

Mixing, Summing and Up/Down Conversion

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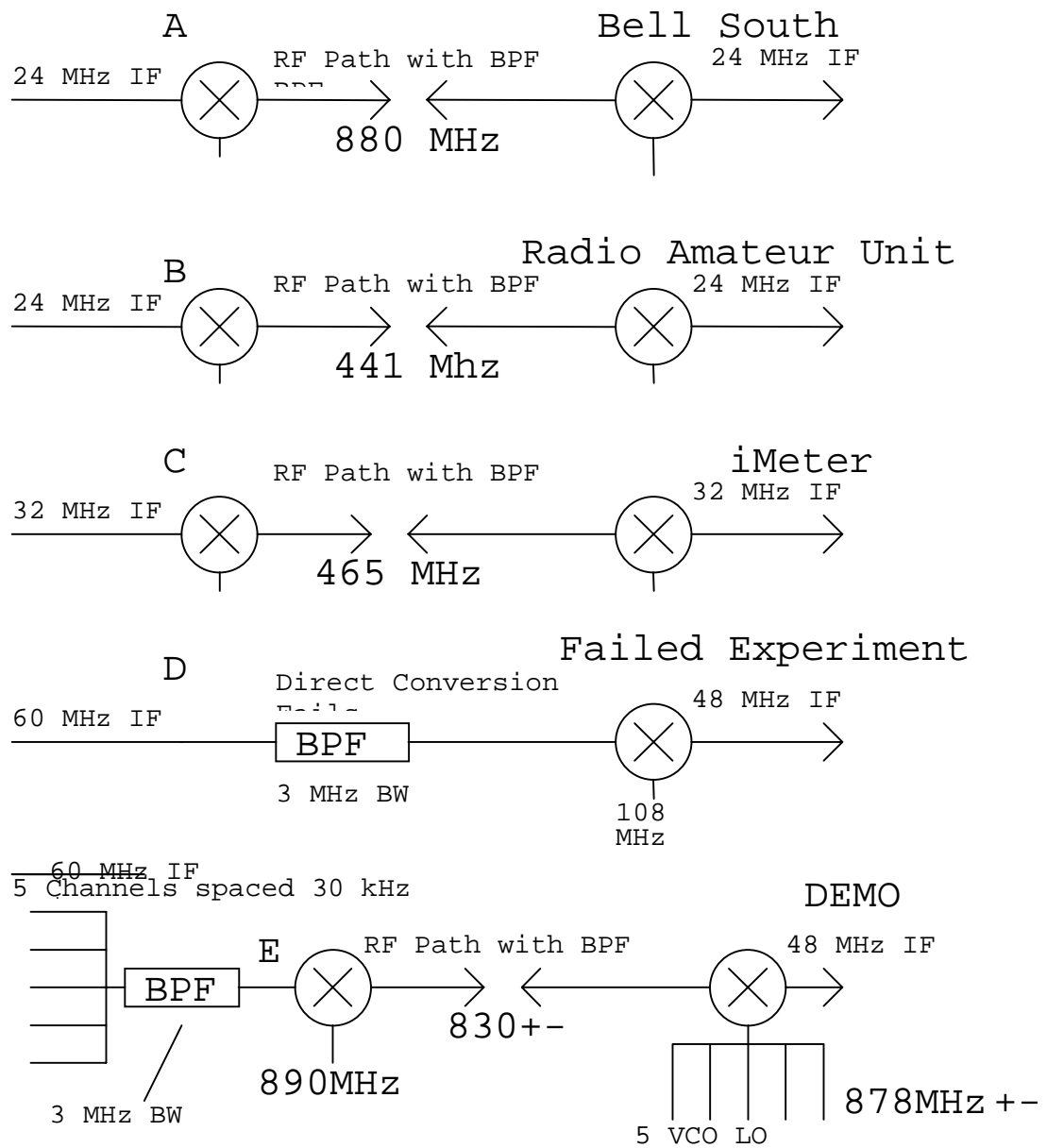


Fig. 1.

Several successful examples of usable Up/Down Conversion are shown, as well as one method that does not work.

Example A was used with multipath testing and fading at Bell South. Note that the RF frequency is considerably higher than the IF frequency. (36 RF cycles per IF cycle.). No problems were encountered with this unit.

