GROUP DELAY AND THE
ADJUSTMENTS OF ACTIVE ALLPASS FILTERS

INDEX

INTRODUCTION

This paper is intended to give television transmitter operation and maintenance personnel the necessary review and explanation of group (envelope) delay and the active allpass network. The adjustment of the active allpass network found in Harris television transmitters is also covered.

Many papers have been written on the subject of group delay and the principles of the active allpass network. Most of these papers are written by engineers for engineers using heavy emphasis on mathematics and minimum emphasis on descriptive analysis. These papers do not provide sufficient review of the underlying principles or give adequate explanation at a technical level.

The first twenty sections of this paper deal with review and explanation of group delay and theory, and adjustment of the active allpass networks.

The remainder of this report deals with the adjustment procedures for the delay compensator in the visual exciter, adjustment of the receiver equalizer (for transmitters without the receiver delay equalizer vestigal sideband filter), and the notch diplexer equalizer (for transmitters that use a notch diplexer).

A section on the television demodulator has been included prior to the receiver equalizer adjustment procedure. The adjustment procedure given in this paper reflect the equipment typical of most television transmitter plants: the sweep equipment, the television demodulator, the waveform monitor, and usually a vectorscope.

If a swept delay measurement set is available, the adjustment procedure for the allpass network is simplified. They are not included in this paper as the television transmitter technical manuals provide adequate information for adjustment with a swept delay measurement set.

BASIC DEFINITION OF GROUP DELAY

Let's talk about group (or envelope) delay. Its effect is noticeable with color pictures when the chroma takes more of less time to get through the transmitter than the luminance. The effect on the monochrome picture is the smearing or out of focus condition that happens when the coarse picture detail takes a different amount of time to get through the system than the fine picture detail. You probably know of group delay by way of the 2T and modulated 12.5T or 20T sine squared pulses. They must leave the transmitter with the same shape that they entered it, quite often they don't. They have either the base line disturbances or are the wrong amplitude. Base line disturbances are caused by improper transmitter delay and the amplitude errors are caused by improper transmitter amplitude response.

What causes group delay? It is caused by a non-linear change of phase with frequency. Wait! Don't quit reading yet, it isn't that bad. Another way to look at it is that it is caused as a result of changing amplitude with frequency. Generally the more rapid the change of amplitude, the greater the envelope delay. This happens in bandwidth limited amplifiers, resonant amplifiers, and bandpass or band reject filters.

In your television transmitter this includes the following visual amplifiers: the I.P.A. amplifiers, the driver amplifier, and the RF power amplifier. In these amplifiers, the sharper the response rolloff, the greater the delay (See Figure 1-A). This delay is on the order of 140 nanoseconds or less, and occurs about the same frequencies that the amplitude response change (at the edge of the passband).

If your vestigial sideband filter is the L-C type, either the small low level I.F. type used in the earlier Harris visual exciters or the larger plumber's nightmare following the visual P.A., it contributes 300 to 500 nanoseconds of group delay. This delay is at the ends of the video passband where the response drops off quite rapidly. (See Figure 1-B)

If your transmitter has the surface acoustic wave (S.A.W.) filter for its vestigial sideband filter as in the newer Harris visual exciter, your delay problems are minimized. The only delay in these transmitters is caused by the visual amplifiers. The S.A.W. filter has very little group delay. Its transit time is quite long, typically 4.5 microseconds, but all frequencies take the same time to get through. Remember that group delay problems in television systems are due to differences in the time that it takes different frequencies to get through the system.

Adjustment for the above mentioned types of group delay in your Harris television transmitter is made in the visual exciter. The visual exciter delay compensator introduces delay in the center of the passband. (See Figure 2)

There are two other sources of group delay your transmitter must compensate for: the Notch Diplexer and the Television Receiver Sound Trap. Not all television transmitting systems use a notch diplexer. Some use a hybrid diplexer which does not cause delay problems.

The notch diplexer has two traps that reflect the aural signal to the antenna port of the notch diplexer.[1] This adds approximately 250 to 450 nanoseconds to the delay time. This delay occurs at the upper end of the passband and acts primarily to delay chroma. This causes the color to shift slightly to the right. In your Harris television transmitter, the notch diplexer equalizer compensates for group or envelope delay and amplitude response problems caused by the notch diplexer by introducing delay to the frequencies below chroma. (See Figure 3) It is not intended to compensate for problems in the visual exciter or the visual amplifiers in the transmitter. It is adjusted only after all of the other transmitter compensation such as response, output power, linearity or differential gain, differential phase, transmitter group delay and receiver equalizer adjustments have been completed.

The last major contributor of group delay is not in the transmitting system. It is the sound traps that are in all television receivers. The sound trap adds 250 to 450 nanoseconds of group delay to the upper end of the video passband and causes chroma delay. Although this delay is not part of the transmitting system it is required to be compensated for here. (See Figure 4)

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1 - See the Quarter Length Hybrid Report by Clarence E. Daugherty, Jr, for Notch Diplexer information.

In your Harris television tranmitter receiver equalization envelope delay predistortion occurs by one of two methods: (1) A vestigial sideband filter is available with the standard F.C.C. receiver equalization envelope delay predistortion curve built in, or (2) a separate receiver equalizer is used to compensate for the sound trap delay only and not amplitude response of delay problems within the transmitter. It is bypassed during all transmitter adjustment procedures.

To facilitate the separation of the sound trap delay problems during the rest of the transmitter adjustment procedure, most television demodulators have provisions to switch the sound trap (or notch) OUT. This will remove the sound trap (or receiver delay) from the demodulator.

To obtain accurate delay compensation adjustment, it is important that the television demodulator have an envelope (or group) delay characteristic conjugate to the standard receiver equalization envelope delay predistortion curve.

The receiver sound notch (trap) introduces delay at the upper end of the passband near chroma. The receiver equalizer of the receiver equalized V.S.F. introduces a predistortion delay below chroma. (See Figure 4)

The purpose for the various delay compensators and equalizers is to insure that all frequency components take the same amount of time to get through the television system. This will create sharp monochrome pictures that are free of smearing, and color picture where the color and the monochrome components of the picture are properly superimposed. It will also remove the base line disturbances from the 2T and modulated 12.5T of 20T sine pulses.

EFFECTS OF AMPLITUDE AND PHASE CHANGE ON DELAY

To more completely understand group delay we must explain the statement: "Group delay is caused by a non-linear change of phase with frequency".

Consider the circuitry in Figure 5-A. A signal is applied to a delay line. All frequencies take 2.77 microseconds to get through the delay line. The 2.77 microseconds delay represents 1° of phase shift at 1 KHz, but it represents 2° of phase shift at 2 KHz, 3° at 3 KHz, 4° at 4KHz, etc... A graph of phase shift verses frequency yields a straight line. (See Figure 5-B)

The formula used to figure the number of degrees of phase shift in a given amount of time is: $\emptyset = T \times 360 F$, when 0 = degrees of phase shift; T = time of delay in seconds; F = frequency in Hertz.

In Figure 6-A, the amount of delay produced by the delay circuit changes with the frequency (group delay). This produces the non-linear change of phase with frequency shown in Figure 6-B.

Most R-L, R-C, of R-L-C circuits that produce a change of signal amplitude will also cause the phase angle of the signal to change over the same band of frequencies that the amplitude changes have occurred. Therefore, with most circuits we would likely expect a constant amount of delay where the amplitude response is flat and a different amount of delay where the amplitude changes.

In the television system this is true on most broadband RF amplifiers, bandpass filters, and band reject filters.

Two general rules result from the above discussion:

1. $\text{Time delay} = \dfrac{\Delta\ \text{phase}}{360\,\Delta\ \text{frequency}}$ where Δ = represents a small change of

2. Time delay is directly proportional to the rate of change of amplitude with frequency when the amplitude changes are accompanied by phase change.

EFFECTS OF GROUP DELAY ON PULSES

Pulses are needed to make the television system work. They are found in many places in the video signal, such as sync pulses, blanking pulses, window pulses, etc.. Another part of group delay is understanding the effects it has on these pulses.

Pulses are composed of a fundamental frequency and many sets of harmonics. The phase and amplitude of each of these harmonics with respect to the fundamental frequency determines the shape of the pulses.

If a system has a flat frequency response and a constant time delay for all frequencies (linear change of phase with frequency), the pulses leave the system with the same shape that they entered it (no distortion).

If the frequency response is not flat or the time delay is not uniform (group delay) or both, the pulse will be distorted.

Common distortions of amplitude are poor rise and fall times (undershoots), or excessive high frequency response (overshoots of spikes) that occur on both leading and trailing edges, or a tilting of the flat portion of the pulse. (See Figure 12 and 13)

Phase or delay distortions can cause a tilt of a spike (overshoot) on one edge of the pulse while the other one is rounded (poor rise or fall times, also called undershoots). See Figure 9, 10, 14, and 15.

If the group delay problem is bad enough, the shape of the pulse could be totally changed.

To show the effects of group delay on pulses, a square wave will be used. A square wave consists of the fundamental frequency and the odd harmonics at reduced amplitude and in phase with the fundamental. It takes 10 sets of harmonics (fundamental through 21st harmonic) to produce a good square wave.

The first approximation of a square wave is shown in Figure 7. It contains the fundamental plus the 3rd harmonic in phase at 1/3 the amplitude of the fundamental. If more harmonics were added, the rise and fall times would decrease and the pulse would flatten.

In Figure 8, the 3rd harmonic leads the fundamental by a few degrees, but the amplitude is correct. This phase of time error causes the resultant pulse to tilt.

In Figure 9 and 10, the amplitude of the fundamental and the harmonics are all proper but a low frequency timing error causes the pulses to tilt.

The components of a square wave are shown separately in Figure 11. The low and mid frequencies for a square wave with rounded corners and excessive transient time. The high frequency components form a series of spikes that make the corners of the square wave sharp and reduce the transit time.

Figure 12 and 13 show the results of improper high frequency amplitude on a square wave. Notice that poor high frequency response in Figure 12 causes the corners of the square wave to be rounded and excessive transit time occurs. Excessive high frequency response in Figure 13 causes spikes (overshoots) to appear on the leading and trailing edges of the square wave.

In Figure 14 and 15, the amplitide of the component frequencies of the square wave is proper but a high frequency timing error exists. In Figure 14, the high frequency components lead the rest (they arrive early). This causes rounding of the leading edge of the square wave and a spike to occur on the trailing edge. The lagging high frequency components of Figure 15 cause the spike on the leading edge and the rounding on the trailing edge.

T.V. pulse risetime is measured from the 10% amplitude point to the 90% amplitude point. (See Figure 16). For T.V. purposes, the maximum frequency content of a pulse can be determined by the formula:

$$B.W. = \frac{1}{2\ RT}$$

where: RT = rise time measured from the 10% level to the 90% level

BW = the bandwidth necessary to pass the pulse with the same rise time and shape as the input pulse.

WHAT THE HOME VIEWER SEES

The final stop the television signal makes is the viewer's receiver. He is the one who benefits from all of the adjustments and compensations involved in the transmitting system.

We transmit background and coarse detail, DC to 0.5 MHz video frequencies, in full color. The medium fine detail, 0.5 MHz to 1.5 MHz, is transmitted in shades of orange and cyan. The fine detail, 1.5 MHz to 4.2 MHz, is transmitted in monochrome. (See Figure 17)

Color television is really a tinted monochrome picture. The monochrome information to be tinted is contained in the low video frequencies, DC to 0.5 MHz, and the tinting information (including the medium fine detail in orange and cyan) is contained by the chroma. The chroma is at the upper end of the video spectrum from 2.08 MHz to 4.08 MHz, and is interweaved with the fine detail video information also present there. (See Figure 18)

Another way to think of color television is that it is a somewhat out of focus full color picture to which sharp black and white (monochrome) fine detail has been added.

The average monochrome television receiver uses video frequencies up to 3.0 MHz in the reproduced picture. The information from 3.0 MHz to 4.2 MHz is not used because of the degradation of quality caused by the chroma information contained within that part of the spectrum. Most of the chroma information is contained in the video spectrum from 3.08 MHz to 4.08 MHz, the part of the chroma that represents full color transmission. The portion of the chroma that represents frequencies transmitted in shades of orange and cyan occupy the spectrum fom 2.08 MHz to 3.08 MHz and contains relatively little energy (See Figure 19).

The average color T.V. receiver reproduces a picture that contains full color reproduction in video frequencies up to 0.5 MHz. The frequencies of 0.5 MHz to 1.5 MHz is reproduced in monochrome because the television color demodulator matrices are simpler that way. Newer sets can now be built that reproduce the medium fine detail (0.5 MHz to 1.5 MHz) in orange and cyan because it is possible to mass produce a more elaborate color demodulator cheaply using micro-circuit techniques.

The video frequencies from 3.0 MHz to 4.2 MHz are normally not used by color T.V. receivers because the picture quality is degraded by the large amount of chroma information present in these frequencies.

Newer monochrome and color television receivers are being built that can use the monochrome information from 3.0 MHz to 4.2 MHz. This is possible because these sets use a device called a comb filter to remove the chroma information from the video at those frequencies.

In summary, the average monochrome television viewer sees a majority of his television reproduced from video frequencies up to 3.0 MHz and sometimes up to 4.2 MHz. The background information, the coarse detail, the medium fine detail, and the fine detail must all arrive at his picture tube at the same time to produce a sharp picture and to avoid the smearing and defocusing effects that group delay (the above mentioned band arriving at different times) can have on his picture.

The color T.V. viewer also requires a clear monochrome picture, but in addition hopes that the color information (upper end of the video band) will arrive at his picture tube at the same time as the monochrome picture that it must tint (lower end of the video band). The effects of group (or envelope) delay on the luminance (monochrome) and chrominance (color) is to have the color information offset from the monochrome information. This is sometimes called the funny paper affect due to the color misregistration that can happen in the color printing process.

Test pulses are available that have energy distribution quite similar to the monchrome and color television signal. The 2T sine squared pulse has an energy distribution that closely resembles the monochrome picture. The modulated 12.5T and modulated 20T sine squared pulses have energy spectrums that approximate the color tinting information spectrum (chroma) and the portion of the monochrome picture spectrum that it tints. The 12.5T pulse has a wider bandpass than the 20T pulse.

THE DEVELOPMENT OF THE SINE SQUARED T PULSES

THE T PULSE (Figure 20)

The first sine squared pulse that will be developed is the T pulse. It starts as part of a 4 MHz sine wave with the negative leads clamped to zero volts (See Figure 20-A). One cycle is selected (negative peak to negative peak). The time of one cycle of 4 MHz sine wave (Time = $^{1}/_{\text{Frequency}}$) is 0.25 microseconds. It is no longer a sine wave but is now a pulse with a large harmonic content. A pure sine wave must be continuous to avoid harmonics. The width of the T Pulse now measures 0.125 microseconds (See Figure 20-B). 0.125 microseconds is the width of one picture element in the N.T.S.C. System and is the unit of time from which N.T.S.C. sine squared pulses are measured.

The energy of the T Pulse extends to a maximum frequency (F max) of 8 MHz. No significant energy exists beyond that frequency.

$$\text{Fmax} = \frac{1}{\text{H.A.D.}}$$

when: Fmax = highest frequency of the sine squared pulse that contains significant energy

H.A.D. = the time duration of the pulse measured at half its maximum amplitude

The energy of the T Pulse is 50% down (-6 db) at 4 MHz. (See Figure 20-C).

The 8 MHz bandwidth of the T Pulse makes it too wide to be used as a test pulse in a television transmitter.

THE 2T PULSE (Figure 21)

The 2T sine squared pulse has a half amplitude duration (H.A.D.) of 0.25 microseconds (See Figure 21-A). This brings its maximum frequency content to 4 MHz ($F_{\text{max}} = {}^{1}/_{0.25\text{ microseconds}}$).

The energy distribution of the 2T Pulse (See Figure 21-B) makes it representative of the monochrome picture. Amplitude changes anywhere within the energy stectrum of the pulse will show up in the amplitude of the pulse.

Relative delay time differences show up as base line disturbances in the form of undershoots and overshoots (See Figure 21-C). It is a sensitive indicator of transmission distortion up to the area of 2.4 MHz to 2.8 MHz. This will be discussed in detail when adjustment of the delay compensator is covered.

THE 20T MODULATED SINE SQUARED PULSE

The 20T Modulated Sine Squared Pulse is composed of two parts (See Figure 22-A).

The low frequency conponent is composed of a sine squared pulse. Its half amplitude duration is 20 times the width of a T Pulse, 20 x 0.125 microseconds = 2.5 microseconds. The maximum frequency extends to $^1/_{2.5\ \text{microseconds}}$ = 400 KHz. The amplitude of this pulse is 50 IEEE (or IRE). units.

The other part of the pulse is the modulation. It is modulated by 3.58 MHz color subcarrier. The burst of subcarrier has a 20T envelope and an amplitude of ± 50 IEEE (or IRE) units. It has a bandwidth of 400 KHz above and below the color subcarrier (Passband of 3.18 MHz to 3.98 Mhz). The low and high frequency components add up to produce a modulated sine squared pulse with an amplitude of 100 IEEE (or IRE) units. (See Figure 22-A) See Figure 22-B for the energy distribution of the modulated 20T sine squared pulse. Notice that with bandwidths of 400 KHz (low frequency component) and 800 KHz (high frequency component) it is slightly narrower than the component of the video signal. that is transmitted in full color (500 KHz with chroma bandwidth of 1MHz). The 20T Pulse does not extend to the band edge of 4.2 MHz but it is a reasonable indicator of the effects of amplitude and delay distorion on the color signal.

Amplitude inequalities at either end of passband show up as improper peak amplitude or the base line errors where the base line extends upward or below the zero IEEE (or IRE) line. (See Figure 22-C)

Relative delay inequalities show up as a sine wave shaped disturbance along the base line (See Figure 22-D). These effects will be discussed in detail when the delay compensators are adjusted.

THE MODULATED 12.5T SINE SQUARED PULSE

The Modulated 12.5T Sine Squared Pulse is similar in all respects to the modulated 20T Sine Squared Pulse (See Figure 23-A) except for its H.A.D. time and its bandwidth. The H.A.D. of the 12.5T Pulse is 12.5 x 0.125 microseconds = 1.5625 microseconds. This makes the maximum frequency of the 12.5T base pulse equal to 640 KHz and the bandwidth of the burst of chroma 640 KHz above and below the 3.58 MHz color subcarrier frequency. The passband extends from 2.94 MHz to 4.22 MHz. This makes the energy spectrum of the 12.5T pulse slightly wider than the portion of the video signal broadcast in full color (See Figure 23-B) and the upper frequency limit of the burst of chroma extends to the video signal's upper band limit.

Amplitude and phase distortion affects the 12.5T Pulse exactly the same way they effect the 20T Pulse. The 12.5T Pulse is a better indication of color distortions than the 20T Pulse owing to its wider bandwidth and its reaching the upper limit of the video spectrum.

DEVELOPMENT OF THE ACTIVE ALLPASS NETWORK

There are three requirements for a circuit that is to compensate for group delay.

1. The circuit must be able to delay a specific band of frequencies.
2. The circuit must be able to provide a known amount of delay to that band of frequencies.
3. The circuit must provide a flat amplitude response across a required band of frequencies, usually much wider than the band of frequencies that it is delaying.

