We hereby apply for the grant of a Patent for an invention entitled

"AN EQUALIZER FOR THE DIFFERENTIAL GAIN OF AN FM DIRECTIONAL RADIO SYSTEM"

which is described in the accompanying complete specification.

This application is a Convention Application and is based on the application numbered P 26 06 368.5 for a patent or similar protection made in Germany on 1st March, 1976.

My address for service is:

Care: SPRUSON & FERGUSON PATENT ATTORNEYS
ESSO HOUSE, 127 KENT STREET
SYDNEY, NEW SOUTH WALES
AUSTRALIA.

Dated this Twenty-first day of January, 1977

Signature of Applicant

To:
The Commissioner of Patents
Declaration in Support of a Convention Application for a Patent or Patent of Addition

In support of the Convention Application made for a patent for an invention entitled 22768/77 "AN EQUALIZER FOR THE DIFFERENTIAL GAIN OF AN FM DIRECTIONAL RADIO SYSTEM"

Full name and address of Declarant.

I, Kurt Schellhorn, (Procurist)
of Munich 90, Werinherstraße 49, Germany

do solemnly and sincerely declare as follows:

1. I am the applicant for the patent of addition
   (or, in the case of an application by a body corporate)

   I am authorized by SIEMENS AKTIENGESELLSCHAFT
   the applicant for the patent of addition to make this declaration on its behalf.

2. The basic application as defined by Section 141 of the Act was made in Germany on the 1st day of March, 1976 by SIEMENS AKTIENGESELLSCHAFT

3. I am the actual inventor of the invention referred to in the basic application
   (or where a person other than the inventor is the applicant)

   WOLFGANG ULMER
   of Grünstrasse 9, München 70, Germany

is the actual inventor of the invention and the last-mentioned upon which the applicant is entitled to make the application are as follows:

The said applicant is the assignee of the actual inventor.

4. The basic application referred to in paragraph 2 of this Declaration was the first application made in a Convention country in respect of the invention the subject of the application.

Declared at Munich this 20th day of January, 1977

Signature of Declarant

To:
The Commissioner of Patents,

SPRUSON & FERGUSON, SYDNEY.
Claim 1. An equalizer circuit arrangement for correcting the differential gain of an FM directional radio system, said circuit arrangement comprising said system and means to superimpose a delayed and attenuated signal upon a main signal, said means comprising a length of cable that is inserted in the signal path of said system carrying the main signal and mismatched at its input and output, said length being selected for the operating band of the system such that the attenuation distortions and differential gain distortions of the main signal 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, whereby a frequency band to be equalised lies in the most linear region of the sine function.
Complete Specification

(Original)

For Office Use

Application Number:
Lodged:

Complete Specification Lodged:
Accepted:
Published:
Priority:

Related Art:

Name of Applicant: SIEMENS AKTIENGESELLSCHAFT

Address of Applicant: Wittelsbacherplatz 2, D-8000 München 2, Germany

Actual Inventor: WOLFGANG ULMER


Complete Specification for the invention entitled:

"AN EQUALIZER FOR THE DIFFERENTIAL GAIN OF AN FM DIRECTIONAL RADIO SYSTEM"

The following statement is a full description of this invention, including the best method of performing it known to me/us:
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 "IP Variable Equalizers for PM 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.

According to the present invention, there is disclosed an equalizer circuit arrangement for correcting the differential gain of an FM directional radio system, said circuit arrangement comprising said system and means to superimpose a delayed and attenuated signal upon a main signal, said means comprising a length of cable that is inserted in the signal path of said system carrying the main signal and mis-matched at its input and output, said length being selected for the operating band of the system such that the attenuation distortions and differential gain distortions of the main signal 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, whereby a frequency band to be equalised lies in the most linear region of the sine function.

Thus, in a circuit constructed in accordance with the preferred embodiment of 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.
A greatly 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 theoretical 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 $U_0$, a resistance $R_1$ 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 $\frac{1}{2}E$ and a characteristic impedance $Z_0$, and with a load resistance $R_2$ 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 $U_0$ connected to the input of a cable $K$ having a characteristic impedance $Z_0$ via a resistance $R_1$ produces a waveform at the cable input having the voltage:

$$U_{G1} = U_0 \frac{1 + r_1}{2} ...(1)$$

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

$$r_1 = \frac{(1 - m_1)}{(1 + m_1)};$$

with $m_1 = R_1/Z_0$.

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

$$-5-$$
\[ U_{G2} = U_{G1} \cdot e^{-j\tau_0\omega}; \]  \hfill (2)

where \( \tau_0 \) is the cable transit time;

\[ \tau_0 = \frac{1}{B/c_0}; \]

and where \( c_0 \) is the speed of light. The wave is partially absorbed and partially reflected at the resistance \( R_2 \). The absorbed wave voltage \( U_{2G} \) can be defined as:

\[ U_{2G} = U_{G2} + U_{R2} = U_{G2} (1 - r_2) \]  \hfill (3)

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

and \( m_2 = R_2/c_0 \).

