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## (54) IMPROVEMENTS IN OR RELATING TO AN EQUALIZER FOR THE DIFFERENTIAL GAIN OF AN FM DIRECTIONAL RADIO SYSTEM

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company of Berlin and Munich, German Federal Republic, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to an equalizer circuit for setting the differential gain of an FM directional radio system, in which there is superimposed upon the main signal a time-delayed, reduced level portion of that signal. The differential gain is defined as the change in level of a measurement signal at the output of an FM-demodulator stage relative to the IF frequency of a carrier that is frequency modulated with this measurement signal.

Attenuation distortions and delay distortions, considered alone or in combination with AM-PM conversion, can lead to distortions in the differential gain without this being visible in the attenuation or delay curves, since one or more non-linear four-terminal networks are present in the signal path, e.g. an IF-limiter stage or a travelling-wave amplifier for example. Consequently smoothing the attenuation and delay distortions on the receiving side is not an effective operation to ensure adequately low intermodulation noise, and an additional equalizer circuit is needed, which permits at least some equalisation of gradients in the differential gain curves.

The production of a variable differential gain gradient by introducing a parabolic delay distortion and inserting a non-linear element with adjustable AM-PM conversion is described in an article entitled "IF Variable Equalizers for FM Microwave Radio Links" by Shiki, Koyama and Kurokawa, published in "IEEE Transactions on Communications" Vol. Com-22, No. 7, July 1974. However, this has the disadvantage that the rotation only takes place in one direction and that it is a relatively costly solution.

One object of the invention is to provide an equalizer circuit which enables gradients in the differential gain curves to be equalised in a simple way.

The invention consists in an equalizer circuit for correcting the differential gain of an FM directional radio system, in which circuit means are provided to superimpose a delayed and reduced signal upon a main signal, said circuit comprising a cable that is inserted in series in the signal patch and mis-matched at its terminations, and being of such a length that the attenuation distortions and differential gain distortions occurring at the cable output substantially correspond to a sine function having its zero point in the middle of the operating band of said system.

Thus, in a circuit constructed in accordance with the invention there is superimposed upon the main signal a signal that is delayed by twice the cable transit time and reduced by the product of the reflection factors. By varying the reflection factor at one end of the cable, both the magnitude and the polarity of the sine ripple content can be changed.

Advantageously the cable may utilise an appropriately elongated form of a connecting cable already required between two units in the directional radio system, thus simplifying the circuit composition substantially.

Preferably a resistance network consisting of a potentiometer in a series arm and resistance connected to the potentiometer slider in a shunt arm is connected before the cable. This has the effect that the reflection factor is changed considerably by modification of a single balancing element but the attenuation in the middle of the band remains practically constant.

Any stray inductance of the potentiometer, or transverse resistance can be compensated for by connecting a variable condenser in parallel with the resistance network at its output end.

The invention will now be described with reference to the drawings, in which:-

Figure 1 is a theorectical circuit diagram of one exemplary embodiment of an equalizer circuit with a cable in the signal path;

Figure 2 is a schematic illustration of an exemplary embodiment showing the equalizer circuit with its cable and feeding network in the signal path; and

Figure 3 is a graphic illustration of the variation in the differential gain produced by changing the potentiometer setting in the embodiments shown in Figure 2.

In the theoretical circuit diagram in Figure 1, a source generator G supplies the circuit with a waveform having a voltage Uo, a resistance R1 is provided in series with the signal path to a cable K having input terminals 1 and 2, output terminals 3 and 4, an electrical length $l_E$ and a characteristic impedance Zo, and with a load resistance R2 connected between the output terminals 3 and 4. By means of this cable, which is mis-matched at both terminations, a delayed correction signal is produced which is superimposed over the main signal, this correction signal having an amplitude that is reduced relative to the latter. This causes attenuation distortions, delay distortions and distortions in the differential gain. The distortions in the differential gain can be changed by adjusting the amplitude of the delayed signal.

The way the circuit works will now be explained in detail. The generator G with the output voltage Uo connected to the input of a cable K having a characteristic impedance Zo via a resistance R1 produces a waveform at the cable input having the voltage:-

$$U_{G1} = U_O (1 + r_1)/2 \;\ldots\ldots\; (1)$$

when $r_1$ is the reflection factor seen from the cable, and has a value:-

$$r_1 = (1 - m_1)/(1 + m_1);$$

with $m_1$ = R1/Zo.

