# ULTRALINEAR SUPER TRUNK AMPLIFIERS

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*The upgrade of a super trunk amplifier in the frequency range 47-862 MHz is described. It is shown that the technology is now available to push the output level over 120 dBμV. The triple beat and second order distortions are typically 80 dB down at the output level. This ultralinear feedforward amplifier is thus an immediate substitute for two distribution amplifiers of conventional design.*

**Keywords:** amplifier, feedforward, linearization, nonlinear distortions

## 1. INTRODUCTION

Multichannel transmission of signals in the contemporary cable communication systems set very strict requirements for linearity of the characteristics of the super trunk and distributing amplifier. Despite the big decrease of the nonlinear distortions while using of push-pull amplifier, reached as in the traditional usage of bipolar transistors, thus like in the hybrid integral circuits (HIC), it doesn't satisfy high requirements at designing CATV systems. Reaching of ultralinear performances of the amplifiers became a reason to be developed methods and technologies for compensating of distortions by applying of feedforward linearization technique. It is been expressed in using of broadband amplifiers as most often HIC is output link with feedforward. The main purpose of that determination is to be achieved highest level of output signal in broad frequency band and minimal nonlinear distortions, if it is possible [1, 2].

As basic defect at the method with feedforward linearization technique can indicate the complexity construction of the super trunk amplifier (STA).

## 2. ESSENCE OF FEEDFORWARD METHOD

At fig.1 is shown block diagram of feedforward amplifier. Input signal is been divided in two with directional coupler $DC_1$ after it has passed through preamplifier *PA* and passive links – tilt and attenuator. The signal at the upper on the diagram branch is strengthen from amplifier $A_1$ (HIC) and it is been diverted by the directional coupler $DC_2$ attenuator *AT*, witch fades away that signal to a level with 10 dB higher than the input. All *DC* are with same tap loss (8÷20 dB) and uniform amplitude-frequency performance (± 0,1 dB), and the phase performance is with ± 2° unevenness in the hole frequency band.

The signal at the lower branch from the diagram is necessary to endure the same delay, as that at the upper $DC_3$ is been used for selectively summating, i.e. stops (fades away with more then 40 dB) main signal, and admits that one, caused from the nonlinear distortions, arising in $A_1$.

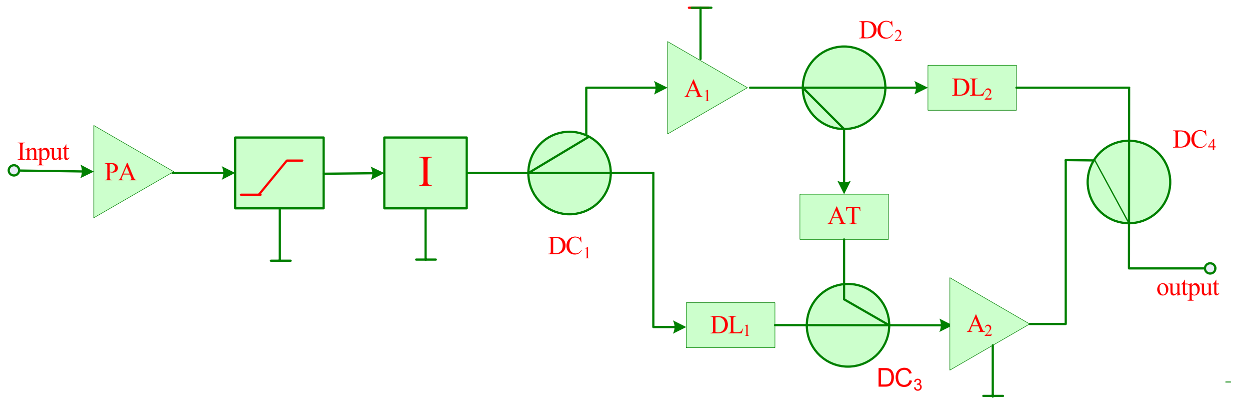


Fig.1. Block diagram of feedforward amplifier

The second loop does the same function, as the isolated nonlinear products and noises from $A_1$ are reversed in phase and amplified by $A_2$. After that a signal coming from $A_1$ is added to the output signal by $DC_4$. That way we cancellation only the distortions produced from $A_1$. The result is increasing of the input signal with almost zero levels of nonlinear distortions [3].