A unit was built for over the air testing on the Ham bands.(B). (18 RF cycles per IF cycle.) No problems were encountered with this unit.

Units are under development for Photron Sciences (iMeters) that transmit 3.2 Mb/s data on a network at 465 MHz. No problems have been encountered so far, with 14 RF cycles per IF cycle.

*****An attempt was made to defy '**Nyquists Sampling Theorem**' in D. The attempt failed for obvious reasons that were not thought of at the time, because an attempt was made to put the equipment together in a hurry. *****

A mixer is a sampling device. In this example, 60 MHz was being sampled at 108 MHz. The output results in a 'beat frequency' of 12 MHz. The 48 MHz output varied in amplitude from 0 to maximum level at a 12 MHz rate. The modulation could be seen, but was useless. There are 60 RF cycles per 48 IF cycles, a ratio of 1.25. The sampling rate simply was not high enough to outline the IF frequency cycle pattern.

A rule for future design is that the RF frequency must not go below 12 times the IF frequency. This sampling rate will detect phase changes in the IF frequency in 15 degree steps. If the total phase changes that survive the near zero group delay filters exceed 30 degrees, there should be little problem with detection.

Equipment is now being built as shown in E. There are approximately 14 RF cycles per IF cycle (60 MHz).

Equipment similar to that shown in A, B, and C was used successfully on a microwave link in Denver for Corbin Communications. There the RF link was at 6 GHz. The data rate was T1, 1.544 Mb/s. The IF frequency 85 MHz.

Reports on the Bell South, Ham Radio and Microwave tests are available from VMSK.org.

When up and down converting, always use a local oscillator above the RF bandpass filter and filter off the upper image. Otherwise, there will be a 50% miss of data from the detector. Example 24 MHz IF, 440 MHz RF= BPF, Local at 464 MHz. Do not pass the image at 488 MHz.

At the request of certain parties, the 3 MHz bandpass filter was added at the transmitter IF input for test purposes. Normally this filter would not be present. All previous work involved a much wider filter with low group delay in the RF path, not the IF path. The spectrum of the MSB method does not require a BPF in the transmitter IF. **There are narrower BPF filters with near zero group delay available for the receiver IF path.** These filters must be used as pre- filters to narrow the noise bandwidth prior to the ultra narrow bandwidth filters. A 3 MHz filter with group delay reduces the available data rate. (Noise power is directly proportional to BW. In a superheterodyne receiver, there is an RF filter ahead of the mixer to limit noise bandwidth before the IF filters. In a TRF receiver, additional stages must be used to keep the bandpass shoulders down.)