The active allpass network can accomplish all of the above. The heart of the active allpass network is a series resonant circiut. If the characteristics of the series resonant circuit are understood, the active allpass network will become understandable and a logical approach to its adjustment is possible.

CHARACTERISTICS OF A SERIES RESONANT CIRCUIT

The series resonant circuit has four parameters that are of interest in the study of group delay. The series resonant circuit is shown in Figure 24-A. It has two variable controls. The variable C sets the resonant frequency of the circuit ($F_R = {}^{1}/_{2n\ LC}$) and the variable R sets the Q of the circuit.

$$(Q = \frac{X_L}{R})$$

Figure 24-B is a graph of the amplitude response of the output voltage versus frequency of the circuit of Figure 24-A. The output voltage developed across R, is maximum at resonance.

When the Q is high (R is low) the resonant peak is quite narrow. This yields a narrow bandwidth and a large change of amplitude over a small frequency span ($\Delta V/\Delta F$ is large).

When the Q is low (R is large) the resonant peak and the bandwidth are wider. The change of amplitude occurs over a wider frequency span (V/ F is small).

At resonance $X_L = X_C$ and cancels, leaving R as the only opposition to current flow in the circuit (Z = R). The output voltage is equal to the applied voltage (See Figure 25-B).

When the applied frequency is not equal to the resonant frequency, X_L and X_C are not equal (See Figure 25-A and 25-C), a net reactance (X_T) equal to the difference between X_L and X_C ($X_T = X_L - X_C$) adds vectorilly with R to produce the total opposition to current flow (Z), where Z = $X_T^2 + R^2$. The output voltage is lower because X_T and R act as a voltage and the applied voltage changes (See Figure 24-C).

When the applied frequency is below the resonant frequency the output voltage leads the phase of input voltage (See Figure 24-C). This happens because X_C is greater than X_L making the total reactance capacitive (See Figure 25-A).

When the applied frequency is greater than the resonant frequency, the output voltage phase lags the input voltage phase (See Figure 24-C and Figure 25-C). The circuit is inductive because X_L is greater than X_C.

When R is large (low Q), the change of phase from $+90^{\circ}$ to -90° occupies a wider bandwidth. This happens because X_T must be many times larger than R to cause the 90° phase shift. X_T results from the difference between X_L and X_C. The value of X_T increases as the applied frequency moves further from the resonant frequency, X_L and X_C change in opposite directions as the applied frequency changes ($X_L = 2n\ F\ L$ and $X_C = {}^{1}/_{2n\ F\ C}$).

When R is small (high Q), the change of phase from $+90^{\circ}$ to -90° occupies a more narrow band of frequencies. The frequency does not have to move as far to make X_T many times larger than R.

For a given Q, the change of amplitude occurs over the same band of frequencies as the change of phase angle. Since time delay depends on the rate of change of phase (or amplitude in this case) with frequency, a low Q produces less time delay over a wider frequency stectrum. A high Q circuit produces a greater time delay over a more narrow band of frequencies (See Figure 24-D).

$$\text{Time} = \frac{\Delta \text{ Phase}}{360 \Delta \text{ Frequency}}$$ See Page 7 for review

Notice if a large delay is required as in the receiver equalizer of the notch diplexer equalizer four allpass sections are used (as the delay of each section increases the bandwidth of the delay decreases). Where smaller amounts of delay are required (as in the S.A.W. filter exciter) only two delay sections are required.

SUMMARY OF THE CHARACTERISTICS OF THE SERIES RESONANT CIRCUIT

A desirable characteristic of the series resonant circuit, when used to correct group delay, is the additional time delay of the output voltage to the input voltage at and near the resonant frequency of the circuit (See Figure 24-D). Also desirable is the fact that the resonant frequency controls where the delay takes place and the Q controls how much delay will be created and over what bandwidth.

The undesirable effect of the series resonant circuit is the change of amplitude with frequency (See Figure 24-B), a flat frequency response is desired.

KEEPING THE DELAY WHILE PROVIDING A FLAT FREQUENCY RESPONSE

The first step in keeping the delay of the series resonant circuit and providing a flat frequency response is to combine Figures 24-B and 24-C on a polar graph (See Figure 26-A).

The positive X axis of the graph represents a zero degree phase shift, the negative X axis represents 180 degrees of phase shift. The Y axis represents positive and negative 90^o phase shifts. The crossing point of the X and Y axis is called the origin. The amplitude of the voltage is measured from the origin and is represented by the length of the vector, The phase angle of the voltage is measured by the angle of the vector from the positive X axis. Thus the amplitude and phase angle of the voltage is represented by the vector.

In Figure 26-A, vector A represents the condition where the applied frequency is equal to the resonant frequency. The phase angle is zero degrees and the voltage is maximum. As the applied frequency is reduced below the resonant frequency vectors B, C, D, and E result. The phase angle approaches 90^o and the voltage amplitude decreases. Vectors F, G, H, and I show the effects as the applied frequency is raised above the resonant frequency (the phase angle approaches -90^o and the amplitude decreases). If enough vectors are added, the tips of all vectors form a circle that is bisected by the positive X axis. The left side of the circle just touches the orgin (See Figure 26-B).

Figures 27 and 28 show the relationship between Q, the positions of the vectors on the polar graph, and the amount of delay encountered. The resonant frequency for both of these examples is 2 MHz. The amount of Q affects the band of frequencies covered by the right two-thirds of the circle formed by the series resonant circuit output voltage vectors. When the Q is low, as in Figure 27, a wide band of frequencies is covered in the right two-thirds of the circle (small rate change of frequency causing smaller delay over a wider band of frequencies). The high Q of Figure 28 causes a narrow band of frequencies to be covered by the right two-thirds of the circle (larger rate of change of phase to frequency causing a larger delay over a smaller band of frequencies).

REMOVING THE AMPLITUDE VARIATION OVER THE FREQUENCY BAND

If the circles of Figure 26 through 28 can be shifted so that they are rotated about the origin of the graph, the frequency response would be flat but the phase shift and the time delay would still be present.

In the next section we will study the allpass network. It provides an increased amount of delay to a small band of frequencies within its passband while maintaining a flat amplitude response across its passband.

THE BASIC ALLPASS NETWORK

Figure 29 shows the block diagram of a basic allpass network. It will keep the delay characteristics of the series resonant circuit and provide a flat frequency response.

The series resonant circuit with its frequency and Q controls provides voltage e_1. It is called the narrow band circuit which provides delay but does not have a flat frequency response.

The other path is formed by a delay line and an attenuator; this is the wide band path. It provides a voltage e_2 such that e_2 is always half of the amplitude of and 180^{o} out of phase with voltage e_1 when e_1 is at resonance. Voltage e_2 has a constant amplitude and phase characteristic over a band of frequencies that is much wider than the required transmitter bandwidth. When vectors e_1 (the narrow band path) and e_2 (the wide band path) are added, e_3 results (See Figure 30-A).

Figure 30-B shows the addition of several phases of e_1 (from Figure 26-A) and e_2. In each example the resultant vector e_3 would form a circle about the origin of the graph (See Figure 30-D). This provides the flat frequency response and the variable delay required of the active allpass network.

The frequency distribution for vector e_3, its amplitude response, and the relative time delay versus frequency characteristic for a high Q active allpass network is shown in Figure 31. The high Q circuit concentrates a narrow band of frequencies in the right hand two-thirds of e_3 vector circle as shown in Figure 31-A. Therefore the change of phase versus frequency is large (large Ø/ F). This produces a large amount of delay over a narrow band of frequencies (See Figure 31-C). Remember that:

$$\text{Time} = \frac{\Delta \text{ Phase}}{360\, \Delta \text{Frequency}}).$$

The frequency distribution for vector e_3, its amplitude response and the relative delay versus frequency characteristic for a low Q allpass network is shown in Figure 32. The right two-thirds of vector e_3 covers a large frequency span. Therefore the change of phase versus frequency is small

(small $\phi/$ F). Thus the low Q allpass network producing a small amount of delay happens over a wider bandwidth.

Adjustment of the Q control determines where the delay takes place. Changing the series resonant circuit frequency moves the delayed passband up or down the spectrum.

ADDING THE BALANCE AND PHASE CONROLS

Figure 29 shows an allpass network in which frequency and Q are the only adjustable parameters. They are used to adjust the delay characteristics of the network.

The attenuation and delay of the wideband path is fixed. In theory the active allpass network will always have a flat amplitude response, but in practice, component tolerances and active device gain variations cannot insure this. Some means is needed to assure that proper phase and amplitude relationship will be maintained between the narrow band signal e_1 at resonance and the wide band signal e_2. This will keep the amplitude response of the active allpass network flat across the passband.

In Figure 33 the phase and balance controls have been added to the allpass network. They provide adjustment of the amplitude response characteristic of the allpass network by providing a compensating adjustment for the amplitude and phase of voltage e_1.

The balance contol adjusts the amplitude of e_1 at resonance so that it will be twice the value of e_2. The phase control rotates the phase of e_1 at resonance so that it will be 180° out of phase with e_2.

ADJUSTMENT OF THE BALANCE CONTROL

If the balance control is adjusted for a greater e_1 voltage, the size of the circle formed by e_1's vectors will increase. It will remain tangent to the origin of the graph and will be centered on the positive zero degree axis. Since the e_2 voltage or phase angle has not changed, vector e_3 will form a circle that is slightly larger than before with its center on the zero degree axis slightly to the right of the origin (See Figure 34-A). The maximum amplitude will occur at the resonant frequency of the allpass network (See Figure 34-B).

Figures 34-C and 34-D show the effects on vectors e_1 and e_3 and the amplitude response when the balance contol is adjusted for a reduced e_1 voltage.

ADJUSTMENT OF THE PHASE CONTROL

When the phase control is adjusted, the phase of vector e_1 at resonance changes (See Figure 35-A). This causes the e_1 circle, with one point still tangent to the origin, to rotate upward. Vector e_2 has not changed, therefore the resultant vector e_3 forms a circle whose center is above the origin of the graph (See Figure 35-B). The frequency response of this adjustment is shown in Figure 35-C. Notice that the amplitude response is tilted about the resonant frequency with the shape of the response resembling a sine wave.

Figure 35-D shows the effect of adjusting the phase control in the opposite direction. In this case the response tilts at the resonant frequency but in the opposite direction. The shape of the amplitude response still resembles a sine wave.

SUMMARY OF THE ACTIVE ALLPASS NETWORK ADJUSTMENTS

1. The balance control affects the frequency response varying the amplitude at the resonant frequency of the allpass network (See Figure 36).
2. The phase control affects the frequency response varying the amplitude about the resonant frequency (See Figure 37).
3. The frequency control affects the position of the delay in the passband (See Figure 38).
4. The Q control effects the amount and bandwidth of the delayed portion (See Figure 39).
    - A. High Q produces much delay over a narrow passband.
    - B. Low Q produces less delay over a wider passband.

TRANSMITTER ADJUSTMENT SEQUENCE

To avoid confusion, this is the order in which the television transmitter adjustment procedures should take place. The delay adjustments will then be considered in detail.

1. The transmitter should be properly tuned using good quality sweep gear.[2] All compensation should be bypassed. This included the notch diplexer equalizer (if applicable), the receiver equalizer, the phase corrector, the linearity corrector, the delay compensator (all sections) and the vesigial sideband filter. If a notch diplexer is used, the RF output sample should be taken before the notch diplexer.
2. The transmitter's output power should now be checked.[2] This is done with both the vestigial sideband filter and the linearity corrector IN. Proper depth of modulation, blanking level and sync level should be established. Full power should be attempted with black picture and should be attained with proper power amplifier meter readings, safe levels of power amplifier dissipation and sync compression which is not excessive. If this cannot be achieved, tuning should be repeated with linearity corrector and vestigial sideband filter bypassed.
3. The differential gain and differential phase is now adjusted with the transmitter operating at 100% power. The linearity corrector, phase corrector, and vestigial sideband filter should be switched IN.

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2 - See the paper entitled "Tuning Procedures for Double Tuned Tube Type Power Amplifiers Used in T.V. Transmitter Application" by Clarence E. Daugherty, Jr.

4. With the transmitter still operating at 100% power, the delay compensators in the visual exciter can be set. For this process, sample the RF before the notch diplexer (if used) and be certain that the notch diplexer equalizer, the receiver equalizer, and the demodulator sound trap are all bypassed.[3] The linearity corrector, the phase corrector, and the vestigial sideband filter are all switched IN.
5. With all the transmitter adjustments completed and switched IN and the transmitter operating at 100% power, the receiver equalizer is now adjusted.[4] The receiver equalizer and the demodulator sound trap are both switched IN. Sample the RF before the notch diplexer if one is used in your system.
6. If the system has a notch diplexer, the notch diplexer equalizer is now adjusted. All other adjustments are completed and switched IN and the transmitter is operating at 100% power. Sample the RF after the notch diplexer.

3 - If your demodulator sound trap (notch) cannot be bypassed, leave the receiver equalizer IN.
If your transmitter has the new V.S.F. with the built in receiver equalization predistortion curve, leave the demodulator sound notch IN.

4 - If your transmitter has the new V.S.F. with the built in receiver equalization envelope delay predistortion curve, you won't have a separate receiver equalizer.

VISUAL EXCITER DELAY COMPENSATOR ADJUSTMENTS

(S.A.W. Filter Type Harris Visual Exciter)

Group delay adjustments are performed after all other tuning and linearity adjustments have been made (see the transmitter adjustment sequence in the previous section).

The preliminary adjustments preset the two delay sections to introduce delay in the center of the visual passband at 1 MHz and 3 MHz above the visual carrier. The delay is introduced to compensate for the delay at the edges of the passband caused by the tuned visual RF amplifier.

Satisfactory delay adjustments may be obtained using standard television test waveforms, but the quality of the pulse reproduction depends upon the T.V. demodulator. It must have an ideal amplitude response (the response of the demodulator's I.F. signal fed to the detector must have a nyquist slope).

If the transmitter's swept response and/or the demodulator's amplitude response is not proper, the demodulated test pulses will have amplitude distortions.

The demodulator should have an ideal group delay response as it is the standard through which the transmitter group delay is measured (see the section on the demodulator in this report).

Sine squared pulses provide a test of envelope delay for visible picture effects, amplitude distortions, and delay distortions.

The 2T pulse is useful in testing group delay in the low to mid frequency range, a good indication of monochrome picture quality. Amplitude distortion affects the height of the reproduced pulses. Envelope delay distortions cause the 2T pulse to be reproduced nonsymmetrically about the base line with incorrect overshoots (See Figure 40).

The modulated 12.5T (or 20T) pulse compares the amplitude and group delay at the low video frequencies (luminance) to the upper end of the video spectrum (chrominance). It is a good indicator of color picture quality. Amplitude distortion will cause the base line of the pulse to expand or contract, and the height of the pulse to be incorrect. This can be understood if this pulse is thought of as a low frequency base pulse to which a high frequency burst of chroma is added. Figure 41 shows several examples of amplitude problems.

Delay distortions cause the base line to assume a sine wave shape. This can also be understood if the 12.5T (or 20T) pulse is thought of as the combination of a low frequency and a high frequency component. Both of these components must arrive at the same time to produce a flat base line. Two examples are shown in Figure 42.

The test equipment is connected to the visual transmitter as shown in Figure 43. Provisions are made to sweep the transmitter by connecting the transmitter's input and RF output samples to the sweep equipment.

Arrange the connections so that the transmitter's input can be quickly changed from the sweep video output to the video test pulse generator output, and the transmitter's RF output sample can be quickly changed from the sweep equipment input to the demodulator's RF input. In this way the transmitter can be swept or the demodulated pulses from the transmitter can be observed.

When applying the test pulses to the transmitter, the test pulses can be a normal amplitude composite video signal if the demodulator has a syncronos detector.

If the demodulator uses an envelope detector, the amplitude of the pulses can be reduced to approximately 200 to 350 mVp-p to reduce the quadrature distortion that the envelope detector produces. The reduced amplitude pulses can ride on a 40 to 50 IRE pedestal with standard sync (See Figure 44).

The receiver equalizer and the demodulator sound notch should be bypassed.

A. Leave the receiver equalizer in if the demodulator sound notch cannot be bypassed.

B. Leave the demodulator sound notch in if the transmitter has a receiver delay equalized vestigial sideband filter.

If the transmitter uses a notch diplexer, sample the RF before the notch diplexer and set the notch diplexer equalizer normal/bypass switch to the bypass position.

EXCITER DELAY COMPENSATOR PRELIMINARY ADJUSTMENTS

The delay compensator board is divided into two identical sections with each section having a wide band and a narrow band path. The frequecies of the narrow band path may be pre-set to approximate resonance using sweep before attempting to align compensator with the transmitter.

1. Apply video sweep and sync to the exciter's input and observe the exciter's RF output on a sideband analyzer. (CAUTION: Use attenuators as needed to prevent damage to test equipment.)
2. Set the delay compensator bypass switches (S-1 and S-2) to OUT position.
3. Set VSB IN/OUT switch to OUT position.
4. Ensure that frequency response is flat ± .5 db with the V.S.B. filter and delay compensator bypassed.
5. Adjust response equalizer on modulator if required.
6. Set Q control of both sections (S-3 and S-4) to 14.
7. Set balance control of both sections fully counterclockwise.
8. Switch in the left delay compensation section.
9. Adjust frequency control of the left section to place null (resonant frequency of narrow band section) 3/4 MHz to 1 MHz above the visual carrier (See Figure 45).
10. Set Q control of the left section to 8.
11. Using phase and balance controls of the left section, adjust for flat swept response.
12. Switch the left delay compensator section OUT.
13. Switch the right delay compensator section IN.
14. Adjust frequency control of the right section to place null (resonant frequency of narrow band section) 2.9 MHz to 3.2 MHz above the visual carrier (See Figure 46).
15. Set Q of the right section to 8.
16. Adjust phase and balance controls of the right section for flat swept response.
17. Set bypass switches (S-1 and S-2) for both delay sections to IN position.
18. Set the VSB switch to the IN position. Reconnect exciter to transmitter.

FINAL ADJUSTMENT FOR DELAY AND AMPLITUDE RESPONSE

1. Ensure that the transmitter has a proper swept response.
    - A. If exciter delay compensator has not been previously set up or the condition of alignment is unknown, refer to the delay compensator preliminary adjustments.
    - B. Using phase and balance controls for both delay sections, adjust for the flattest frequency response through the transmitter.
2. With 2T + 12.5T test pulses applied to the transmitter's input, adjust the transmitter for 100% peak of sync power and observe the demodulated pulses on the waveform monitor.
3. The frequency of the low frequency section is adjusted for symmetrical overshoot of the 2T pulse (See Figure 40-D and 40-E).
    - A. CAUTION: Do not turn the frequency adjustment more than one turn in either direction or the resonant frequency of that section will be moved too far from the preset condition. It might even be moved out of the transmitter's passband.
    - B. Turning the frequency control clockwise increases the resonant frequency of the allpass network.
4. The Q of the low frequency section is adjusted for optimum overshoot of the 2T pulse (See Figure 40-B and 40-C).
    - A. Zero is minimum Q and 15 is maximum Q. Each step adds approximately 15 nanoseconds of group delay at the resonant frequency of the allpass section.
5. The resonant frequency of the high frequency section is adjusted for minimum sine wave shaped base line disturbance of the modulated 12.5T (or 20T) pulse (See Figure 42).
    - A. CAUTION: Do not turn the frequency control more than 3/4 turn in either direction or the resonant frequency of that allpass section will be moved too far from the preset condition or out of the passband.
6. The Q of the high frequency section is adjusted to clean up the short duration spikes of window pulse transients or the base of the 2T pulse. It can also be somewhat effective in removing delay problems (sine wave shaped base line disturbances) in the 12.5T (or 20T) pulse.