To equalize the signal levels at $DC_3$ and $DC_4$ with a nominal coupling of 10 dB are used throughout the whole feedforward stage. In order to achieve - a 25 dB cancellation in each loop the two paths must match to within ±0,4 dB in amplitude and $\pm 3^\circ$ in phase. If the two hybrid amplifiers are matched in gain to within 0.25 dB the only alignment required for achieving signal level balance in both loops is the adjustment of flat loss network *AT*. To attain the phase balance in each loop across the 47 to 862 MHz band is, however, more difficult. This difficulty is primarily due to the deviation from phase linearity of the hybrid amplifiers near the band edges. The low frequency deviation is more severe and requires the use of phase equalizers. Without phase equalizers, cancellation of only 10÷15 dB is possible below 100 MHz although the rest of the band is simultaneously aligned for a minimum of 25 dB cancellations.

The low frequency phase nonlinearity is small enough not to cause any group delay problems but large enough to upset the phase balance in each loop. By subtracting the phase shift of the upper path from that of the lower path, we find the desired information for the design of the phase equalizers. A set of phase equalizers was then built and each of them successively tried in the feedforward stage.

The output feedforward stage having a nominal gain approximate equal to 20 dB (HIC is with $G \geq 33$ dB). According to the fact that the distortions in the output decrease with 25dB, we can say that at the worst case the triple beat is with 85 dB lower amplitude, in relation to the level (120 dBμV) of a useful signal.

The feedforward amplifier exhibits some of the properties of the basic push-pull amplifier, but in addition provides the cancellation of all distortion products ($2^{nd}$, $3^{rd}$, $4^{th}$, $5^{th}$, $6^{th}$, etc). The magnitude of distortion cancellation is directly proportional to loop cancellation. It is important for the two branches of the amplifier to be balanced (amplitude and link). That's why in a lots of practical circuits, when using amplifiers from that type, we mounting adjustment attenuator, as the loop between $DC_2$ and $DC_3$, thus like after the error amplifier $A_2$ [4].

Besides the gain and gain flatness there is another parameter equally important to the design of the feedforward stage. It is the phase versus frequency characteristic of the hybrid amplifiers. This phase characteristic can be evaluated using a network analyzer. It was found that there are; basically two regions where the phase departs from a linear relationship: the first, more pronounced region is for frequencies below about 100 MHz and the second one for frequencies above 375 MHz. The departure from linear phase below 100 MHz was attributed to the effect of coupling and bypass capacitors inside, the HIC. The zero frequency phase intercept is equal to an even multiple of $180^\circ$. This implies that at one of the summing points an $180^\circ$ phase reversal will be required.

The excess phase shift of some hybrid amplifiers is about 300° at 300 MHz, equivalent to about 55 cm of delay line. Due to the high overall gain of the distribution amplifier, the radiation from ordinary coaxial cable was found to affect the RF stability and alignment of the feedforward stage. For this reason a coaxial cable with a solid copper outer conductor must be used.

Once the feedforward stage is set to degree of balance necessary the cover is placed over the entire stage sealing the HIC and DC from possible damage. The amplifier may then be aligned according to conventional methods.