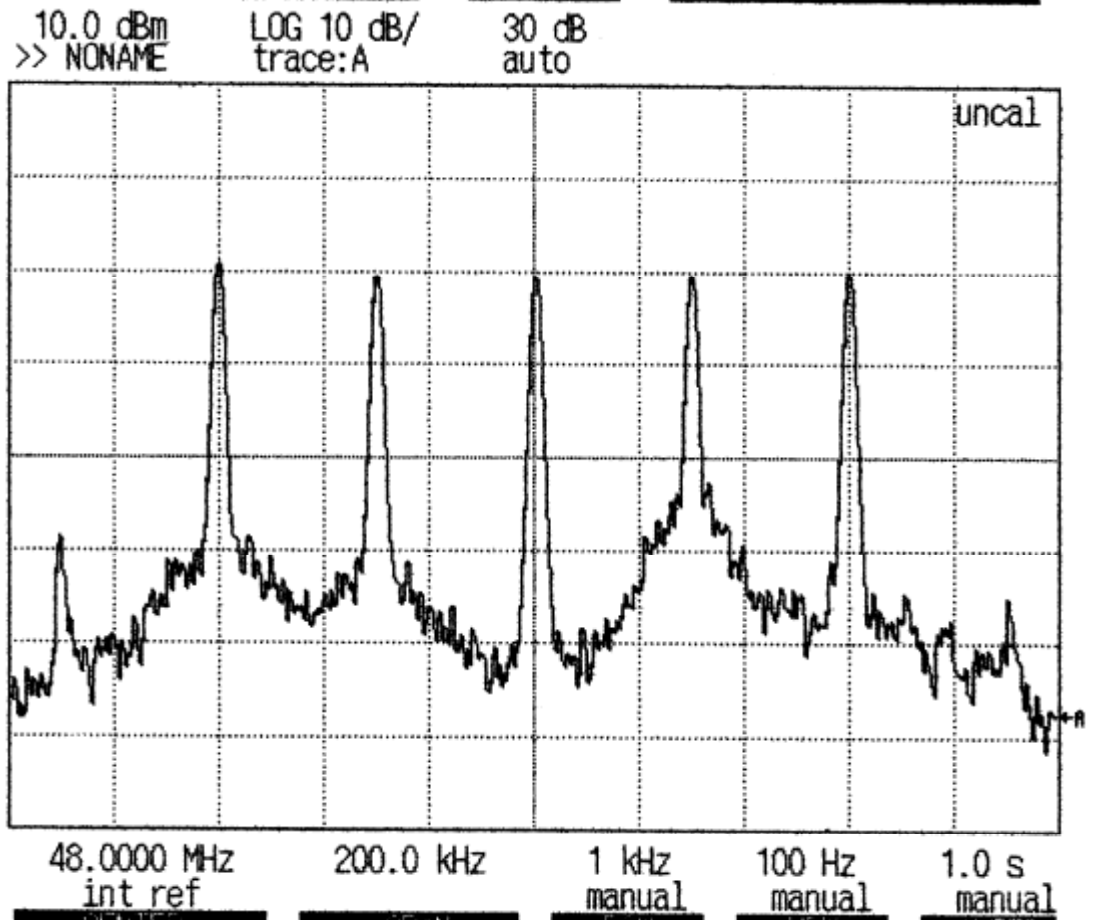


Figure 2. Five Channels separated 30 kHz apart, after summing. Each channel is independently modulated.

The channels shown in Fig. 2 show a variety of defects. The carrier oscillators, particularly those at +30 and -30/-60 have high levels of phase noise. The oscillators used were programmable ECS units. The 48.000 MHz oscillator, which was not a programmable unit, is much cleaner. There is evidence of multi-tone third order intermodulation as well. Both of these problems need to be minimized.

The hardware used contained two 74AC86 gates that were used as modulators, with one chip having 4 channels through it and the other a single channel. There is cross modulation within the 74AC86 chip. Independent modulator chips for each channel are a much better choice.

Obviously, carrier oscillators with lower phase noise are desirable.

The receiver circuitry must separate these individual channels.

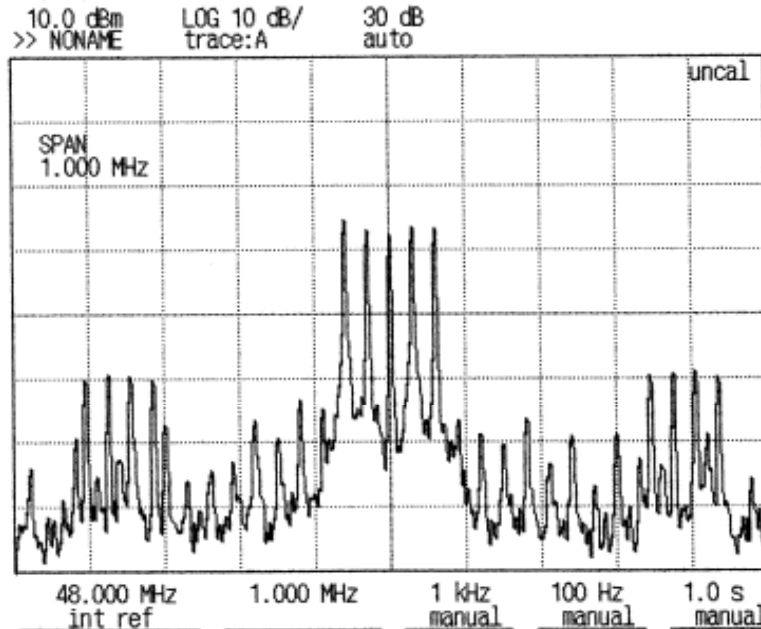


Figure 3. The spectrum of Figure 2, expanded. The spikes at the right and left extremes are the Fourier modulation products related to the data rate with a fixed data pattern. The RMS value is much lower than the peak values seen. The spikes between the extremes (± 200 kHz) are multi-tone third order products that need to be reduced to comply with FCC regs.