7. When delay caused base line disturbances of the pulses have been improved by the frequency and the Q adjustments, the amplitude response must again be checked using sweep.
    A. An indication of the amplitude response problems can be observed by comparing the height of the pulses to the level of the window reference pulse that is usually included on that same horizontal line. The expansions or contraction of the base line of the 12.5T (or 20T) pulse is also an indication of amplitude response problems. (Refer back to Figure 41)
    B. To avoid being mislead by possible amplitude response problems in the demodulator, sweep the transmitter to check its amplitude response. Avoid the temptation of adjusting the amplitude response of the transmitter by observing the demodulated pulse.
8. Sweep the transmitter and adjust the phase and balance controls of each allpass section for a flat swept amplitude response of the transmitter.
9. Repeat steps 2 through 6 for the best pulse base line shape.
10. Repeat step 8 for the best swept response.
11. Steps 2 through 6 and step 8 must be repeated alternately until good pulse base lines and good swept response are both achieved. Usually 3 to 5 cycles are necessary. Each cycle will show progressively better pulses and swept response.
    A. When the pulses and swept response are close to correct, double check the adjustment of the differential gain and phase correctors.
    B. If the pulses still indicate a problem with amplitude response, but the swept response of the transmitter is proper, the problem might be in the demodulator's amplitude response or sound trap alignment.

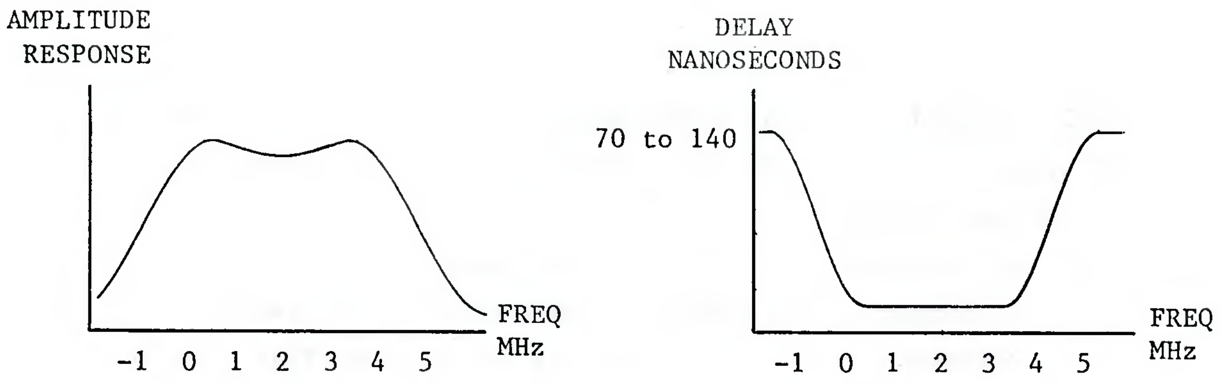


FIGURE 1A - Transmitter swept response and delay characteristics with the V.S.F. out.

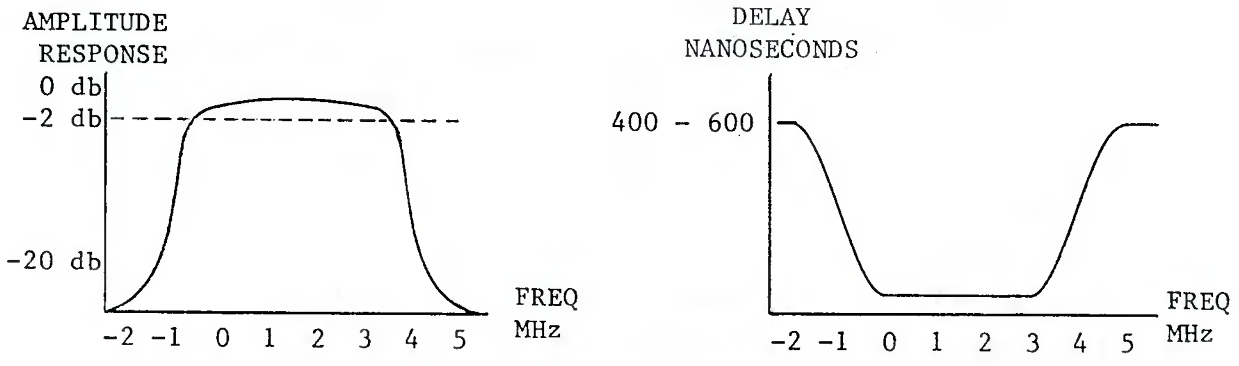


FIGURE 1B - Response and delay characteristics of an L-C type V.S.F.

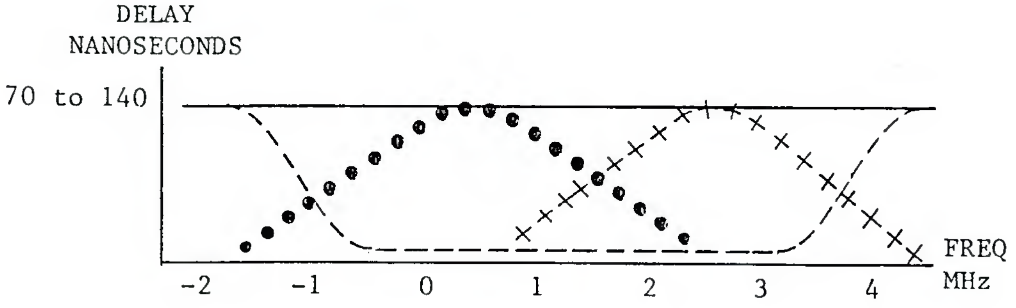


FIGURE 2 - TRANSMITTER DELAY -

1st DELAY COMPENSATOR ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●

2nd DELAY COMPENSATOR + + + + + + + + + + + + + + + +

RESULTANT DELAY ————————————————————

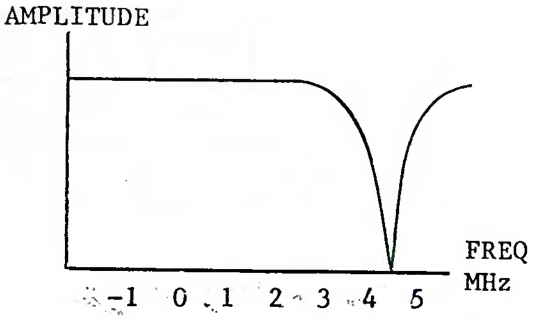
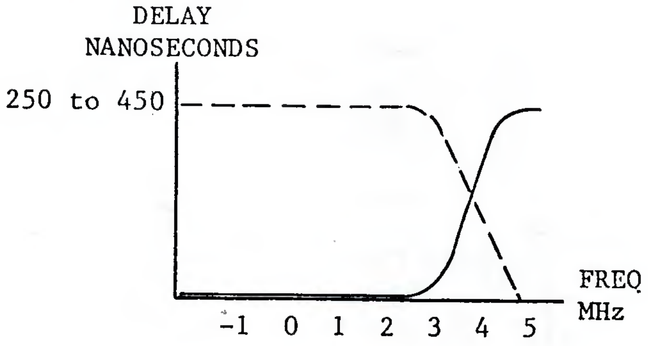


FIGURE 3 - Visual response of a notch diplexer.



Notch Diplexer Delay

Notch Diplexer ————————

Equalizer Delay— — — — — — —

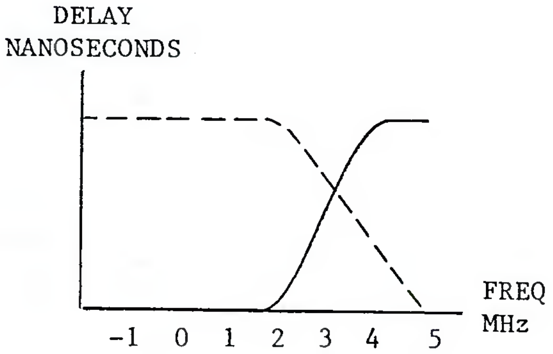


FIGURE 4 - Receiver Sound Notch Delay ————————————

Receiver Equalizer Delay— — — — — — — — — —

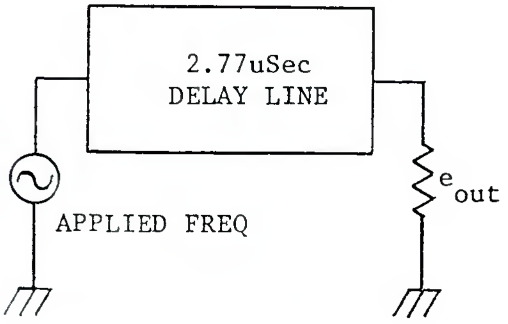


FIGURE 5a - A 2.77uSec delay circuit.

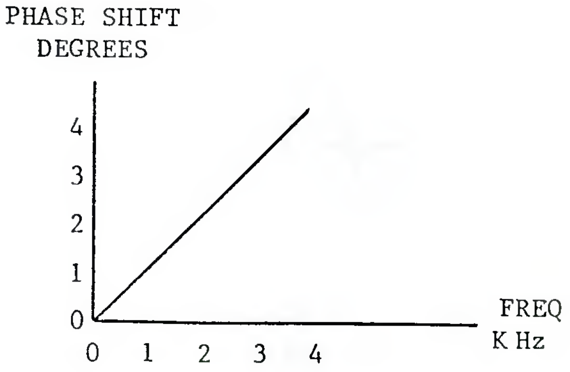
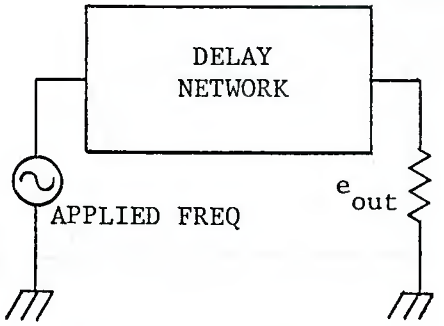


FIGURE 5B - Graph of phase shift versus frequency for the circuit of FIGURE 5A.



FREQUENCY IN KHz	1	2	3	4
DELAY TIME IN uSEC	0.694	1.04	1.11	3.4
DEGREES OF PHASE SHIFT	0.25	0.75	1.2	5

FIGURE 6A - A circuit to produce a non-linear change of phase with frequency.

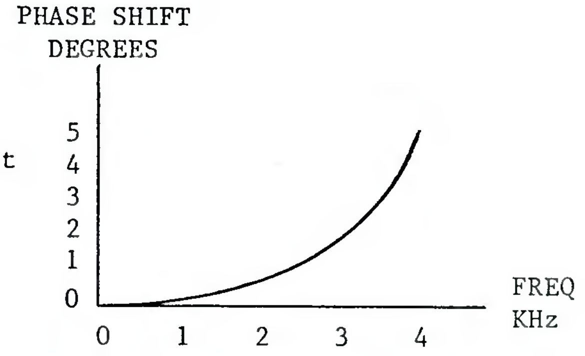


FIGURE 6B - Graph of phase shift to frequency for the circuit of FIGURE 6A.

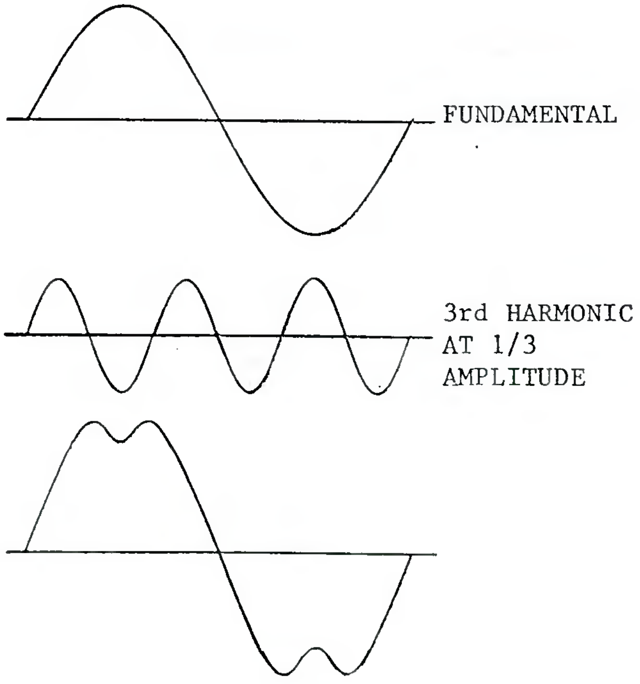


FIGURE 7 - 1st approximation of a square wave.

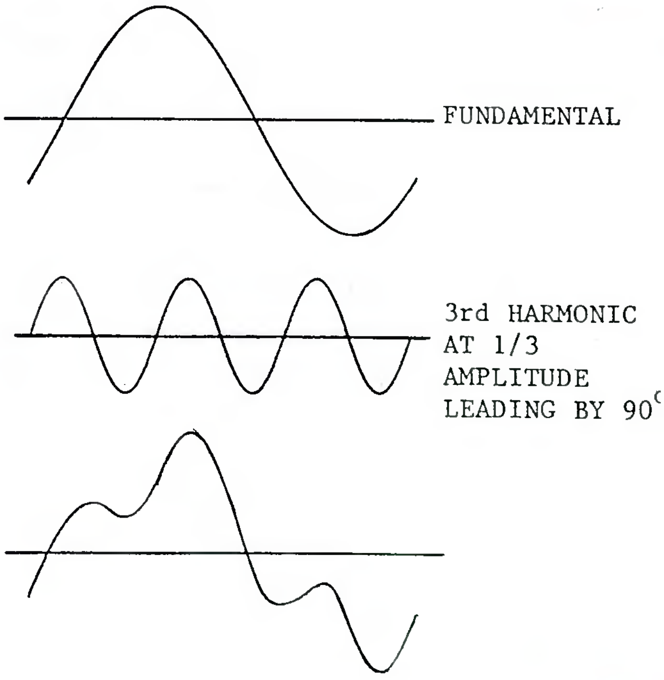


FIGURE 8 - Pulse tilted by improper phase shift (group delay).

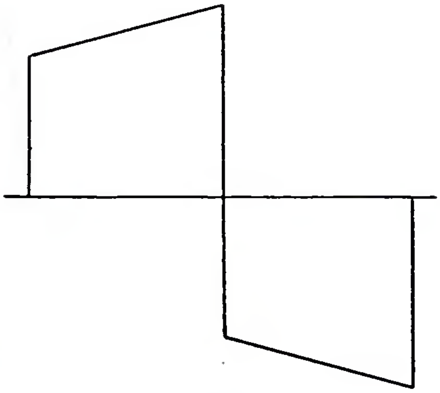


FIGURE 9 - Square wave with low frequency phase lag.

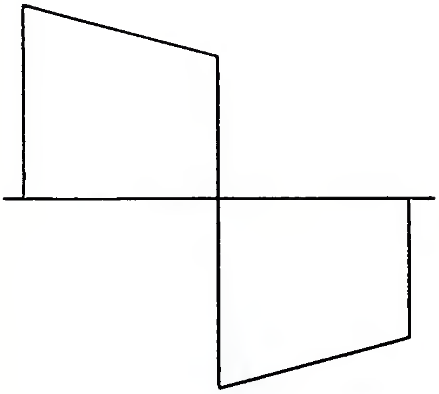
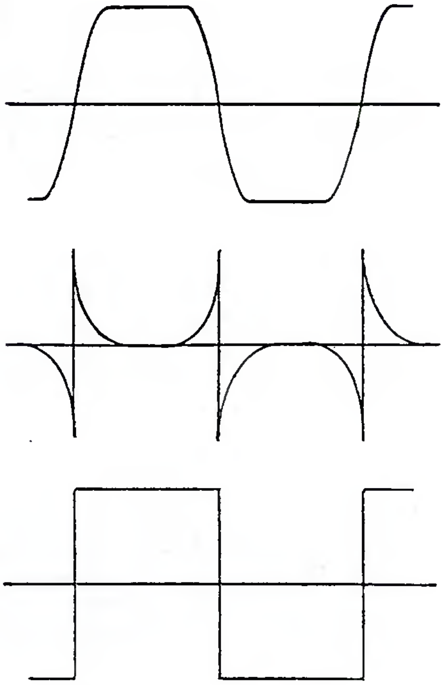


Figure 10 - Square wave with low frequency phase lead.



Square wave with low and medium frequencies present and high frequencies missing.

High frequency component of a square wave.

Resultant square wave

FIGURE 11 - Components of a square wave.

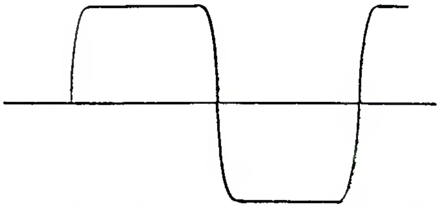


FIGURE 12 - Square wave with poor high frequency response.

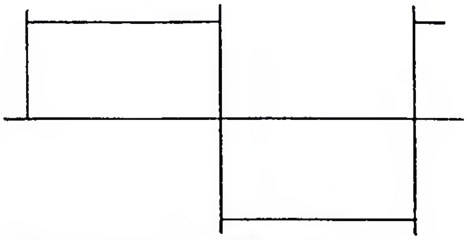


FIGURE 13 - Square wave with excessive high frequency response.

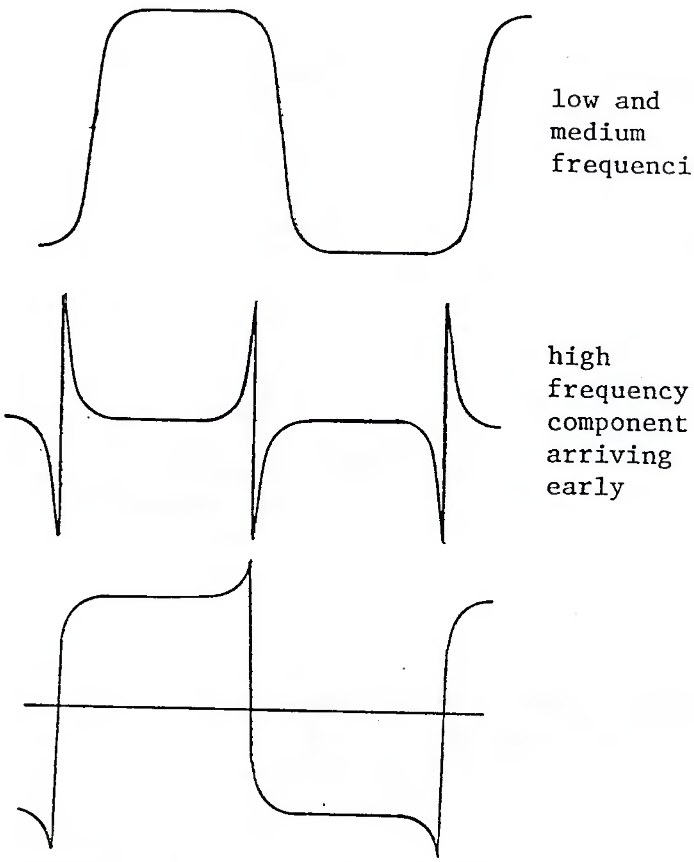


FIGURE 14 - Square wave resulting from high frequency component with a leading phase shift.