### 3. PRACTICAL REALIZATION

Method of feedforward was applied to a trunk amplifier VX97/G, which is batch production from the German company WISI [5]. Its construction allows assembling additional necessary elements for practical realization of the feedforward amplifier. Because it is with tow active outputs, one HIC is used as a main amplifier and the other one – as an error amplifier (Fig.2). That HIC can be easy replaced with similar (smaller of bigger amplification), but they must be with same parameters. It is important their faze performances to be same. Because there is always production differences, for obtaining of full balance between two shoulders of the feedforward step, we can include faze equalizer. According to the measured results of obtainable cancellation in each loop the most suitable phase equalizer was then selected (Fig. 3). Remaining feedforward elements are assembled on a special elaboration printed plates, which are plugged in the socket, free from superfluous elements (equalizer, HP/LP filter). The pluggable tap after test point "Transp. RX" is used as $DC_1$, if needed parameters is available or is has been replaced with other one from the WISI catalogue with the needed parameters. Its necessary for some existing bunches to be cut off and to create new one. Modified amplifier remains with one output. Second output can be got, if an additional splitter is been built in the amplifier box, or for more easy, if we put out trunk splitter. In the both cases the output level of the amplifier decreases with 4 dB for every output. That could be compensated using of HIC with high gain.

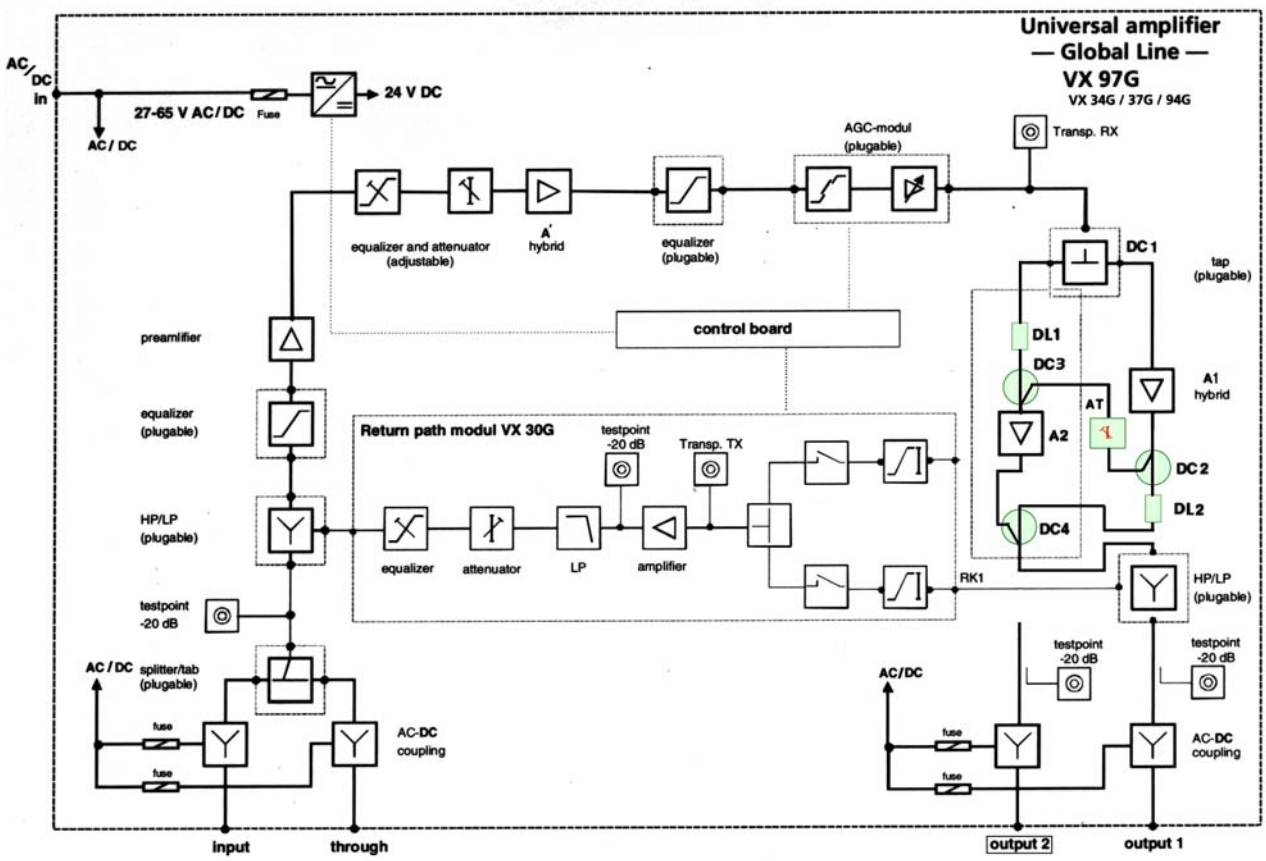


Fig.2. Super trunk feedforward amplifier VX97/G

As a delay line with a solid copper outer conductor is more difficult to handle than ordinary coax the following steps are being taken to ensure easier alignment on a production basis: The coaxial line is cut slightly short and the final line length adjustment is done by plugging in a short section of microstrip line. A similar plug-in unit with two grounded 75 Ω resistors is used in place of the microstrip line while the alignment of the other loop in the feedforward stage is carried out. The overall

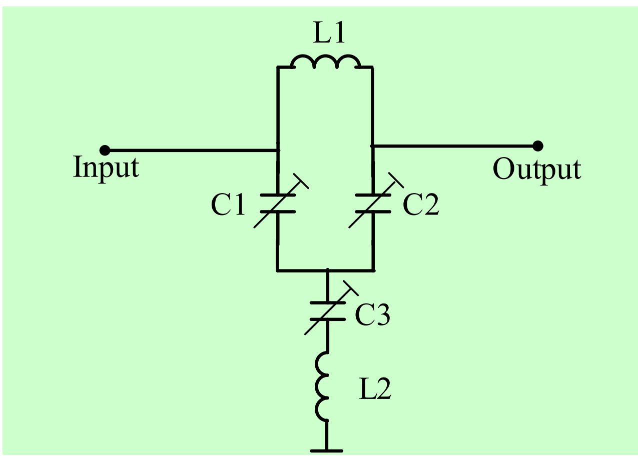


Fig.3. Phase equalizer

alignment of the feedforward stage thus consists of adjusting the lengths of the delay lines and setting the amplitude balance by means of the flat loss network AT.