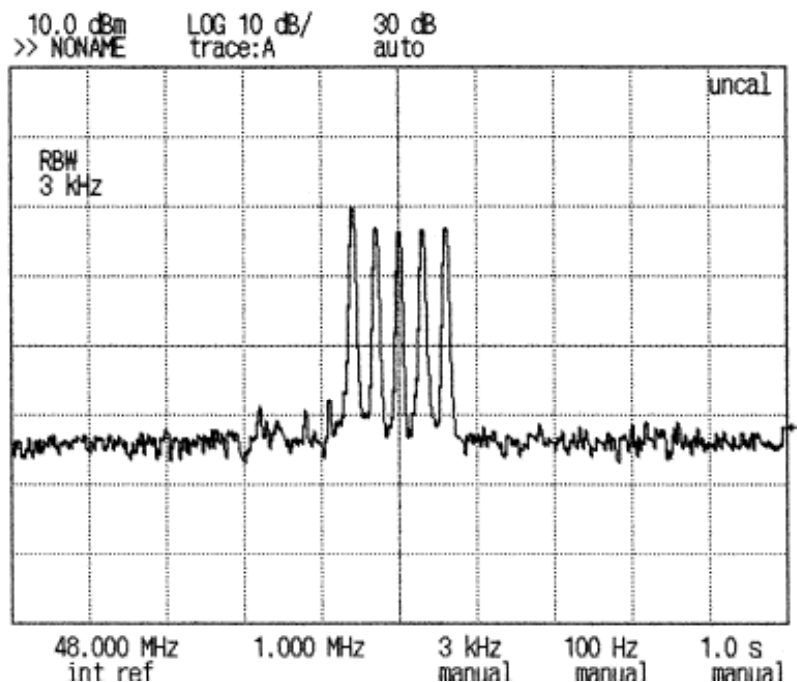


Figure 4. Spectrum of Fig. 3 with Random Data instead of a fixed pattern. The low level grass floor is caused by a number of factors including the data pattern and the random intermodulation. Cleaning up the overall system will reduce this to an acceptable FCC RMS level.