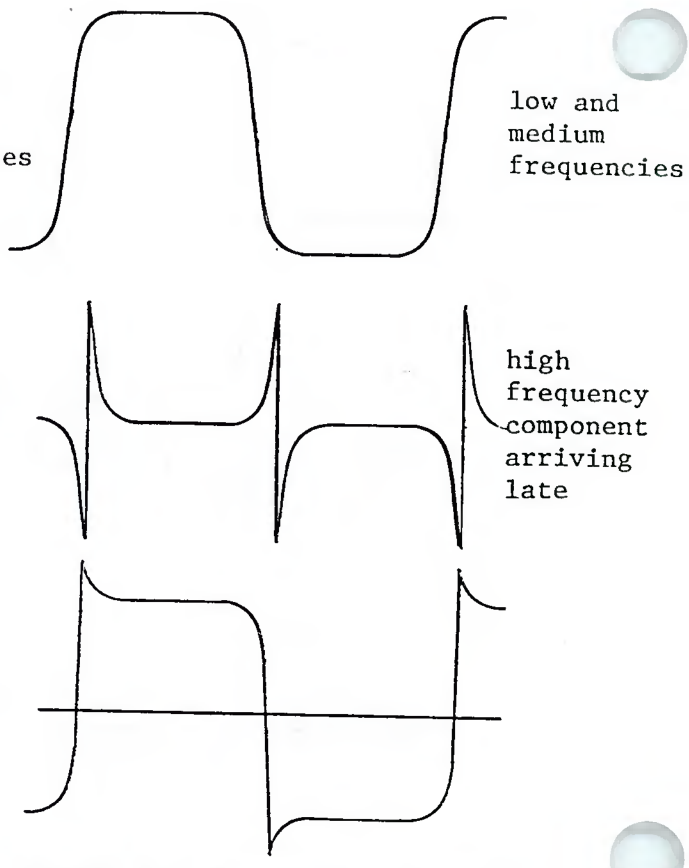


FIGURE 15 - Square wave resulting from high frequency component with a lagging phase shift.

	Frequency	Transmitted	Received
Coarse Detail	DC to 0.5 MHz	Full Color	Full Color
Medium Detail	0.5 MHz to 1.5 MHz	Orange and Cyan	Monochrome
Fine Detail	1.5 MHz to 4.2 MHz	Monochrome	Monochrome

FIGURE 17 - Video spectrum information

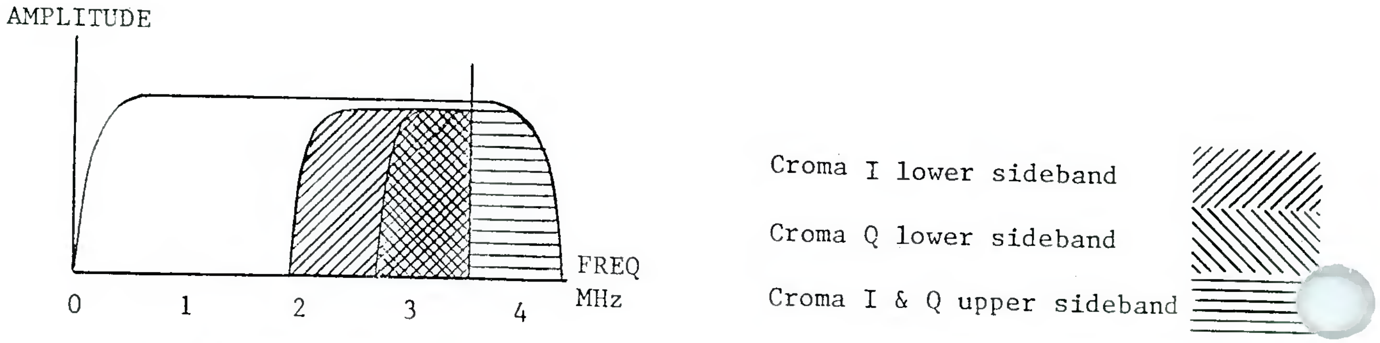


FIGURE 18 - Croma spectrum of video

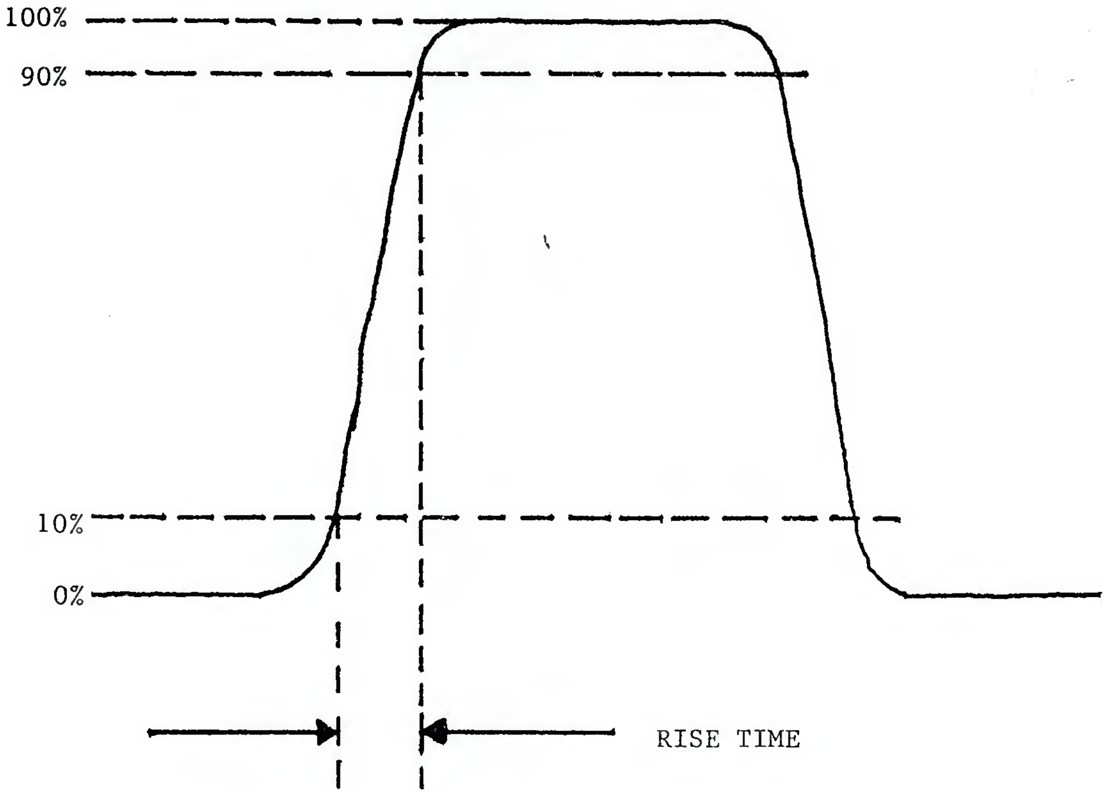


FIGURE 16: MEASURING THE RISE TIME OF A TELEVISION PULSE. THE RISE TIME IS MEASURED AT THE 10 % AND THE 90% LEVELS.

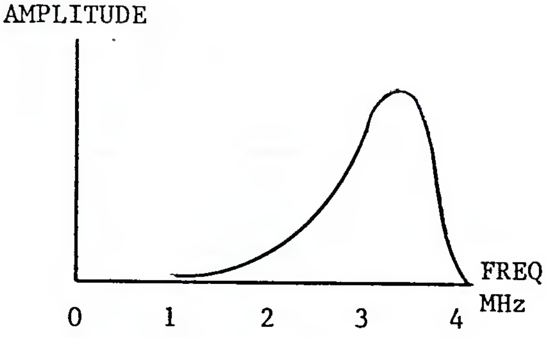


FIGURE 19 - Energy spectrum of chroma.

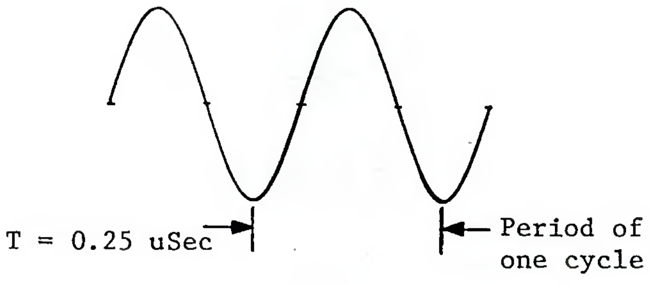


FIGURE 20A - 4 MHz sine wave

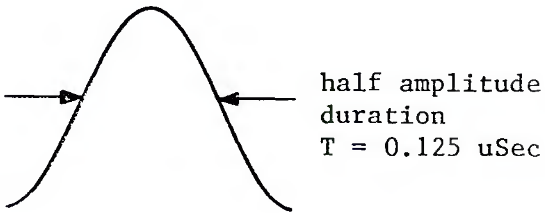


FIGURE 20B - T pulse resulting from one cycle of 4 MHz sine wave.

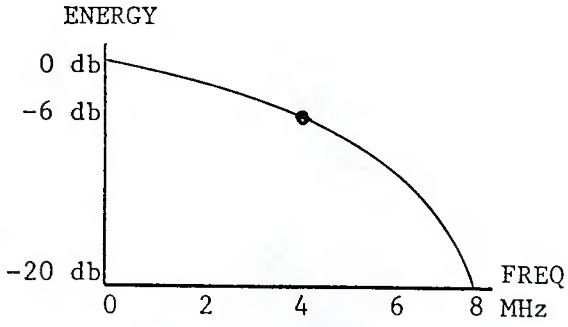


FIGURE 20C - Energy distribution of a T pulse.

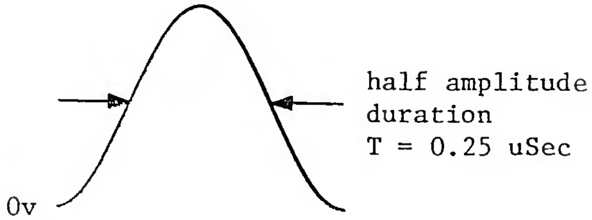


FIGURE 21A - The 2T pulse

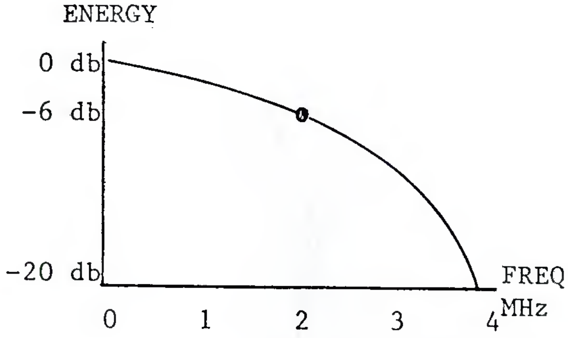
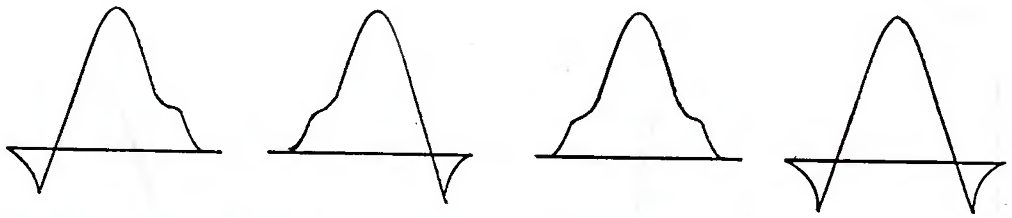


FIGURE 21B - Energy distribution of a 2T pulse.



Delay at the wrong frequency

Wrong amount of delay

FIGURE 21C - Group delay problems with the 2T pulse.

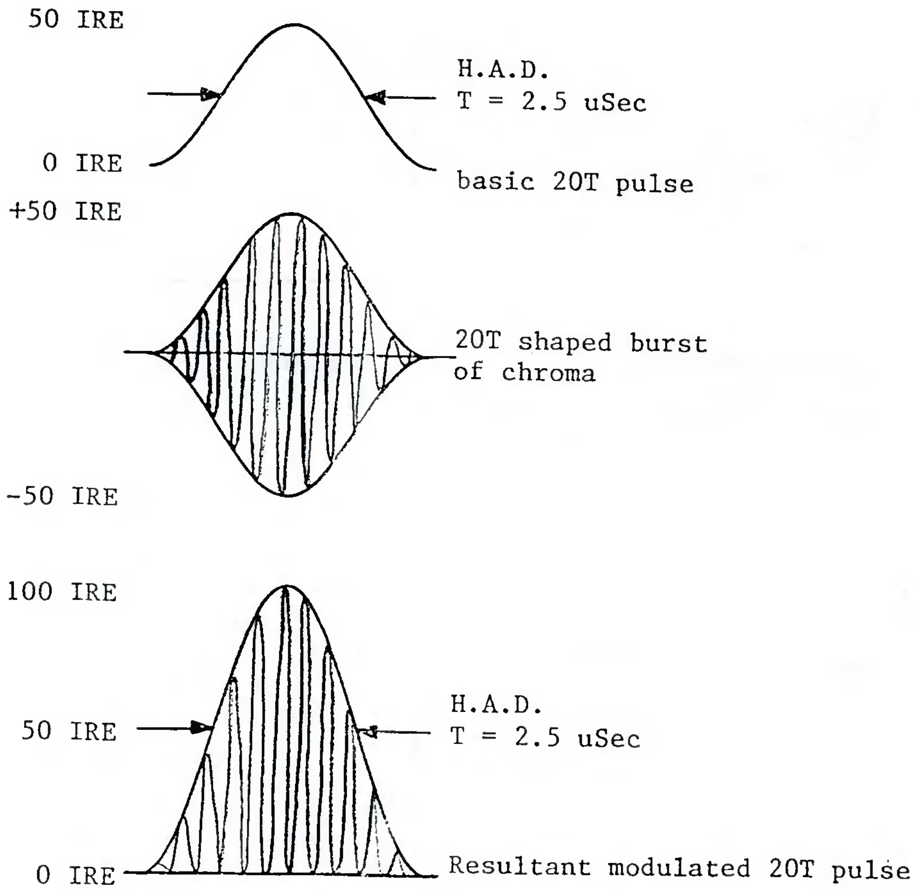


FIGURE 22A - Components of the modulated 20T sine squared pulse.

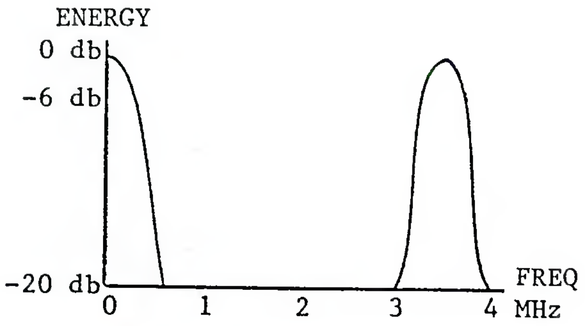


FIGURE 22B - Energy distribution of the modulated 20T sine squared pulse.

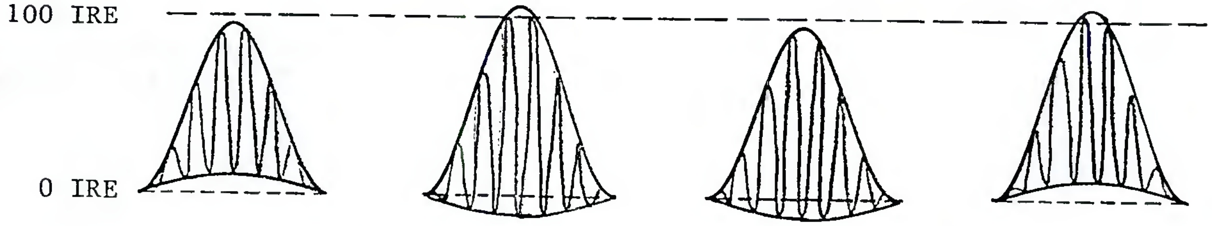


FIGURE 22C - Effects of amplitude distortion on the modulated 20T pulse (and also on the 12.5T pulse).

FIGURE 22D - Effects of delay distortions on the modulated 20T pulse (and also on the 12.5T pulse).

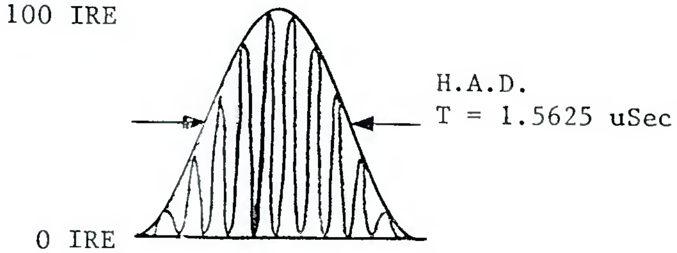


FIGURE 23A - The 12.5T modulated sine squared pulse

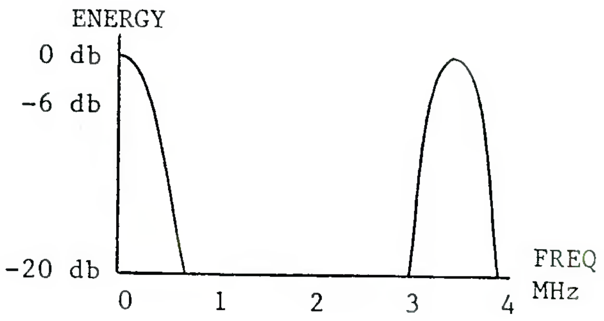


FIGURE 23B - Energy distribution of the modulated 12.5T sine squared pulse.

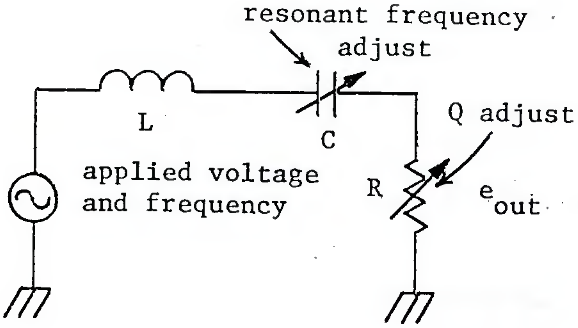


FIGURE 24A - The series resonant circuit.

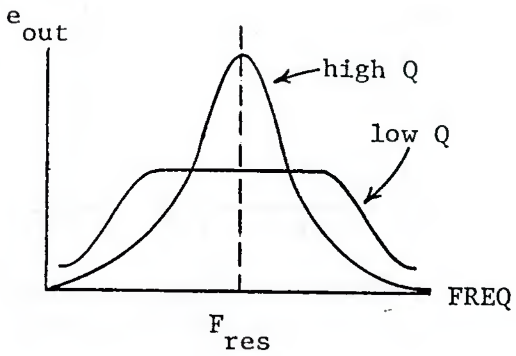


FIGURE 24B - Graph of amplitude of output voltage versus frequency for the circuit of FIGURE 24A.