Practical tests indicate that a cancellation of more than 23 dB in each loop can be reproduced without any problem. We were able to attain cancellations of greater than 28 dB but, this required considerable time for alignment and could not be made easily repeatable in production.

The preliminary temperature tests indicate that the loop cancellation degrades from an initial value of 24 dB (worst case) down to 30 dB at 0°C and +60°C.

All channel levels were set equal. In each case the feedforward stage was aligned for a minimum of 24 dB of cancellation.

Numerical results for the composite nonlinear distortions from intermodulation accordance with the Annex C from CENELEC EN 50083-3 are given in Table 1, and their graphic interpretation is shown at Fig. 4. Results are valid for combined remote supply.

Table 1

| *f* *MHz* | Intermodulation composite distortions, dB | | | | *f* *MHz* | Intermodulation composite distortions, dB | | | |
|---|---|---|---|---|---|---|---|---|---|
| | batch STA | | feedforward STA | | | batch STA | | feedforward STA | |
| | $CSO_b$ | $CTB_b$ | $CSO_{ff}$ | $CTB_{ff}$ | | $CSO_b$ | $CTB_b$ | $CSO_{ff}$ | $CTB_{ff}$ |
| 49,75 | 62 | 60 | 77 | 76 | 479,25 | 63 | 62 | 80 | 79 |
| 119,25 | 62 | 60 | 77 | 76 | 495,25 | 64 | 61 | 81 | 78 |
| 175,25 | 62 | 61 | 77 | 77 | 511,25 | 64 | 61 | 82 | 79 |
| 191,25 | 62 | 60 | 76 | 76 | 527,25 | 63 | 61 | 81 | 80 |
| 207,25 | 60 | 60 | 76 | 76 | 543,25 | 65 | 61 | 83 | 80 |
| 223,25 | 61 | 60 | 78 | 77 | 567,25 | 65 | 63 | 83 | 82 |
| 231,25 | 65 | 61 | 81 | 79 | 583,25 | 64 | 63 | 82 | 82 |
| 247,25 | 61 | 60 | 79 | 78 | 599,25 | 63 | 62 | 82 | 82 |
| 263,25 | 62 | 60 | 80 | 79 | 663,25 | 62 | 62 | 81 | 80 |
| 287,25 | 62 | 61 | 80 | 80 | 679,25 | 62 | 61 | 81 | 80 |
| 311,25 | 61 | 60 | 79 | 80 | 695,25 | 63 | 62 | 82 | 81 |
| 327,25 | 62 | 60 | 78 | 81 | 711,25 | 64 | 64 | 84 | 84 |
| 343,25 | 62 | 62 | 80 | 79 | 727,25 | 62 | 60 | 82 | 81 |
| 359,25 | 63 | 62 | 81 | 78 | 743,25 | 63 | 63 | 82 | 82 |
| 375,25 | 62 | 62 | 80 | 80 | 759,25 | 65 | 62 | 85 | 82 |
| 391,25 | 61 | 63 | 78 | 80 | 775,25 | 65 | 61 | 85 | 82 |
| 407,25 | 62 | 61 | 79 | 78 | 791,25 | 64 | 61 | 84 | 81 |
| 423,25 | 63 | 61 | 79 | 78 | 807,25 | 64 | 62 | 84 | 81 |
| 439,25 | 64 | 62 | 81 | 79 | 823,25 | 63 | 62 | 82 | 81 |
| 447,25 | 62 | 63 | 78 | 78 | 839,25 | 63 | 61 | 82 | 80 |
| 463,25 | 63 | 64 | 80 | 81 | 855,25 | 64 | 62 | 83 | 82 |