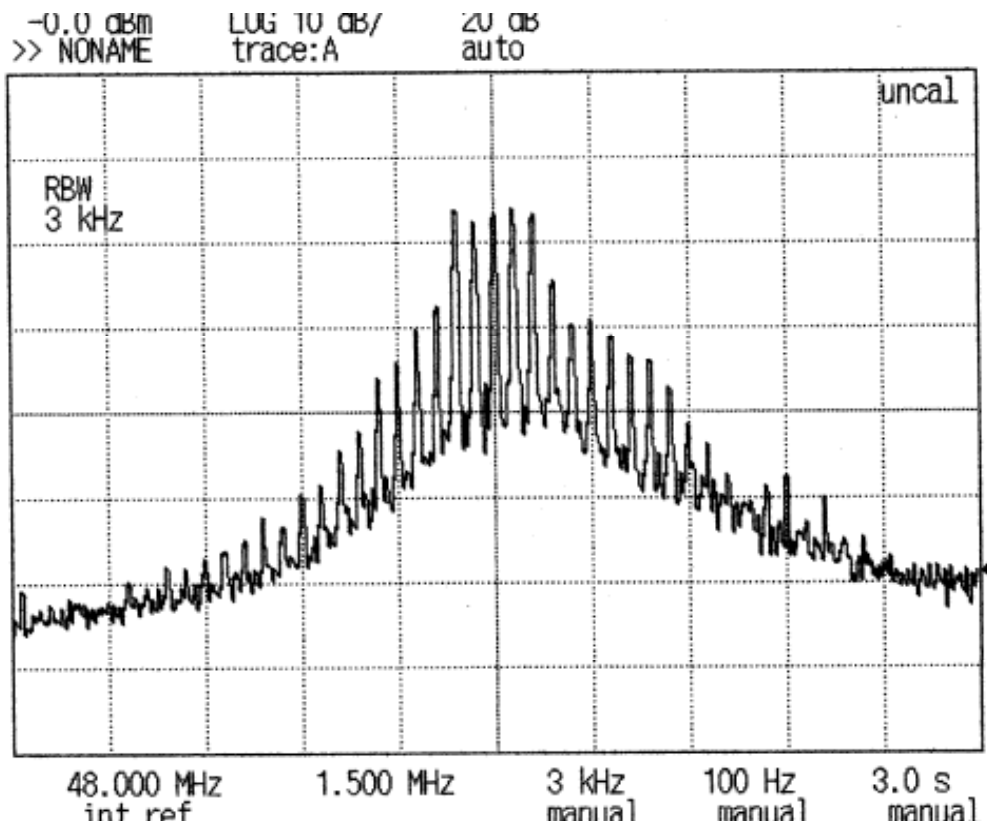


Figure 5. The spectrum of Figs. 3 and 4 after passing through an active zero group delay pre-filter with approximately 250 kHz 3dB bandpass. Obviously the filter is introducing a high level of multi-tone intermodulation. The bandpass of the filter can be seen from the bottom edges of the trace. This filter is usable for noise bandwidth reduction in a receiver where it is preceded by an Ultra Narrow Band filter, but is too non-linear for use with combined signals on an uplink. The ultra narrow band filter improves the IP3 level.

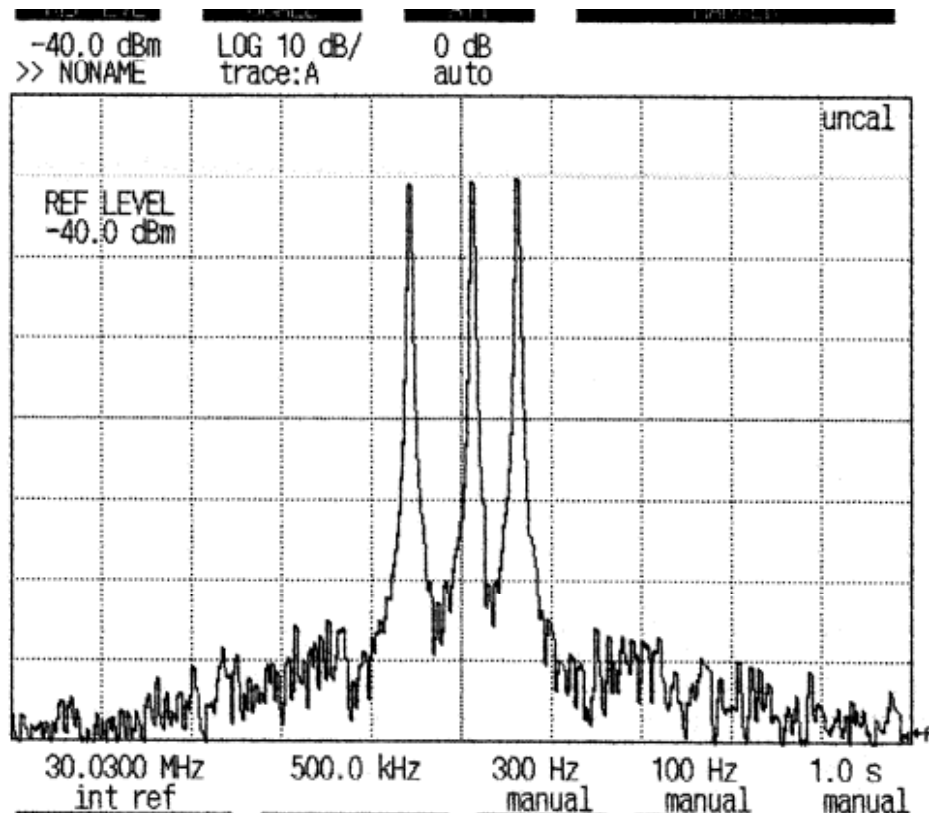


Figure 6. Three MCM signals combined or added in a totally passive combiner. The individual signal carriers have very low phase noise. As can be seen, there is no cross modulation. The lower noise level is the spectrum analyzer floor.

FCC specs can be met without any broadband pre-filter in the transmit portion of the system. The spikes seen at the right and left in Fig.3 can be reduced below FCC requirements with individual single channel ultra narrow band filters alone.

Whenever a non-linear amplifier is used after combining, there will be 3rd order cross modulation. This can defeat the FCC out of band requirements. DO NOT USE A MULTI-CHANNEL combiner that has any non-linearity if possible.