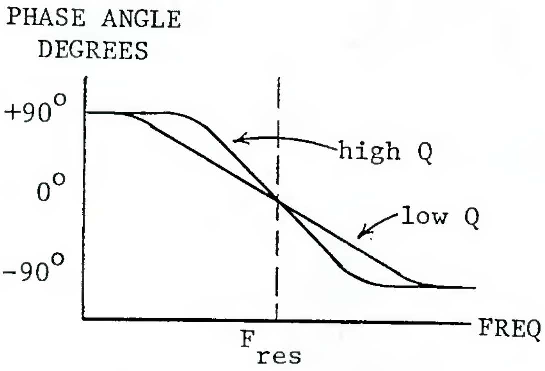


FIGURE 24C - Graph of phase shift of output to input versus frequency.

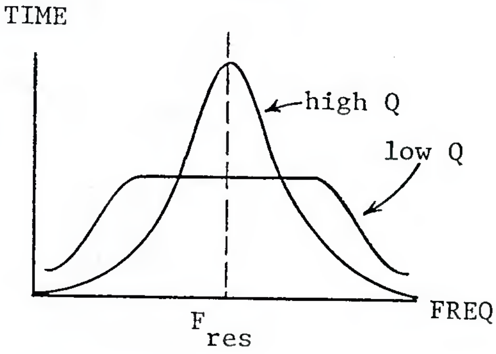
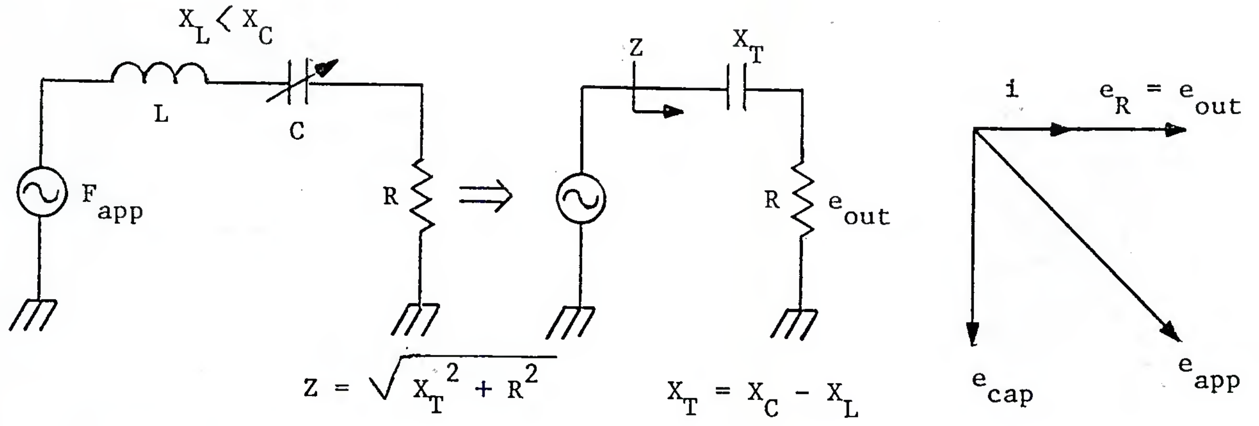


FIGURE 24D - Graph of time delay versus frequency for the circuit of FIGURE 24A.



$$Z = \sqrt{X_T^2 + R^2} \qquad X_T = X_C - X_L$$

FIGURE 25A - When F_{app} is lower than F_{res}, then X_C is greater than X_L. The circuit impedance (Z) is capacitive. This causes e_{out} to lead e_{app}.

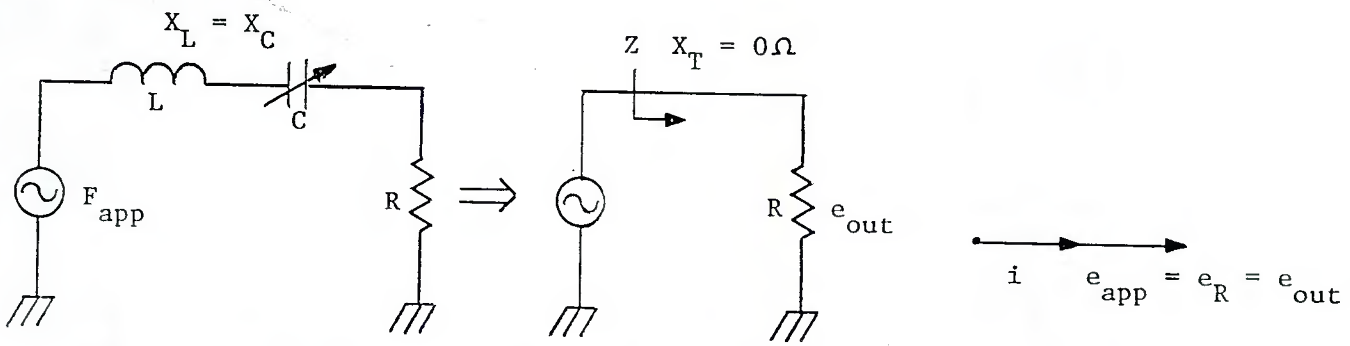
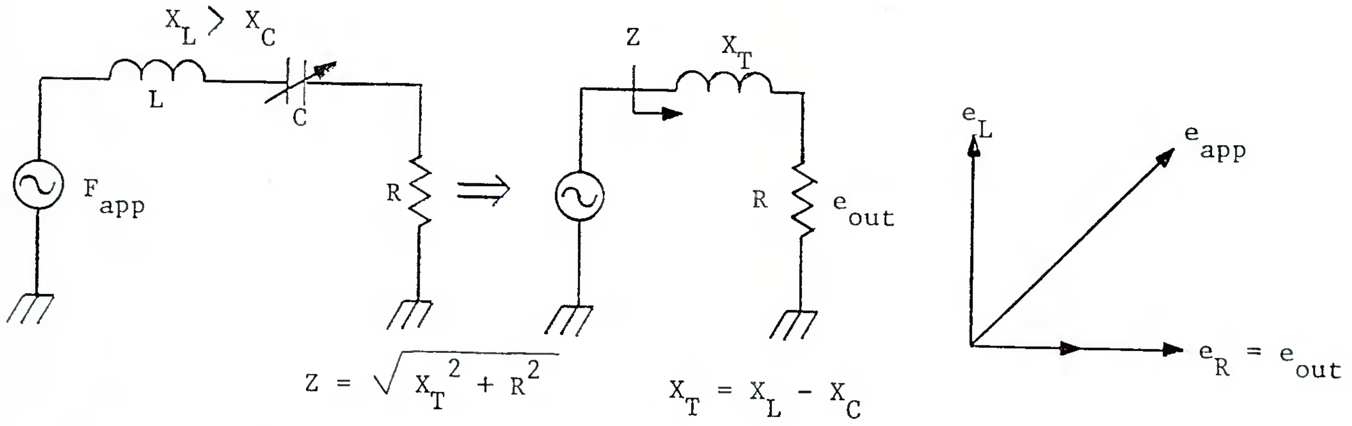


FIGURE 25B - When $F_{app} = F_{res}$, $X_L = X_C$ and cancel. Z = R and $e_{app} = e_{out}$. The phase angle is zero.



$$Z = \sqrt{X_T^2 + R^2} \qquad X_T = X_L - X_C$$

FIGURE 25C - When F_{app} is higher than F_{res}, X_L is greater than X_C. The circuit Impedance is Inductive. This causes e_{out} to lag e_{app}.

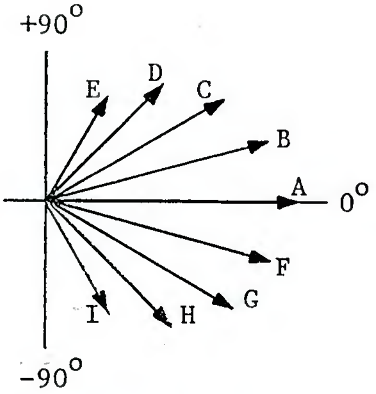


FIGURE 26A - Polar graph of the series resonant circuit of FIGURE 24A. The graph combines the graph of FIGURE 24B and 24C and shows amplitude and phase of e_{out}.

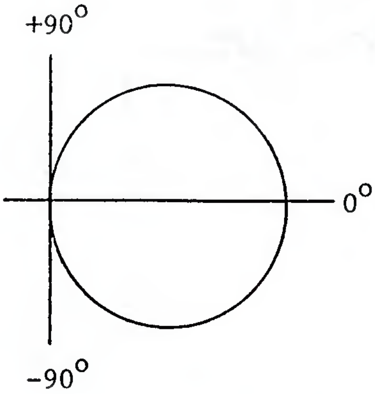
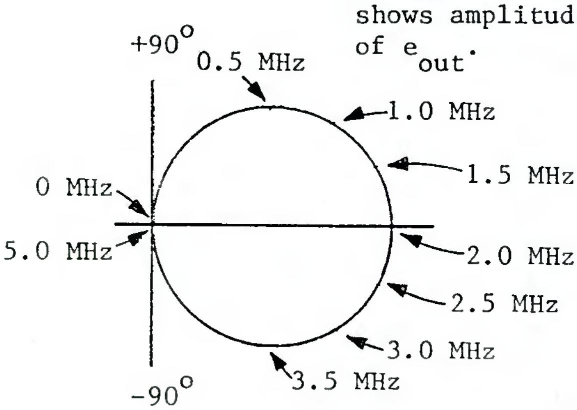


FIGURE 26B - When the tips of all possible vectors of FIGURE 26A are shown, they form a circle that is tangent to the origin. It is bisected by the 0° line.



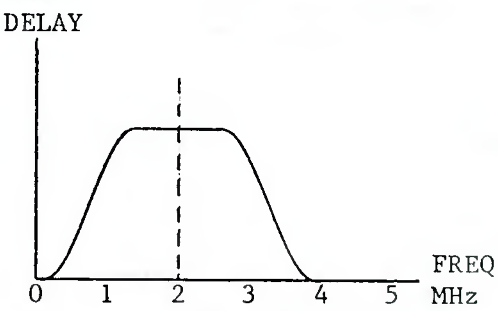


FIGURE 27 - Polor graph of the series resonant circuit of FIGURE 24A. It shows the relationship of frequency versus phase angle.

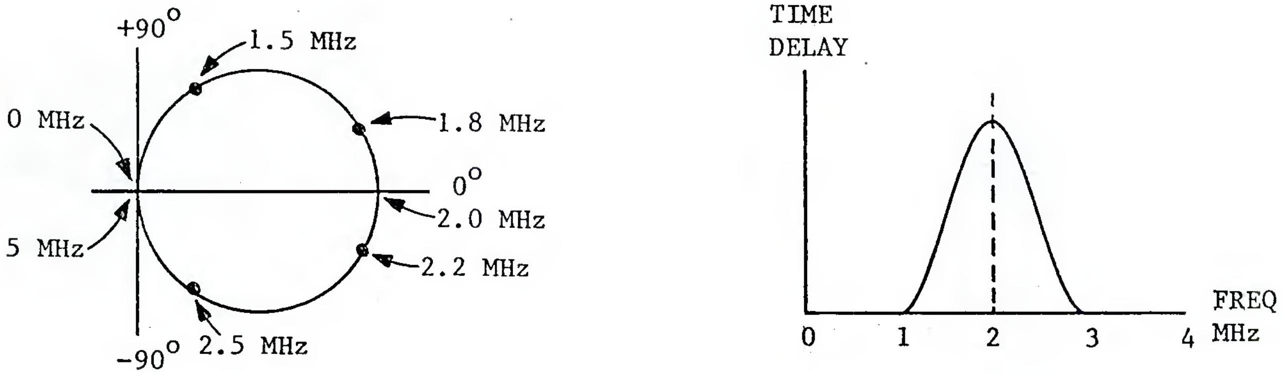


FIGURE 28 - Polar graph of the series resonant circuit of FIGURE 24A. It shows the relationship of frequency versus phase angle versus delay for a high Q circuit. F_{res} = 2.0 MHz

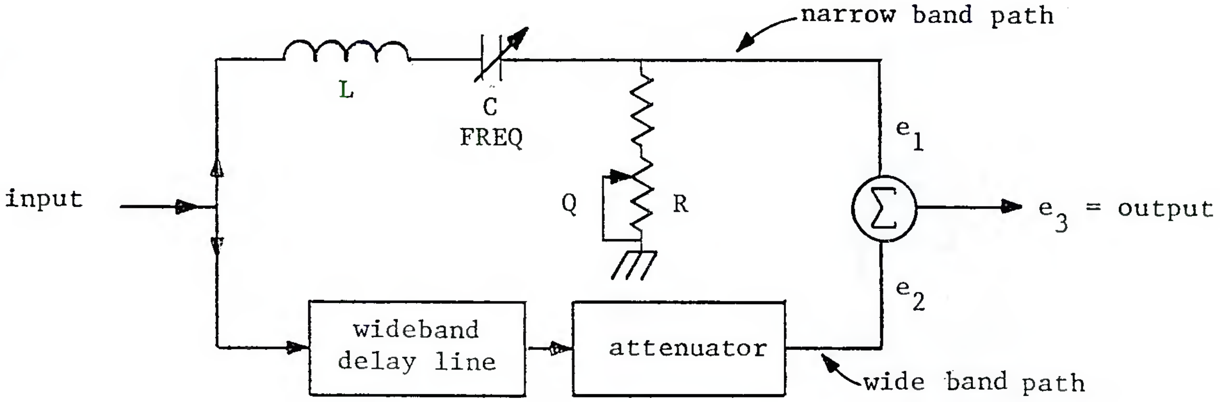


FIGURE 29 - Simplified block diagram of an allpass network.

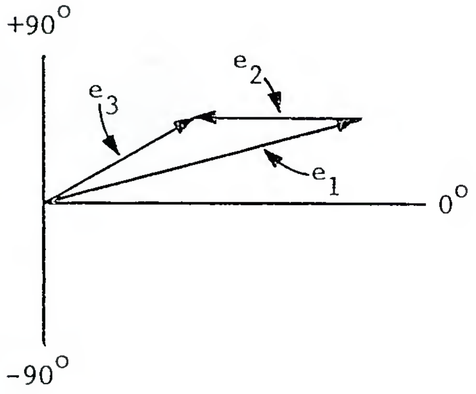


FIGURE 30A - Vectors e_1 and e_2 adding to produce e_3. Vector e_1 is shown slightly below resonance to improve the clarity of the drawing.

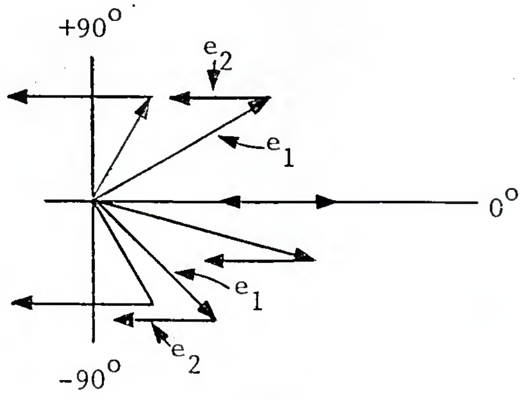


FIGURE 30B - The addition of several phases of e_1 to constant phase and amplitude e_2.

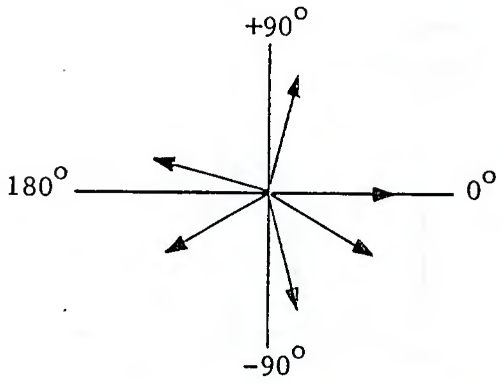


FIGURE 30C – Showing the vectors of e_3 that result from the addition of vectors e_1 and e_2 in FIGURE 30B.

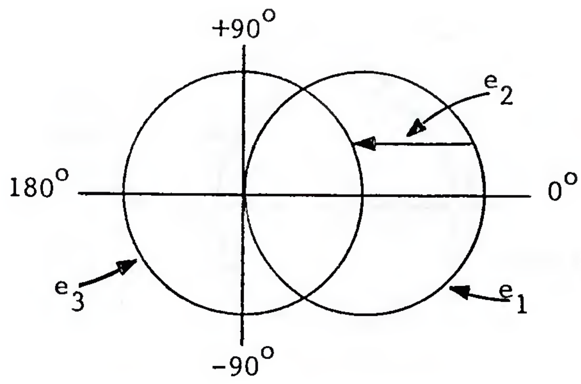


FIGURE 30D – Showing the addition of all possible phases of e_1 to e_2. This produces e_3, a circle concentric about the origin.

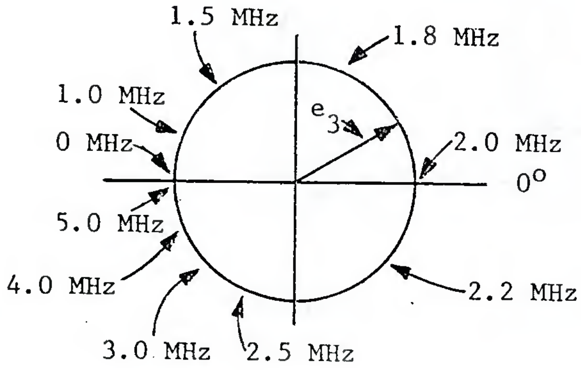


FIGURE 31A – The frequency, phase, and amplitude relationship of the allpass network. F_{res} = 2 MHz and the circuit has a high Q.

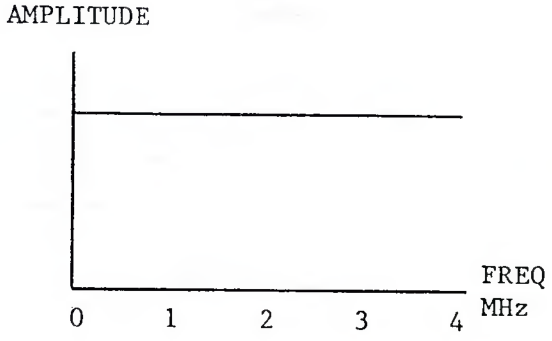


FIGURE 31B – Graph of amplitude versus frequency for FIGURE 31A.

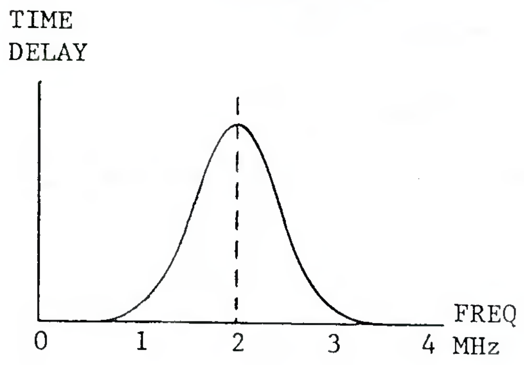


FIGURE 31C – Graph of time delay versus frequency for FIGURE 31A. (high Q and F_{res} = 2.0 MHz)

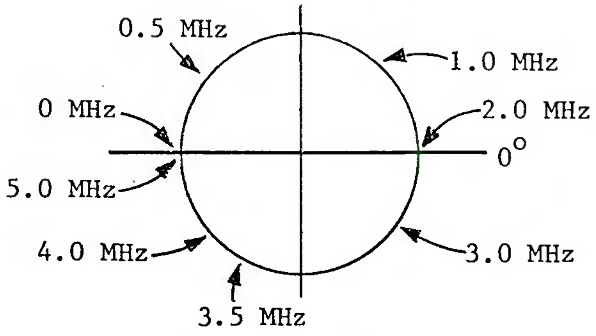


FIGURE 32A - The frequency, phase and amplitude relationship of the allpass network. $F_{res} = 2.0$ MHz and the circuit has a low Q.