## 4. Conclusion

The received results for composite distortions acquit all the efforts put for improving the linearity of batch produced super trunk amplifiers. As hybrid amplifiers may to use integrated circuits' from different producers: Philips, NEC, Motorola, etc. $A_1$ and $A_2$ must be from same producer and type. While using BGY 888, amplifier gain is $G_A \geq 45$ dB, and at BGD 802, $G_A \geq 35$ dB. HIC $A'$ can also be

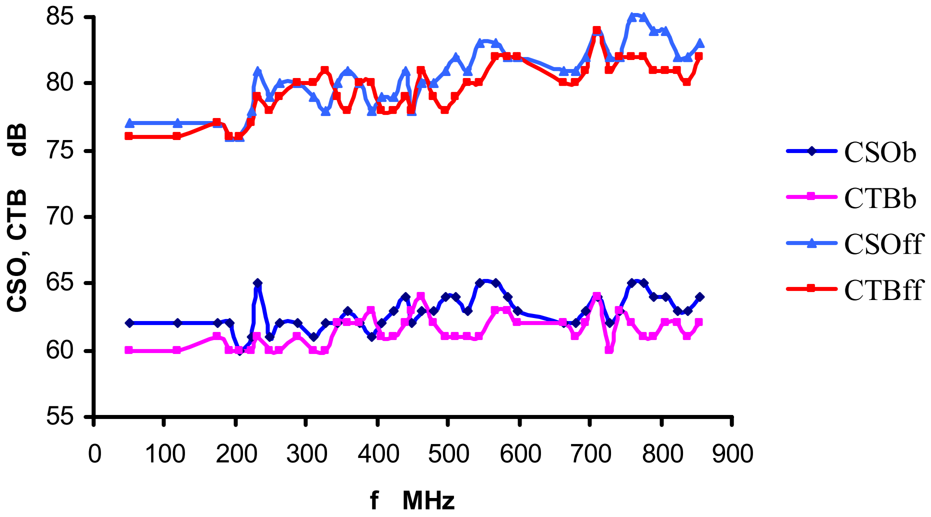


Fig.4. CSO and CTB for batch and feedforward super trunk amplifier VX97/G

embraced from a feedforward loop, which additionally will increase the linearity of the super trunk amplifier. Problem is insurance of:

- place for assembling of the error amplifier $A_2^{'}$ and other elements;
- temperature stabilization of the parameters of the active elements;
- current for supplying $A_2^{'}$.

That case will be an object for future work, as the expectations are for getting values for the composite distortions with 25 ÷ 30 dB better then other one the batch produced VX97/G.

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