Assuming the cable to be free of any significant loss, the wave voltage $U_{G2}$ at the cable output is given by the expression:-

$$U_{G2} = U_{G1} \cdot e^{-j\tau_O\omega}; \ldots (2)$$

where $\tau_0 = l_{E}/c_O$;

and where $c_o$ is the speed of light. The wave is partially absorbed and partially reflected at the resistance R2. The absorbed wave voltage $U_{2G}$ can be defined as:-

$$U_{2G} = U_{G2} + U_{R2} = U_{G2} (1 - r_2) \;\ldots (3)$$

where $r_2 = (1 - m_2)/(1 + m_2)$

and $m_2 = R_2/Z_O$.

The reflected wave $U_{R2} = r_2 \cdot U_{G2}$ returns the cable input and is reflected there a second time. At the cable output it then has the voltage $U_{RR2}$, given by the expression:-

$$U_{RR2} = r_1 \cdot r_2 \cdot U_{G2} \cdot e^{-j2\tau_O\omega}. \;\ldots (4)$$

The reflected wave $U_{2RR}$ absorbed in resistance R2 can then be defined by the expression:-

$$U_{2RR} = U_{RR2} (1 - r_2). \;\ldots (5)$$

Disregarding any further reflections, the voltage $U_2$ at resistance R2 is then given by the expression:-

$$U_2 = U_{2G} + U_{2RR}. \;\ldots (6)$$

If the values obtained from equations (3) and (5) for $U_{2G}$ and $U_{2RR}$ are inserted in equation (6), we obtain:-

$$U_2 = U_{G2} (1 - r_2) + U_{RR2} (1 - r_2) \;\ldots (7)$$

and from this we can obtain the expression:-

$$U_2/U_{O/2} = (1 + r_1)(1 - r_2)(1 + r_1 r_2 e^{-j2\tau_O\omega}) e^{-j2\tau_O\omega}. \;\ldots (8)$$

Thus, superimposed over the main signal, the cable gives a signal which is delayed by twice the cable transit time and is reduced by the product of the reflection factors. For $r_1 \cdot r_2 << 1$ the absolute amount can be fairly approximated as:-

$$\left| \frac{U_2}{U_0/2} \right| = (1+r_1)(1-r_2)(1+r_1 r_2 \cos 2\tau_0\omega) \qquad (9)$$

For this the cable length is so chosen that the attenuation distortions occurring at the cable exit may be regarded as substantially corresponding to a sine function, the zero point of which lies in the middle of the band and the period of which is such that the frequency band to be equalised falls in the straightest part of the sine function. This means that the cable length $l_E$ is chosen so that:-

$$2\tau_0\omega_0 = (2n - 1) \cdot \frac{\pi}{2}$$

where:-

$$\tau_0 = \frac{l_E}{c_0};$$

$$\omega_0 = 2\pi f_0;$$

$f_0$ is the mid-band frequency; and
$n$ is a positive whole number.

Then the absolute amount becomes:-

$$\left| \frac{U_2}{U_0/2} \right| = (1+r_1)(1-r_2)\left[1+(-1)^n r_1 r_2 \sin 2\tau_0 \Delta\omega\right] \quad (10)$$

in which $\Delta\omega$ was set equal to $\omega - \omega_0$.

The differential gain DG, which is defined as the change in phase deviation $\delta\eta$ relative to the phase deviation $\eta$, may be expressed as

$$DG = \delta\eta/\eta = -(-1)^n r_1 r_2 (1-\cos 2\tau_0\omega_s) \sin 2\tau_0\Delta\omega \quad (11)$$

where $\omega_s = 2\pi f_s$ and $f_s$ is the measurement frequency for the DG measurement. Thus at the same time the differential gain has a sine ripple content. By varying the reflection factor at one end of the cable both the magnitude and the polarity of the sine ripple content can be changed.

