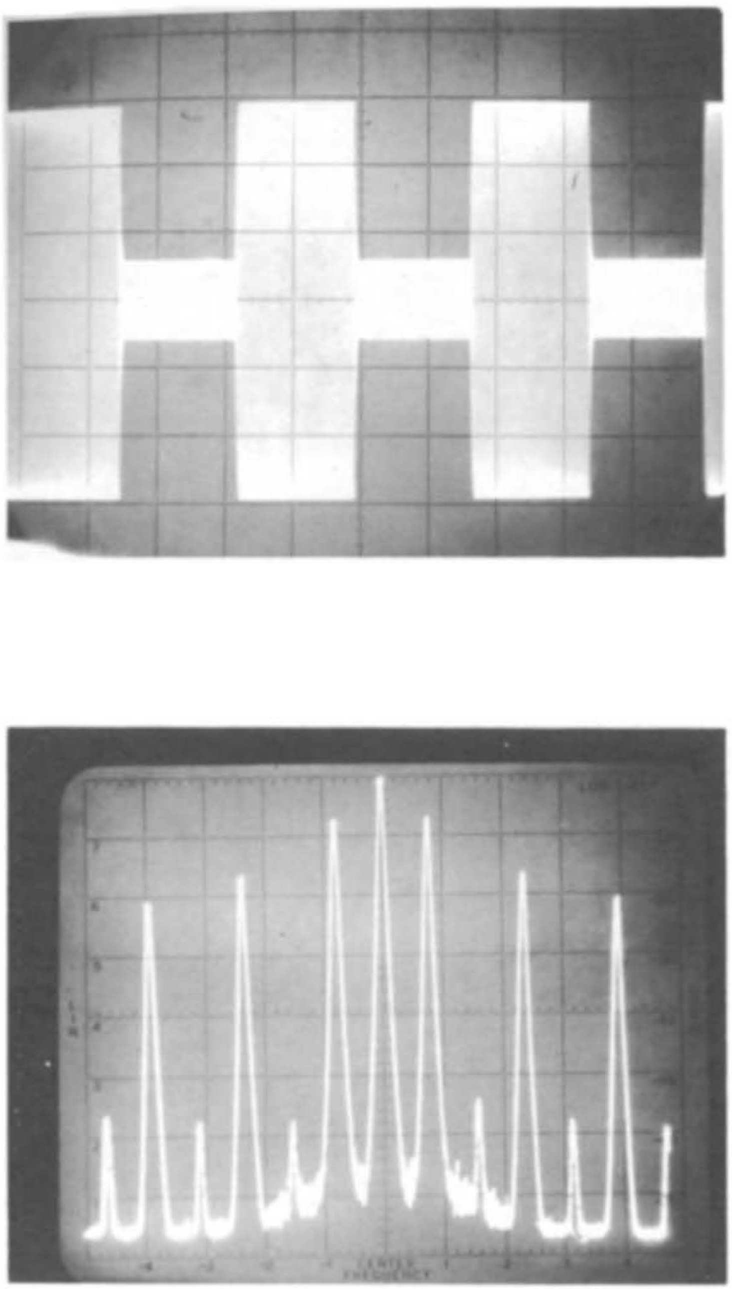
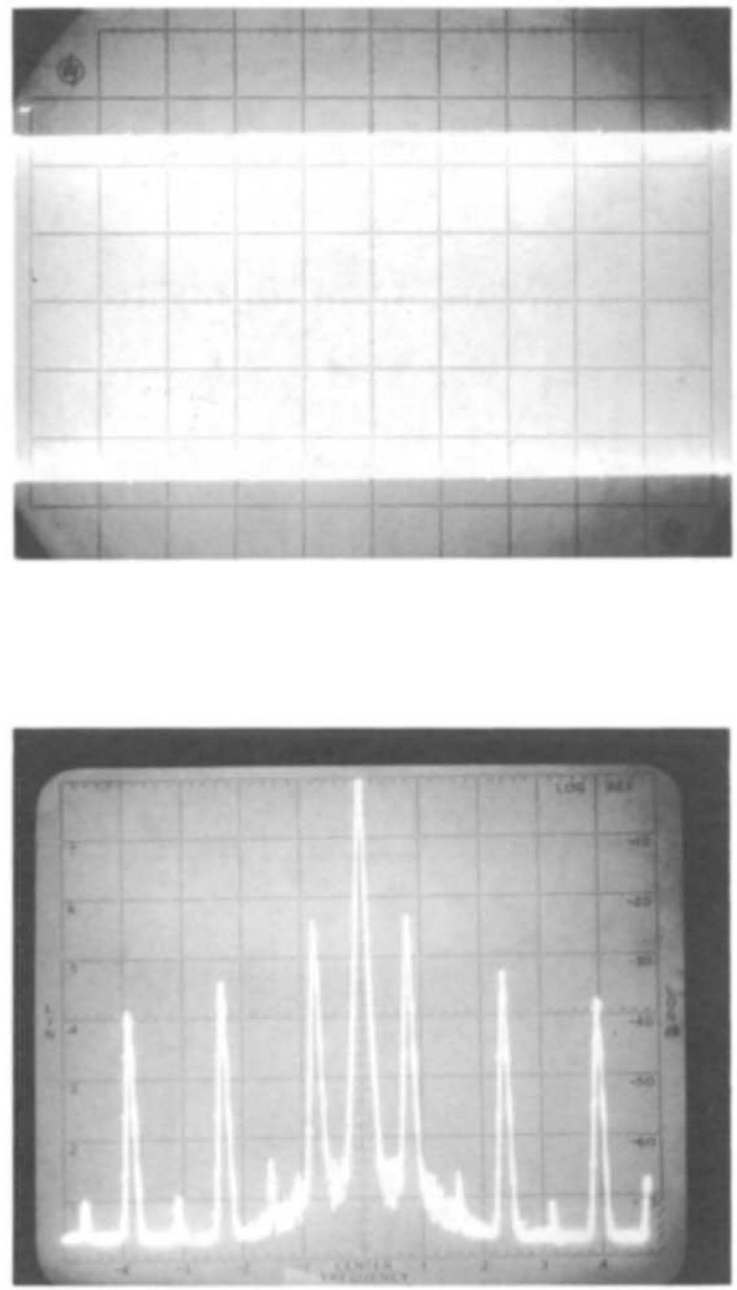