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:

\[ U_{RR2} = r_1 \cdot r_2 \cdot U_{G2} \cdot e^{-j2\tau_0\omega}. \]  \hfill (4)

The reflected wave \( U_{2RR} \) absorbed in resistance \( R_2 \) can then be defined by the expression:

\[ U_{2RR} = U_{RR2} (1 - r_2). \]  \hfill (5)

Disregarding any further reflections, the voltage \( U_2 \) at resistance \( R_2 \) is then given by the expression:

\[ U_2 = U_{2G} + U_{2RR}. \]  \hfill (6)

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

\[ U_2 = U_{G2} (1 - r_2) + U_{RR2} (1 - r_2) \]  \hfill (7)

and from this we can obtain the expression:

\[ U_2/U_0/2 = (1+r_1)(1-r_2)(1+r_1r_2e^{-j2\tau_0\omega})e^{-j\tau_0\omega}. \]  \hfill (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 \( r_1 r_2 \ll 1 \) the absolute amount can be fairly approximated as:

\[
\left| \frac{U_2}{U_{0/2}} \right| = (1 + r_1) (1 - r_2) (1 + r_1 r_2 \cos 2\gamma_0). \quad ... (9)
\]

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:

\[ 2\gamma_0 \omega_0 = (2n - 1) \cdot \frac{\gamma}{2}; \]

where:

\[ \gamma_0 = \frac{l_E}{C_0}; \]

\[ \omega_0 = 2\pi f_0; \]

\( f_0 \) is the mid-band frequency; and \( n \) is a positive whole number.

Then the absolute amount becomes:
\[
\frac{U_2}{U_{0/2}} = (1+r_1) (1-r_2) \left[1+(-1)^n r_1 r_2 \sin 2\gamma_0 \Delta \omega \right]
\]

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

The differential gain \(DG\), which is defined as the change in phase deviation \(\eta_1\) relative to the phase deviation \(\eta\), may be expressed as

\[
DG = \frac{\Delta \eta}{\eta} = -(-1)^n r_1 r_2 (1-\cos 2\gamma_0 \omega_s) \sin 2\gamma_0 \Delta \omega
\]

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 \(R_3\) in a series arm and a resistance \(R_5\) connected to the potentiometer slider in a shunt arm. The feed circuit, comprising the generator \(G\) of internal resistance \(Z_0\) and this resistance network has a variable source impedance \(R_Q\) defined by the expression:

\[
R_Q = R_3 - R_4 + \frac{R_5(R_4+Z_0)}{R_5+R_4+Z_0}
\]

and the circuit exhibits a substantial constant output level if \(R_3\) and \(R_5\) 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:

\[
m_{11} = \frac{1}{m_{12}};
\]

\( m_{11} \) being equal to \( R_{Q1}/Z_0 \);

\( m_{12} \) being equal to \( R_{Q2}/Z_0 \); 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 \( R_3 \) and the transverse resistance \( R_5 \). It also makes it possible to set the source resistance \( R_Q \) exactly to the characteristic impedance \( Z_0 \) and permits correct setting of the partial series resistance \( R_4 \) of the potentiometer \( R_3 \) lying before the tapping point.

Fig. 3 shows the differential gain \( \delta V/V \) as a function of \( \Delta f \) for various values of the partial resistance \( R_4 \) of the potentiometer \( R_3 \), 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 \( R_4 \) (in the circuit under
consideration the partial resistance is variable between 0 and 47 ohms), i.e. at the two end settings of potentiometer R3.
The claims defining the invention are as follows:

1. An equalizer circuit arrangement for correcting the differential gain of an FM directional radio system, said circuit arrangement comprising said system and means to superimpose a delayed and attenuated signal upon a main signal, said means comprising a length of cable that is inserted in the signal path of said system carrying the main signal and mis-matched at its input and output, said length being selected for the operating band of the system such that the attenuation distortions and differential gain distortions of the main signal 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, whereby a frequency band to be equalised lies in the most linear region of the sine function.

2. An equalizer circuit arrangement as claimed in Claim 1, in which said directional radio system includes two spaced apart components and said cable is an elongated connecting cable between said two components.

3. An equalizer circuit arrangement 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 arrangement 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 arrangement for correcting the differential gain of an FM directional radio system, said arrangement being substantially as described with reference to Figures 1 and 2.
DATED this EIGHTH day of NOVEMBER 1979

SIEMENS AKTIENGESELLSCHAFT

Patent Attorneys for the applicant
SPRUSON & FERGUSON