Figure 2 shows an advantageous embodiment constructed in accordance with the invention, in which it is possible to change the reflection factor considerably through modification of a single balancing element, whilst maintaining the attenuation in the middle of the band practically constant, using a resistance network connected before the cable K. This network consists of a potentiometer R3 in a series arm and a resistance R5 connected to the potentiometer slider in a shunt arm. The feed circuit, comprising the generator G of internal resistance Zo and this resistance network has a variable source impedance $R_Q$ defined by the expression:-

$$R_Q = R3 - R4 + \frac{R5(R4+Zo)}{R5+R4+Zo}$$

and the circuit exhibits a substantial constant output level if R3 and R5 are chosen appropriately, i.e. so that at the potentiometer end settings the reflection factors are substantially inversely equal, i.e. $r_{11} = -r_{12}$. Thus for the voltage standing wave ratios we obtain the expression:-

$$m_{11} = 1/m_{12};$$

$m_{11}$ being equal to $R_{Q1}/Zo$;
$m_{12}$ being equal to $R_{Q2}/Zo$; and
$R_{Q1}$ and $R_{Q2}$ being the source impedance values at the potentiometer end settings. The feed circuit in this embodiment constructed in accordance with the invention offers a large change in the reflection factor with a relatively small change in attenuation, that may be disregarded during operation. However, the maximum possible gradient for the differential gain curve also depends upon the magnitude of the product of the reflection factors $r_1 r_2$. A trimmer capacitor C connected in parallel with the resistance network at its output side serves to equalise any stray inductance of the potentiometer R3 and the transverse resistance R5. It also makes it possible to set the source resistance $R_Q$ exactly to the characteristic impedance Zo and permits correct setting of the partial series resistance R4 of the potentiometer R3 lying before the tapping point.

Fig. 3 shows the differential gain $\delta\eta/\eta$ as a function of $\Delta f$ for various values of the partial resistance R4 of the potentiometer R3, and thus for various values of the reflection factor $r_1$. It can be seen from the group of curves that the ripple content is highest at the minimum and maximum values of the partial resistance R4 (in the circuit under consideration the partial resistance is variable between 0 and 47 cms), i.e. at the two end settings of potentiometer R3.

WHAT WE CLAIM IS:

1. An equalizer circuit for correcting the differential gain of an FM directional radio system, in which circuit means are provided to superimpose a delayed and reduced signal upon a main signal, said circuit comprising a cable that is inserted in series in the signal path and mis-matched at its terminations, and being of such a length that the attenuation distortions and differential gain distortions occurring at the cable output substantially correspond to a sine function having its zero point in the middle of the operating band of said system.

2. An equalizer circuit as claimed in Claim 1, in which said cable is an elongated connecting cable between two units of said directional radio system.

3. An equalizer circuit as claimed in Claim 1 or Claim 2 in which a resistance network is connected before the cable, this network consisting of a potentiometer in a series arm and a resistance connected to the potentiometer slider in a shunt arm.

4. An equalizer circuit as claimed in Claim 3, in which a variable capacitor is connected in parallel with the resistance network at its output.

5. An equalizer circuit substantially as described with reference to Figures 1 and 2.

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Fig. 1

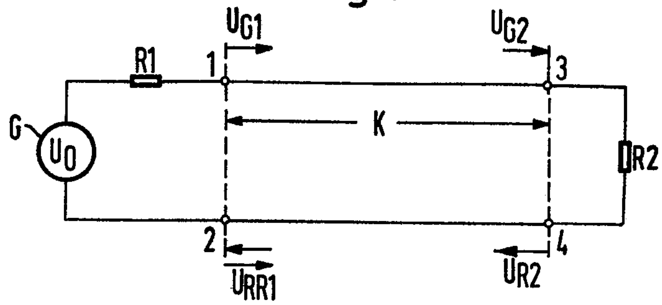


Fig.2

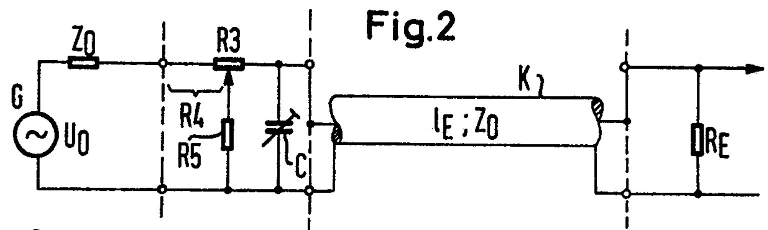


Fig.3