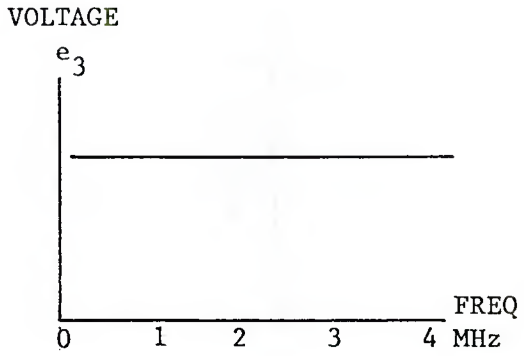


FIGURE 32B - Graph of amplitude versus frequency for FIGURE 32A.

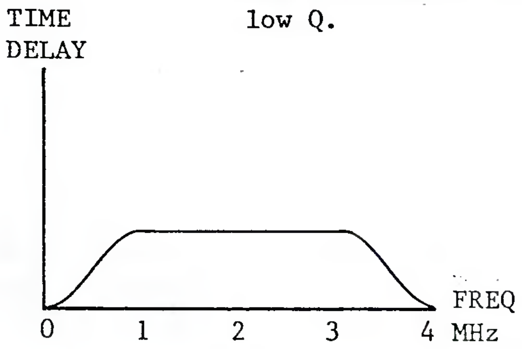


FIGURE 32C - Graph of time delay versus frequency for FIGURE 32A. (Low Q and $F_{res} = 2.0$ MHz)

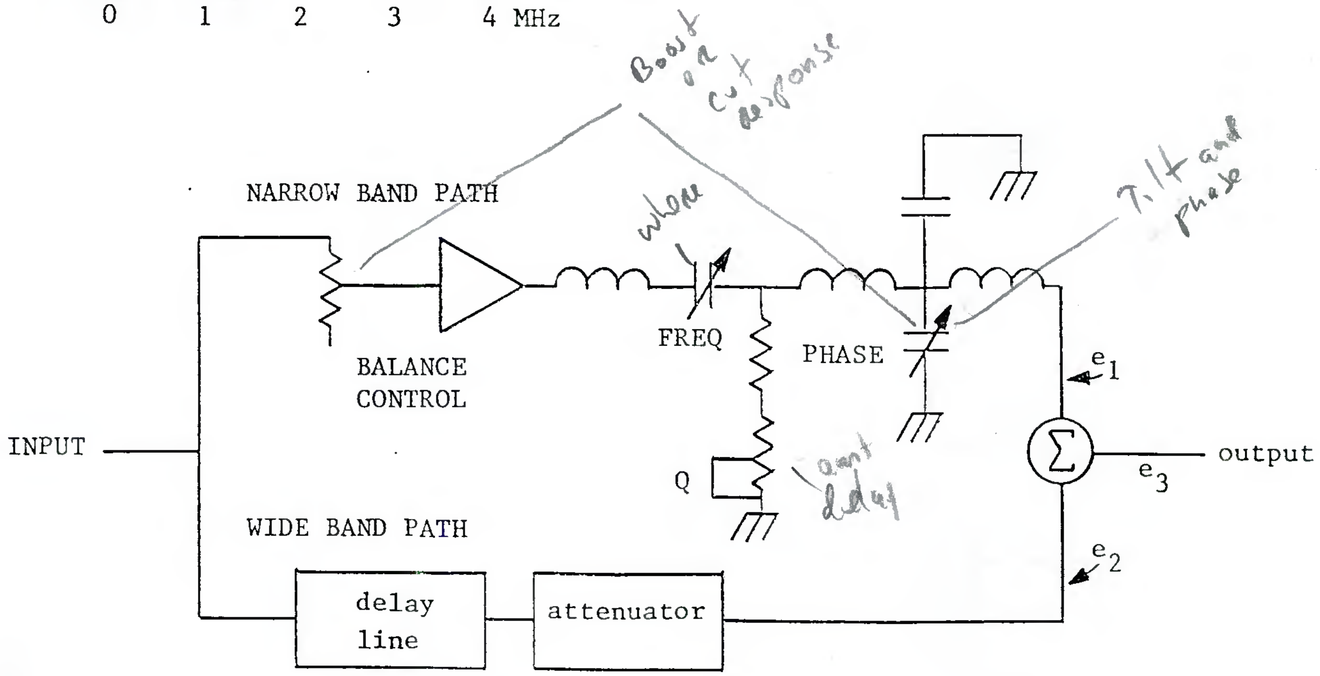


FIGURE 33 - Diagram of an active allpass network showing the addition of a balance and a phase control.

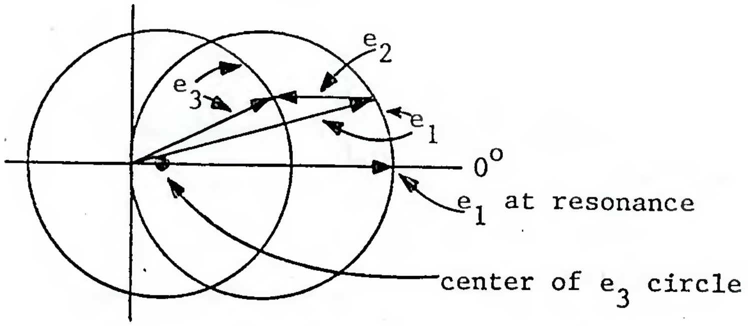


FIGURE 34A - The effect of increasing the balance control. Vector e_1 is larger but vector e_2 remains unchanged. This throws the center of the circle formed by vector e_3 to the right of the origin.

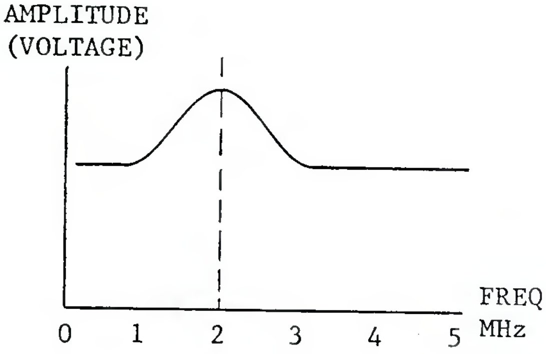


FIGURE 34B - Graph of voltage versus frequency for output vector e_3 in FIGURE 34A.

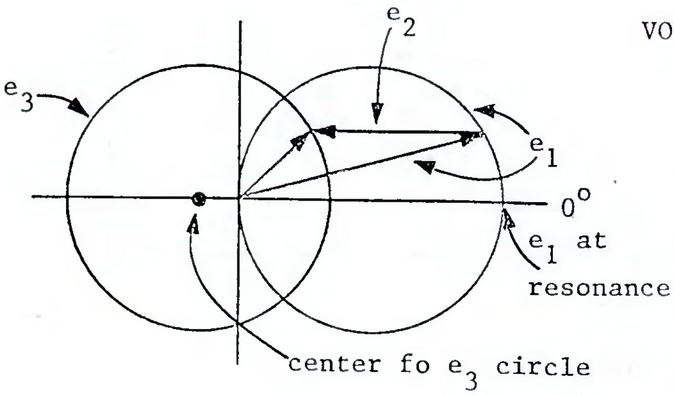


FIGURE 34C - Decreasing the balance control. The center of vector e_3's circle is to the left of the origin.

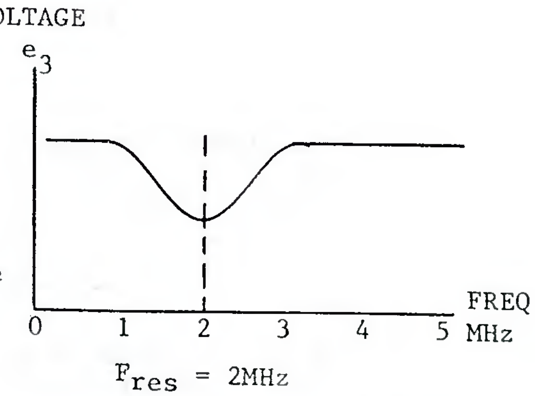


FIGURE 34D - Graph of voltage e_3 (output) versus frequency for FIGURE 34C.

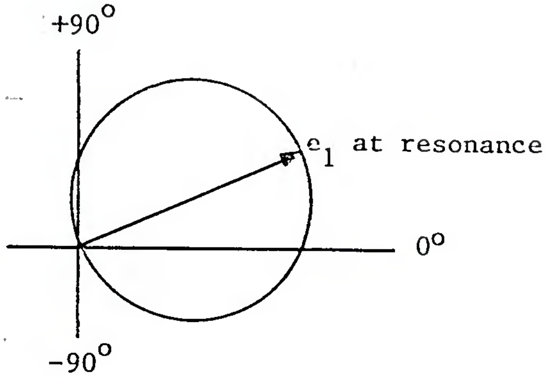


FIGURE 35A - Adjusting the phase control rotates vector e_3's circle upwards. One point still touches the origin.

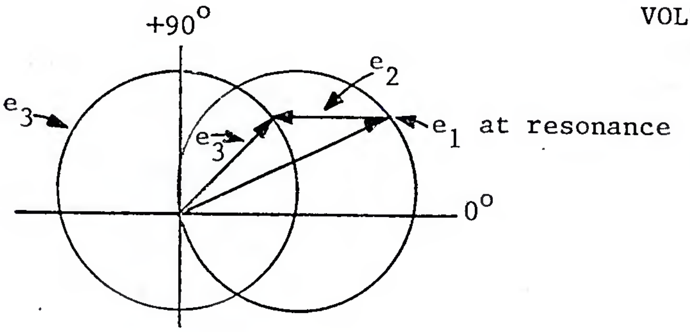


FIGURE 35B - The effect of adjusting the phase in FIGURE 35A is to throw the center of output vector e_3's circle above the origin.

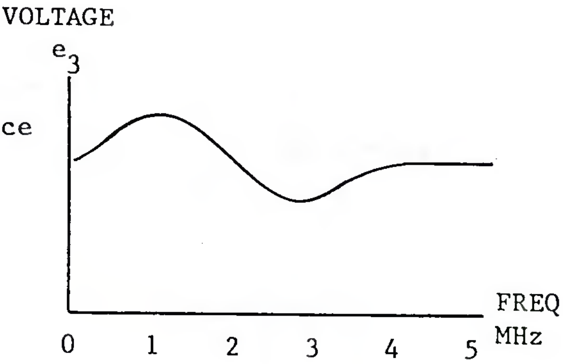
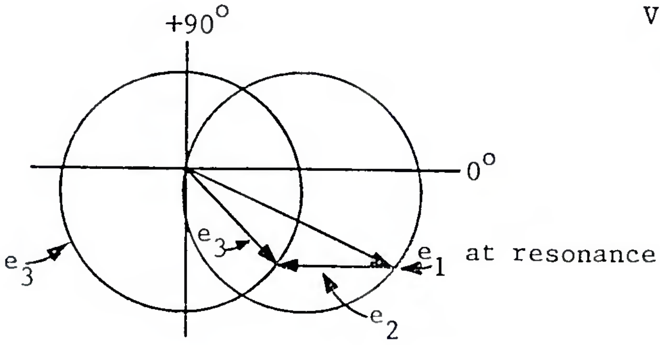


FIGURE 35C - Graph of output vector e_3's versus frequency for FIGURE 35B.



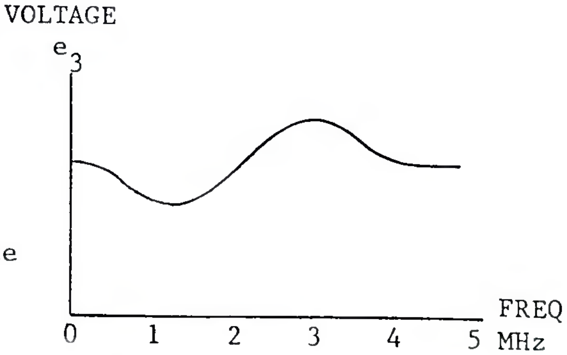


FIGURE 35D - Results of adjusting the phase control in the opposite direction.

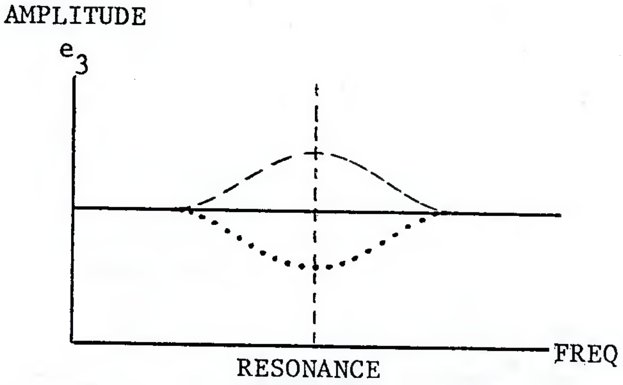


FIGURE 36 - The effect of the balance control on the frequency response of the allpass network.

NORMAL RESPONSE ————————

BALANCE INCREASED - - - - - - - - - -

BALANCE DECREASED ················

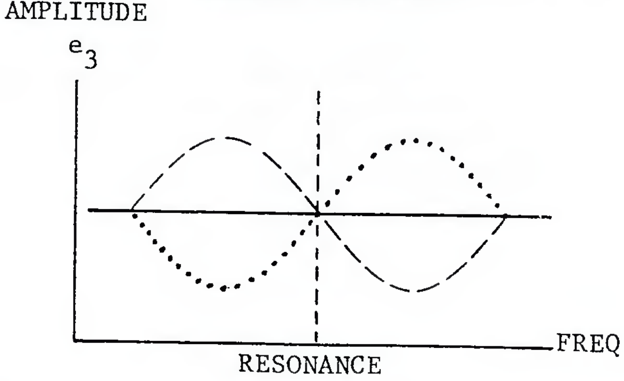


FIGURE 37 - The effect of adjusting the phase control on frequency response.

NORMAL RESPONSE ————————

PHASE SHIFTED POSITIVE - - - - - - - -

PHASE SHIFTED NEGATIVE ············

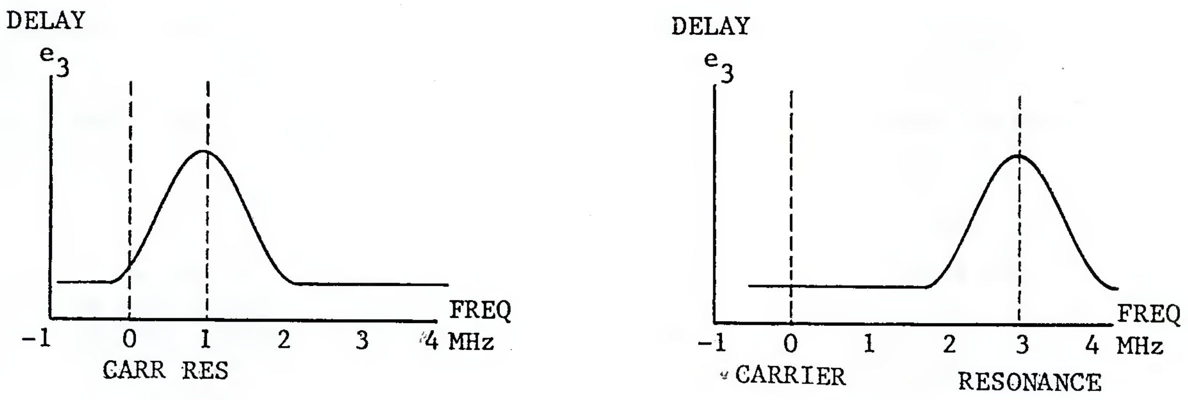


FIGURE 38 - The effect on delay of changing the resonant frequency of the allpass filter's resonant frequency from 1 to 3 MHz.

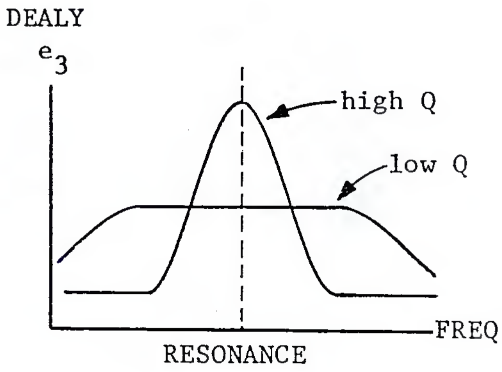


FIGURE 39 - The effect of Q on delay.

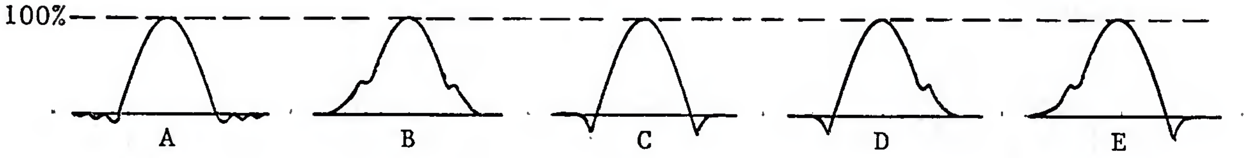


FIGURE 40 - The effects of delay distortions on the 2T pulse. Frequency and Q of the low frequency section will have the greatest effect when correcting 2T pulse delay distortion.

A. Correct shape

B. Undershoots caused by insufficient delay. Adjust the Q for greater overshoots (increase the Q).

C. Excessive overshoots caused by too much delay. Adjust Q for less overshoot (decrease Q).

D & E. The delay is occuring at the wrong frequency (timing error). Position the delay properly by adjusting the frequency control for symmetrical overshoots.

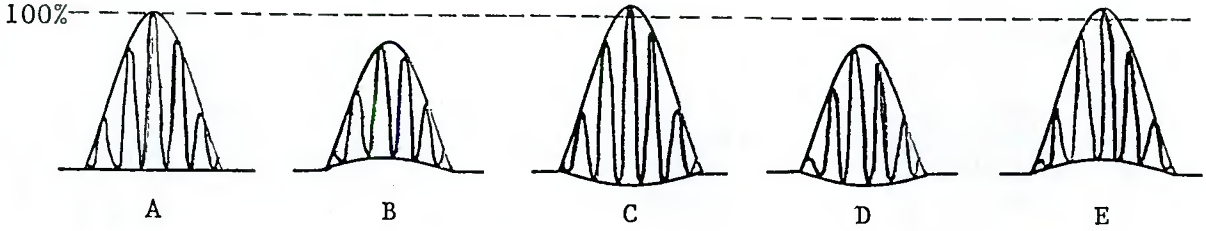


FIGURE 41 - The effects of amplitude response on the modulated 12.5T or 20T sine squared pulses. Amplitude response problems are corrected by adjusting the phase and balance controls for flat swept response.