The pre-filter used to obtain near zero group delay in Fig. 5 has a phase non-linearity, which is necessary to obtain zero group delay. $T_g = [\Delta\Phi / (2\pi \Delta f)]$. To obtain zero group delay, $\Delta\Phi$ must be zero. This can only occur around an inflection point. Figure 7 shows how the inflection point (where the derivative becomes zero) enables a crystal to be used as a narrow band filter with zero group delay at a single frequency.

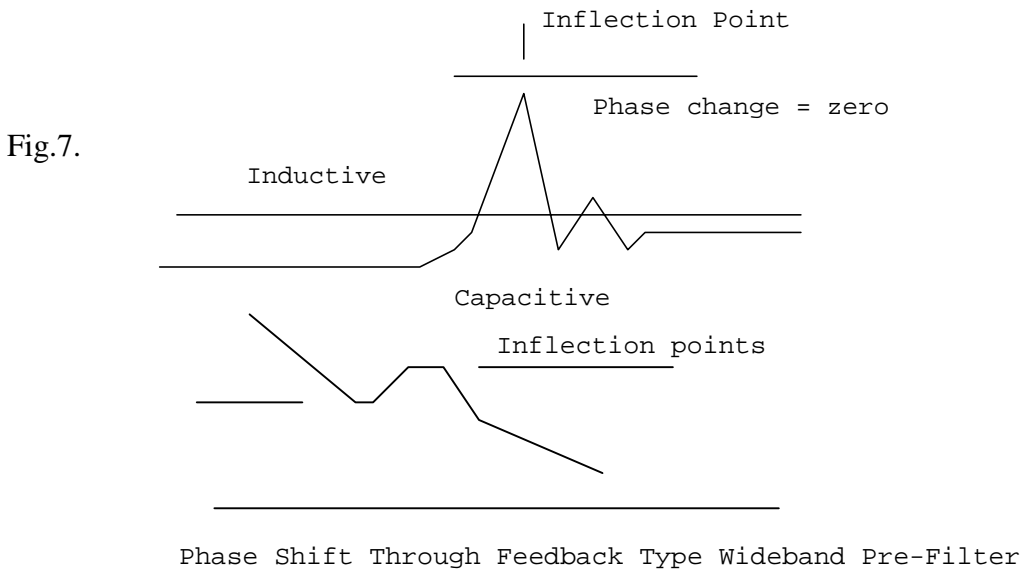


Figure 7b. The zero group delay pre-filter used to pass 6-10 Mb/s MSB data through a 250 kHz bandwidth has a phase non-linearity, which is well known to produce mixing and cross modulation. (Pure Textbook Math.),

Intellectual Trap:

When two channels of equal level are added in a transformer or resistive combiner, the added vectors of the two cancel as seen in Fig. 8 (top). This may lead some to think there will be a null in the signal at these crossover points, which will cause numerous data errors. This is not the case. When the added signals are passed through a narrow bandpass filter to separate the channels, these zero crossovers do not appear. The lower trace is the filter output for one channel alone. There is no inter- or cross modulation.