INPUT
TUNER
IF AMPLIFIER
LIMITER
MIXER
SWITCHABLE
BAND PASS FILTER
AMPLIFIER
FREQUENCY
COUNTER

FIGURE 1

80% modulation (15.75 KHz square wave)



after limiting

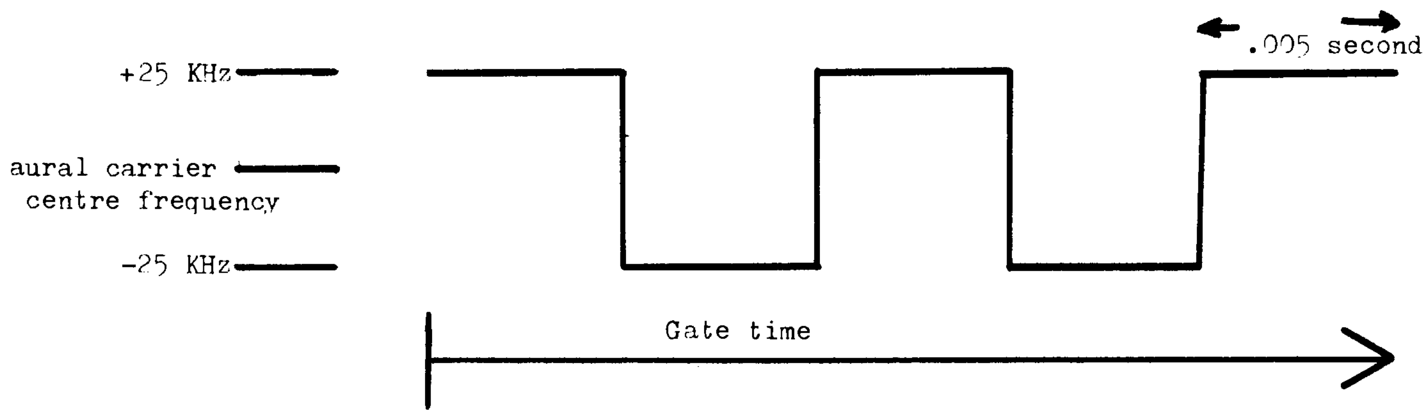


10 db/div

---------- 20 KHz/div ------------

FIGURE 2

FIGURE 3



Idealized FM (100 Hz square wave modulation)

Figure 4