A. Correct shape

B. Amplitude deficiency at subcarrier

C. Excessive amplitude at subcarrier

D. Amplitude deficiency at carrier

E. Excessive amplitude at carrier

FIGURE 42 - The effects of timing errors (delay in the wrong place) on the modulated 12.5 or 20T sine squared pulse. This is corrected by adjusting the frequency of the high frequency board.

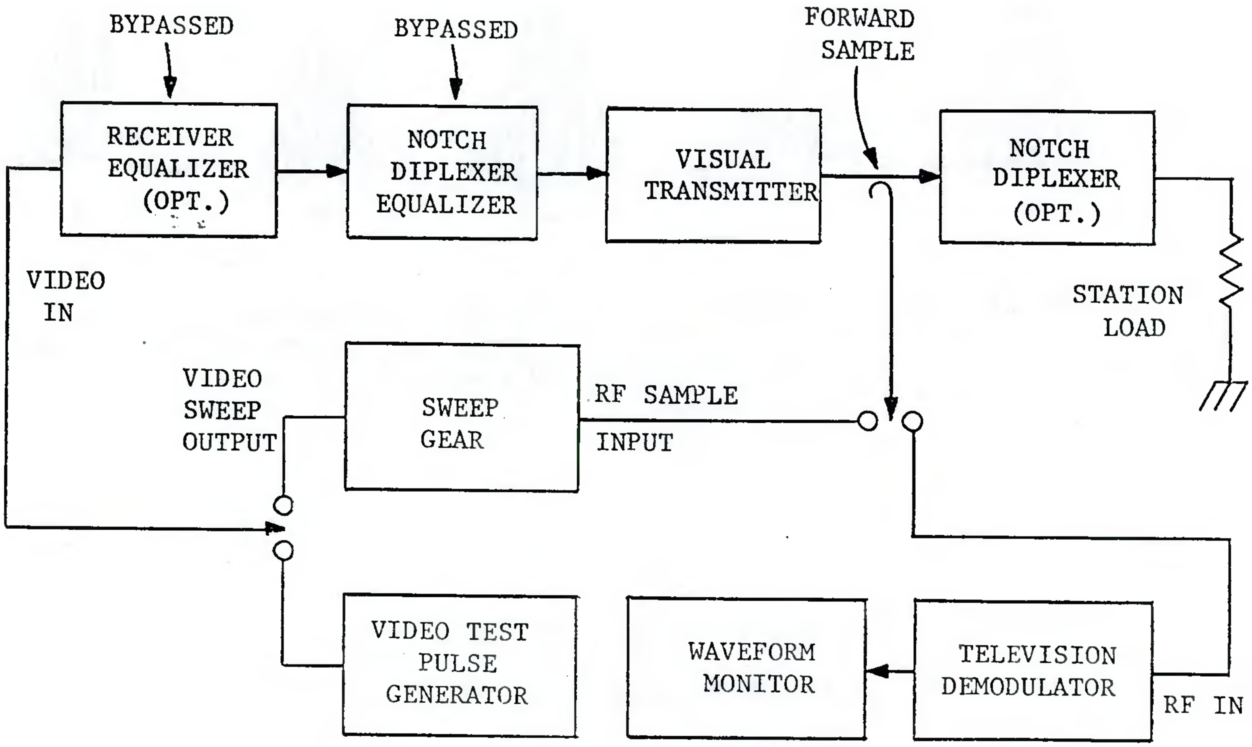


FIGURE 43 - Test setup for adjusting the visual transmitter's group delay (or envelope) delay.

A. If the transmitter has a separate receiver delay equalizer, bypass the receiver equalizer and switch the demodulator sound notch out.

B. If the transmitter has the receiver delay equalizer vestigial sideband filter (no separate receiver equalizer), switch the demodulator sound notch (trap) in.

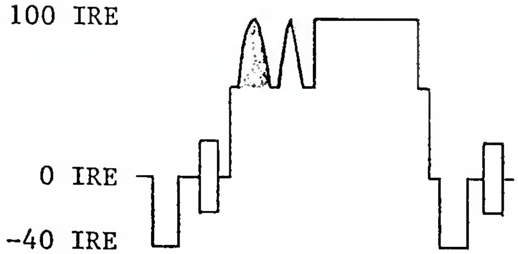


FIGURE 44 - Reduce amplitude sine squared test pulses. Test pulse amplitude is reduced to minimize the quadrature distortion that is caused by using a demodulator with an envelope detector.

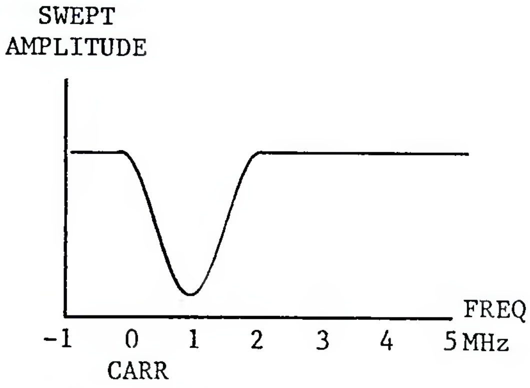


FIGURE 45 - Preliminary adjustment of the left section of the delay equalizer to place the null (resonant frequency) 3/4 to 1 MHz above the carrier.

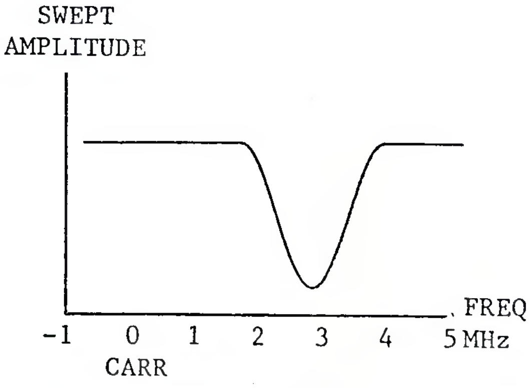


FIGURE 46 - Preliminary adjustment of the right section of the delay equalizer to place the null (resonant frequency) 2.9 to 3.2 MHz above the visual carrier.

THE PASSIVE GROUP DELAY
EQUALIZER

Passive Group Delay Equalizer

INTRODUCTION

The passive video delay equalizer is shown in Figure 1. It provides a flat frequency response and a lumped delay at the resonant frequency of the circuit. The equalizer consists of two resonant circuits: A parallel circuit consisting of L1 and C1, and a series circuit consisting of L2 and C2. Both of the tuned circuits have the same resonant frequency.

CIRCUIT OPERATION

To understand the circuit, Figure 2 is redrawn without the series resonant circuit. The parallel resonant circuit shown in Figure 2 offers maximum impedance at resonance and the output voltage is low. Above and below resonance the parallel resonant circuit impedance decreases and causes the output voltage to increase. See Figure 3A.

Figure 3B shows a graph of output phase compared to input phase as a function of frequency for the circuit of Figure 2. This phase shift can be understood by studying Figures 4, 5 and 6.

In Figure 4, the applied frequency is below the resonant frequency of the circuit. The resonant circuit in Figure 4A is inductive and the output voltage (e-out) lags the input voltage (e-applied). This is shown in the vector diagram of Figure 4B.

At resonance, Figure 5 shows the parallel resonant circuit to be resistive. The output voltage is in phase with the input and is attenuated.

Above resonance, shown in Figure 6, the parallel resonant circuit is capacitive. The output phase leads the input phase as shown by the vector diagram of Figure 6B.

In Figure 3C, the graph shows that a time delay is achieved at resonance that is greater than that for other frequencies. This delay is proportional to the change of phase divided by the corresponding change of frequency.

The formula for time delay is:

$$\text{Time delay} = \frac{\text{change in phase}}{360 \times \text{change in frequency}}.$$

The amount of delay and its bandpass depends upon the Q of the resonant circuit L1 - C1 in Figure 1.

From the above discussion it is apparent that the circuit described gives a controlled amount and bandwidth of delay but it has an undesirable amplitude response problem. That is, it is not constant with frequency.

PROVIDING A FLAT AMPLITUDE RESPONSE AT THE RESONANT FREQUENCY

At the resonant frequency, L1 - C1 of Figure 1 provides a large opposition to the flow of current. This produces a voltage null in the output response. This problem is corrected by the series resonant circuit L2 - C2 of Figure 1. At the resonance this circuit (L2 - C2) offers a low impedance to ground and effectively center taps the parallel resonant circuit (L1 - C1), in Figure 7. Under these conditions the voltage developed across the resonant circuit (V total) is split into two equal parts (V-in and V-out). These two voltages are 180 degrees out of phase. V-in is equal to the input voltage and V-out, the output voltage, therefore, is the same amplitude but 180 degrees out of phase. See Figure 10A.

OPERATION BELOW THE RESONANT FREQUENCY

When operated far below the resonant frequency, L1 of the parallel resonant circuit is effectively a short circuit and offers little or no phase shift or attenuation to the output signal. See Figure 10. At the same time, C2, of the series resonant circuit cffers maximum reactance and has little or no effect on the circuit.

When operating slightly below resonance the vector sum of the voltages developed by the parallel resonant circuit and the series resonant circuit produces an output voltage equal to the input voltage.

The major influence of the parallel resonant circuit (series inductance of lower Z) and the minor influence of the series resonant circuit (shunt capacitor of higher Z) causes the phase of the output voltage to lag the phase of the input voltage by a value between 0 and 180 degrees depending upon the exact frequency.

OPERATION ABOVE THE RESONANT FREQUENCY

When operating far above the resonant frequency, C1 of the parallel resonant circuit is effectively a short circuit and offers little or no phase shift or attenuation to the output signal. (See Figure 10.) At the same time, L2 of the series resonant circuit has maximum reactance and has little or no effect on the circuit.

When operated slightly above resonance, the vector sum of the voltages developed by the parallel resonant circuit and the series resonant circuit produce and output voltage equal to the input voltage. The major influence of the parallel resonant circuit (series capacitance of low Z) and the minor influence of the series resonant circuit (shunt inductance of high Z) causes the phase shift of the output voltage to lead the phase shift of the input voltage by a value between 0 and 180 degrees depending upon the exact frequency.

If a polar graph of the output voltage versus the input voltage were to be drawn, it would be apparent that the output voltage is phase shifted 360 degrees while the frequency is being swept. The amplitude of the output voltage is constant at all times. This causes the graph to be a circle about the origin. See Figure 10. If the circuit has a high Q, the vector travels around the circle quite rapidly (high change of phase/change of frequency), causing a large amount of delay over a narrow frequency range of resonance. See Figure 11. If the equalizer has a low Q, the vector travels the circle more slowly causing a smaller amount of delay over a wider frequency.

SUMMARY

1. Where the delay takes place is controlled by the resonant frequency of the parallel resonant circuit, L1 - C1.

2. How much delay over what bandwidth is determined by the Q of the parallel resonant circuit, L1 - C1.

   Since the resistance of the coil is fixed and its inductance can be varied, the Q becomes dependant on the ratio of L1/C1.

3. The flatness of the response depends on the Q of the series resonant circuit L2 - C2.

   Again in the series resonant the Q is determined by the ratio of L2/C2.

4. The equalizer circuit of Figure 12 will operate the same as the circuit in Figure 1. The only difference is that the capacitors are center tapped instead of the inductor.