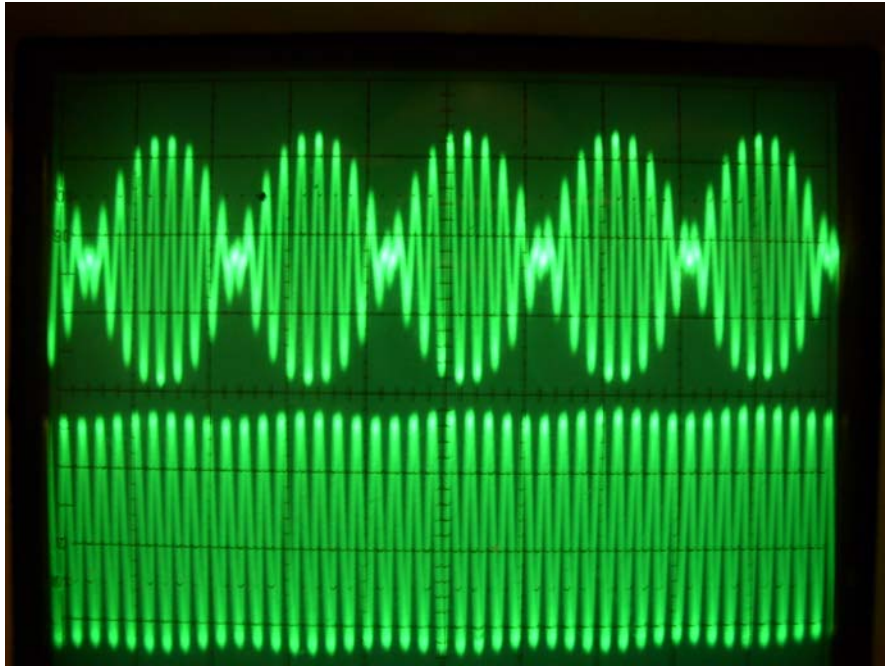
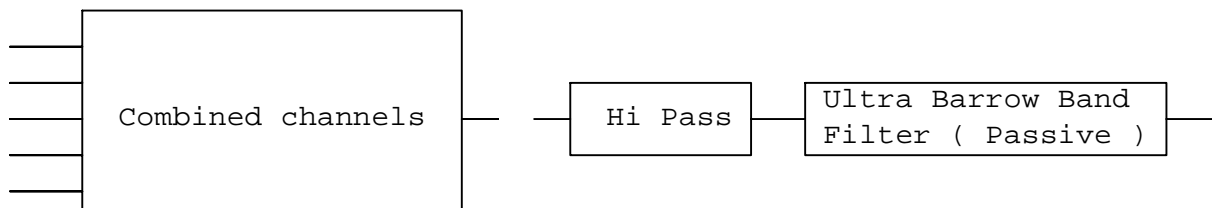


Fig. 8.
 Figure 8. Two channels at equal levels summed in a passive linear summer. The vector sum at the top shows cancellations as the vector sum passes through zero. This does not affect the individual channels, which remain undisturbed. One of the two frequencies passed through a narrow band filter is seen at the bottom. There is no cancellation of either channel to cause data errors.

However, there are several cautionary notes. If the combiner is followed by an a non linear amplifier, there can be second and third order cross modulation products as noted in Figures 3, 4 and 5. Reducing the level in the amplifier reduces the 3rd order effect.

Further, when adding several channels, this beat effect may carry over into the amplifier stage following the filter as a low frequency offset. To avoid this, and correct for this effect, use a high pass filter, or zero group delay pre-filter ahead of the narrow band filter.



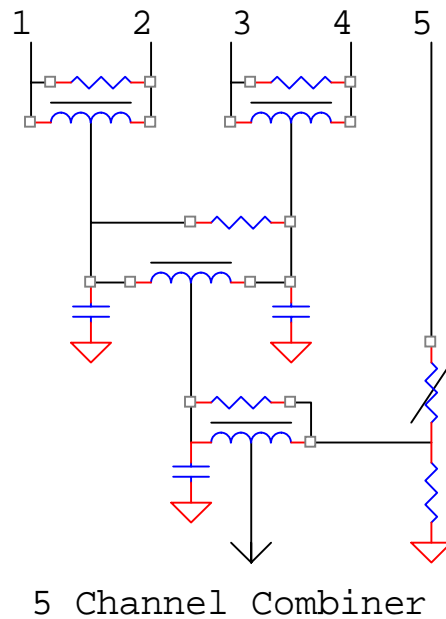


Figure 9. Five Channel Linear Passive Combiner.

References:

- 1) W. A. Rheinfelder, " CATV System Engineering" TAB Books, 1967.
- 2) J. Sevick, " A Simplified Analysis of the Broadband Transmission Line Transformer",
High Frequency Electronics Magazine, Feb. 2004.
- 3) Mini Circuits "RF/IF Designers Handbook", Brooklyn NY, 1997.
- 4) W.A. Rheinfelder, Design of Low Noise Transistor Input Circuits, Hayden Book Co. 1964.
- 5) Howard Hausman, "Estimate Multiple Carrier Interference", Microwaves and RF Magazine, May 2004

Cross-modulation is caused by third or higher order curvature. Inter-modulation is caused by second or higher order curvature. Curvature being the non-linearity. Quoted from (1),(3)(4) and (5) above