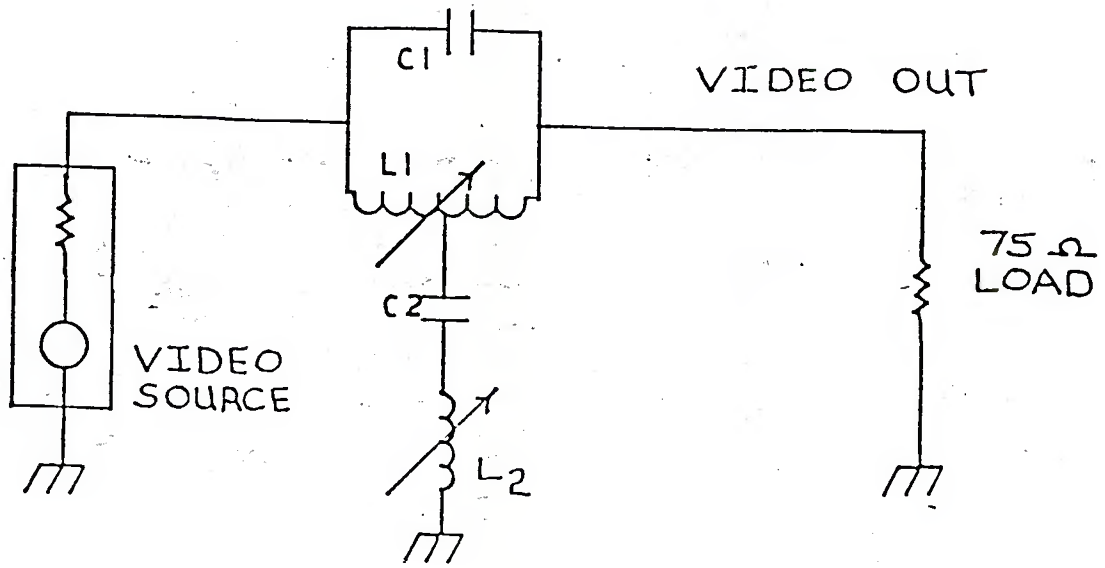


FIG.1 PASSIVE VIDEO DELAY EQUALIZER

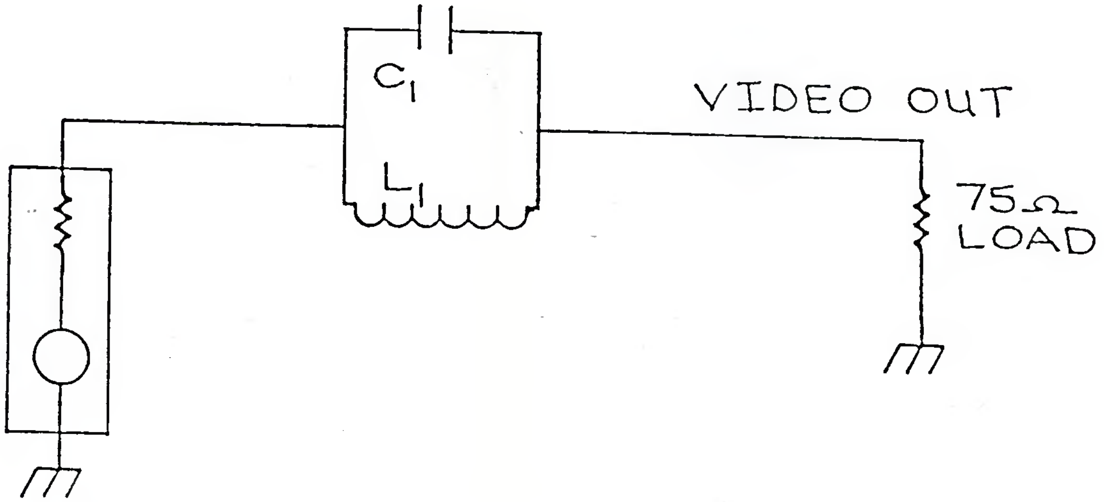


FIG. 2 EXPLAINATORY VERSION OF THE PASSIVE VIDEO DELAY EQUALIZER

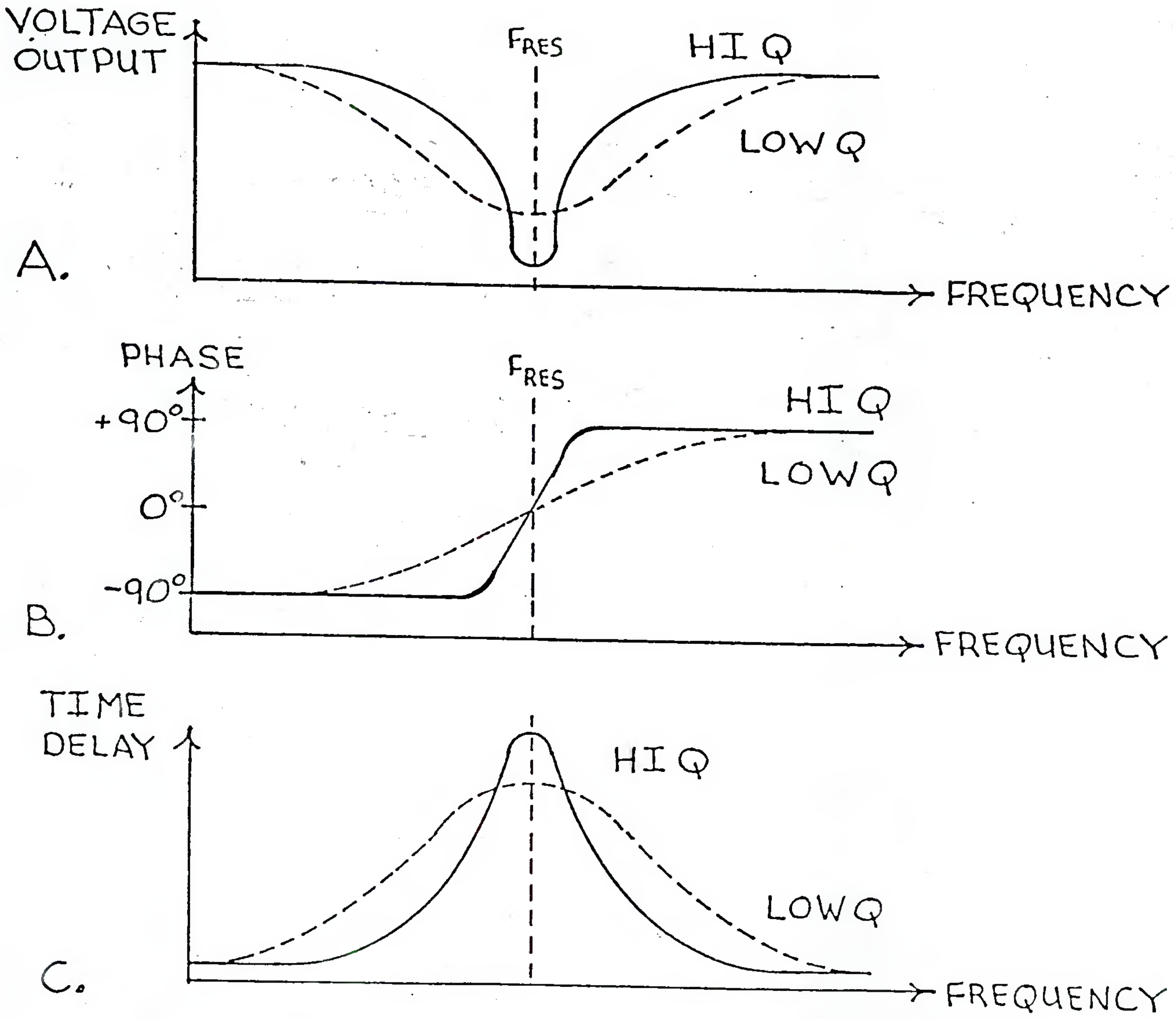


FIG. 3 GRAPHS OF OUTPUT VOLTAGE, PHASE, AND DELAY

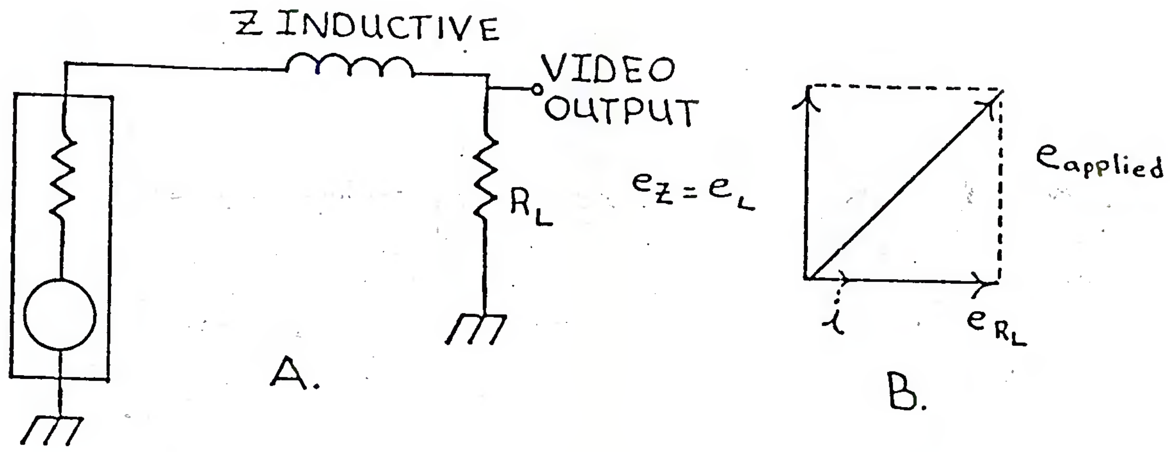


FIG.-4 THE CIRCUIT OF FIG 2 OPERATED BELOW RESONANCE

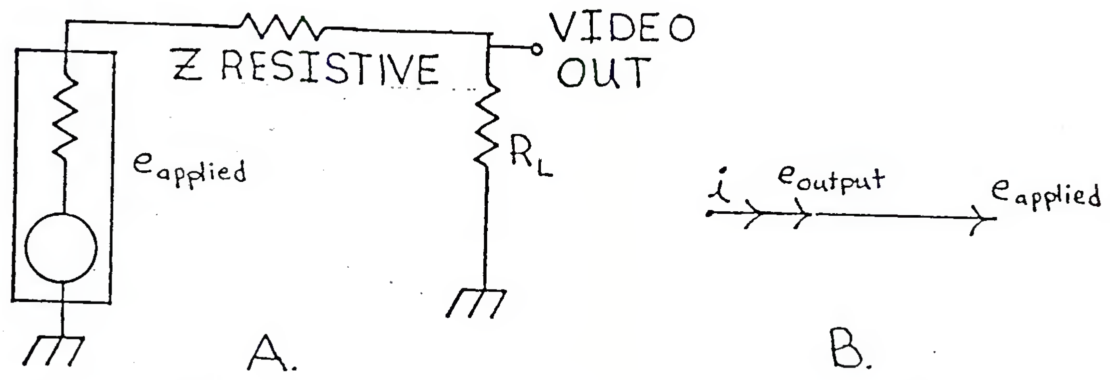


FIG-5 THE CIRCUIT OF FIG 2 OPERATED AT RESONANCE

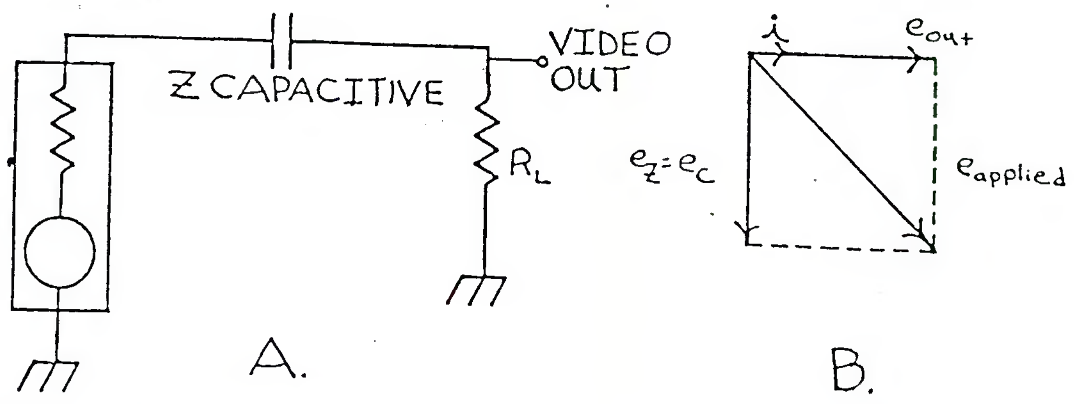


FIG-6 THE CIRCUIT OF FIG 2 OPERATED ABOVE RESONANCE

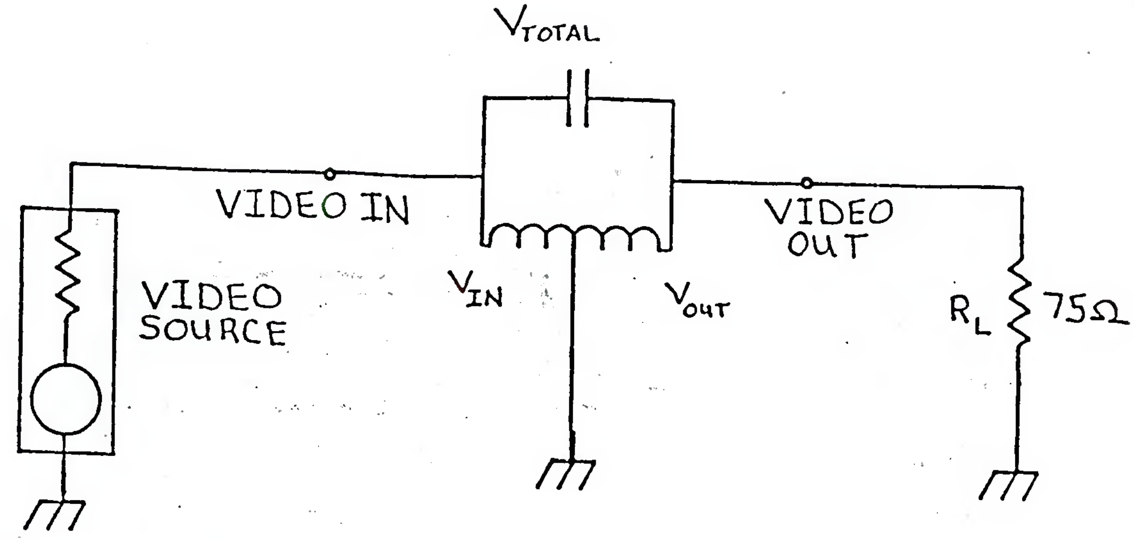


FIG-7 EQUIVALENT CIRCUIT OF THE DELAY EQUALIZER NETWORK, FIG1, SHOWING THE SERIES RESONANT CIRCUIT AT RESONANCE

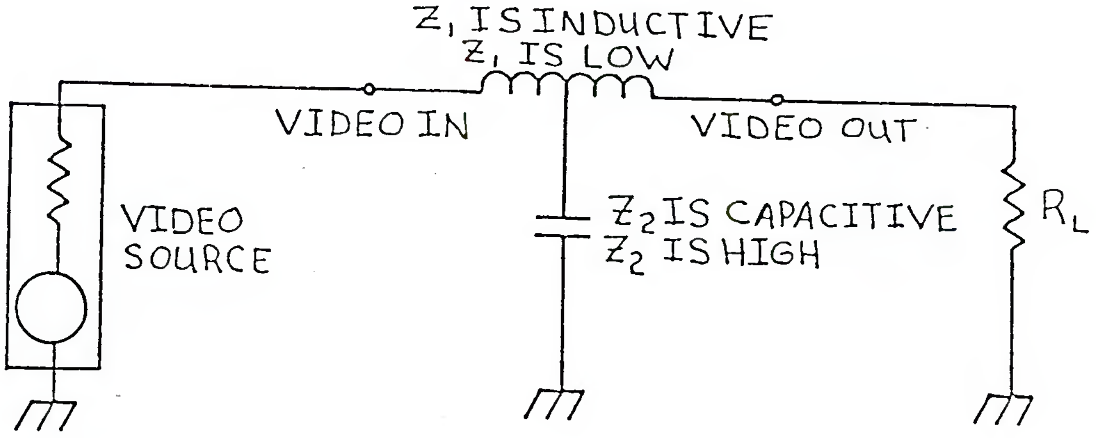


FIG-8 EQUIVALENT CIRCUIT OF THE DELAY EQUALIZER NETWORK, FIG1, OPERATING BELOW RESONANCE

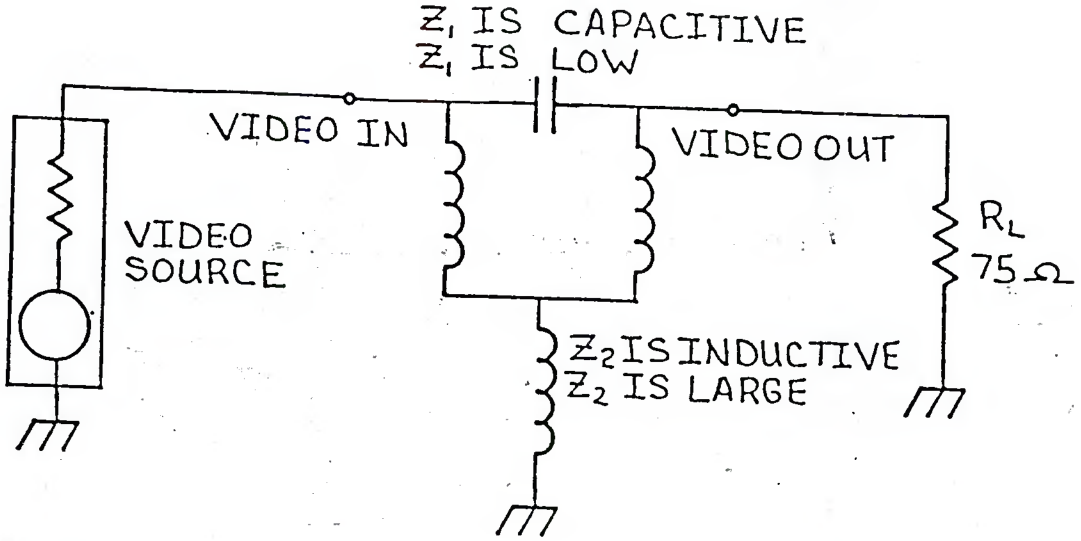


FIG-9 EQUIVALENT CIRCUIT OF THE DELAY EQUALIZER NETWORK, FIG 1, OPERATING ABOVE RESONANCE

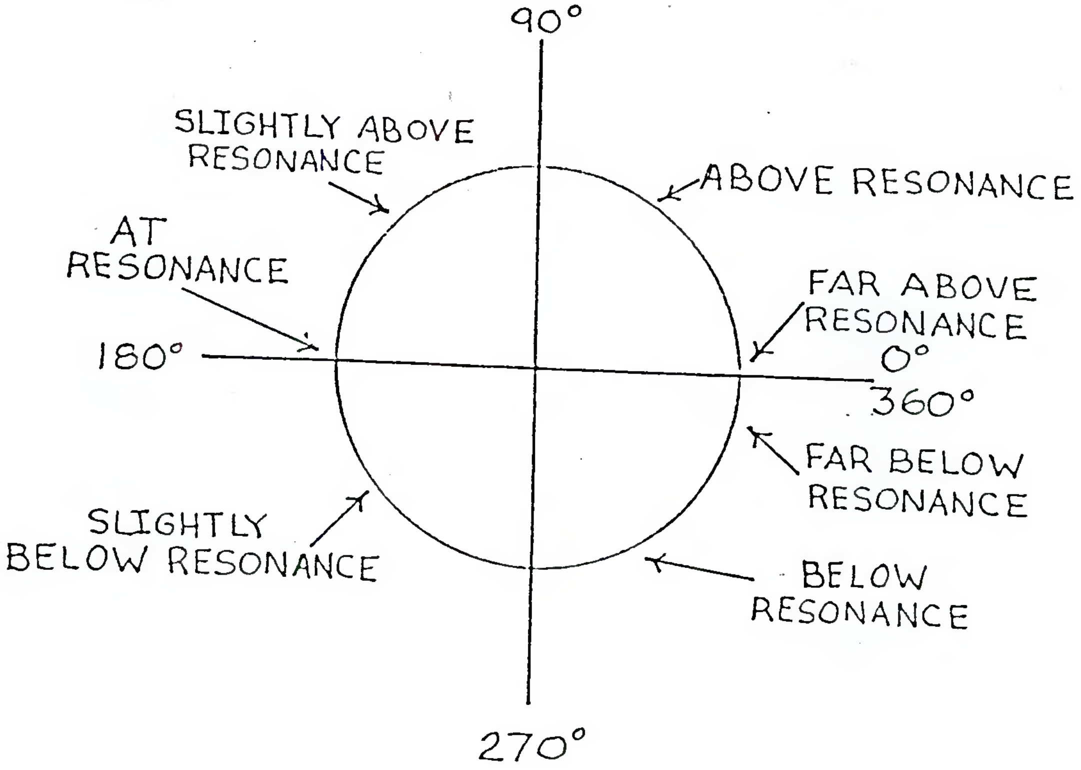


FIG-10 A POLAR GRAPH OF THE OUTPUT OF THE EQUALIZER OF FIG 1

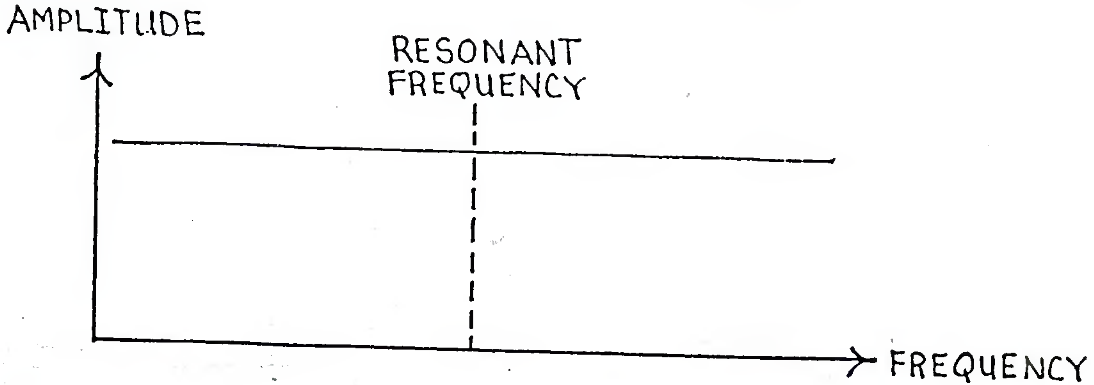


FIG-11A GRAPH OF OUTPUT VERSES FREQUENCY

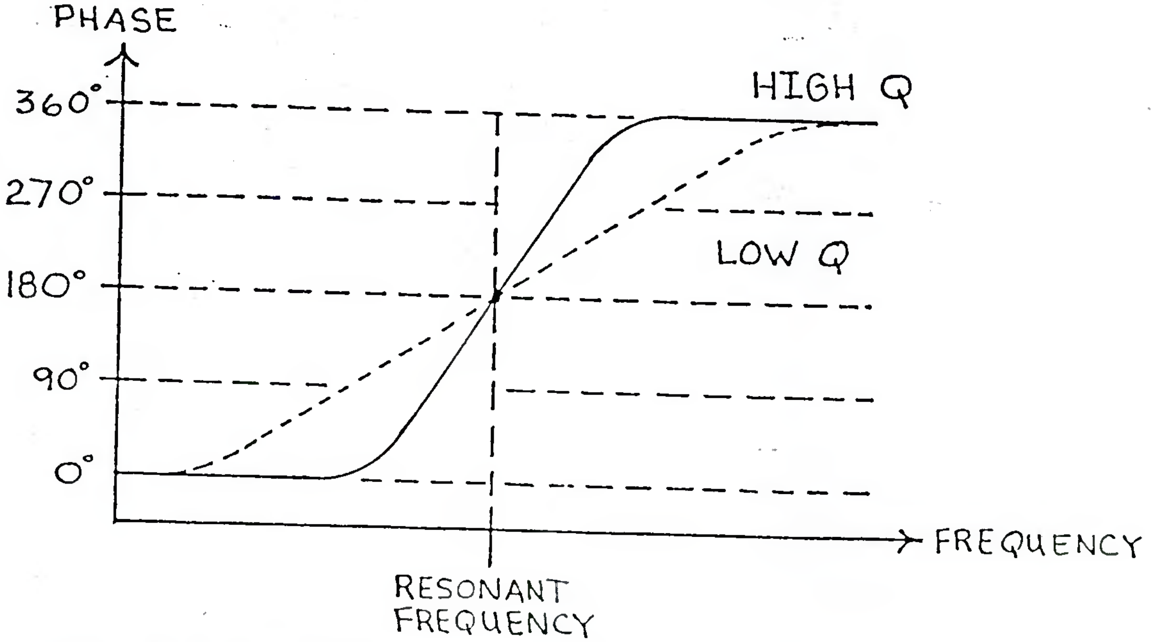


FIG-11B GRAPH OF OUTPUT PHASE VERSES FREQUENCY

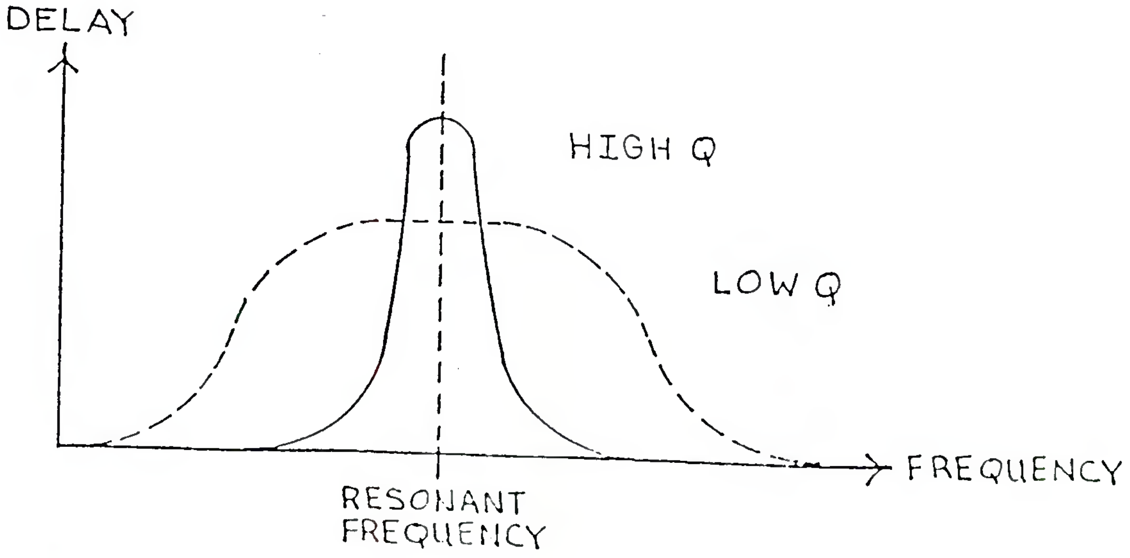


FIG-11C GRAPH OF DELAY VERSES FREQUENCY