Unwanted-Signal Canceller for Co-located Communications Antennas

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Abstract

The problem of interference suppression from co-located transmitter antennas under multi-path signal propagation is discussed. A signal canceller using a time-delay equalizer circuit is proposed and experimental results are reported proving broad-band cancellation of the unwanted signal. Limitations of the concept are discussed and improvements are proposed.

Introduction

Co-location of antennas, e.g., for communication base stations may pose increasing interference problems with co-existence of different systems and with growing numbers of antennas and reduced spacings. If frequency filtering and/or decoupling of antennas by optimisation of mounting fails to achieve interference suppression goals, active cancellation in the RF domain /1/ may be needed, as described in this presentation. In Fig.1, the scenario of two mutually coupled antennas is presented, where one antenna may be assumed to be the transmit antenna of one communication system while the second antenna may be assumed to be the receive antenna of a second system. The transmitted signal from the first antenna is received by the second antenna via a direct path, a ground reflection path and one or several scattering paths. The unwanted signal received at the second antenna interferes with the wanted signals of the second communication system and it may be necessary to increase the unwanted signal attenuation in order to allow proper system operation.

In principle, this can be achieved by coupling out a portion of the interfering signal from the first transmitter and adaptively feeding this signal into the receiving second antenna in such a way that cancellation of the two signals occurs /1/. Adaptive cancellation can be achieved by employing an agile I/Q-modulator to match the compensating signal exactly to the interfering received signal. Such circuits have been used in CW-radar systems to decouple transmit- and receive-antennas in order to preserve the sensitivity of the receiver under the presence of a high-power transmitter in close spacing /2/.

In a communications antenna scenario, it may be impossible to realize stable control loop operation of the adaptive canceller circuit due to the long delay times of the various signal paths in Fig.1 and wide bandwidth signals.

It is therefore proposed in this presentation to employ a canceller circuit which compensates the individual time-delays of various signal components by using a time-delay equalizer circuit similar to the *finite impulse response* (FIR) filter concept used in digital signal processing, Fig.2. The dashed part of the circuit contains the directional couplers needed to couple-out the transmit signal and couple-in the compensating receive signal with the time-delay equalizer in-between. The equalizer circuit incorporates signal splitters to separate individual signal paths, adjust the levels of the signals by the power division ratio and adjust the phase shift / time-delay by connecting fixed length transmission lines such that the time-delay of the radiated and received signals between the antennas is correctly represented.

Test Antennas Arrangement

A demonstrator system was built using two wideband discone antennas mounted on the roof platform of our building. At a spacing of about 20 meters, the direct path and reflections from the roof skin, a metal fence and from a roof house produced antenna coupling at about –40dB with strong frequency variation of phase and amplitude. Various signal paths were identified by analysing the coupling signal in the time-domain: The frequency-swept response was *Fourier*-transformed into the time-domain, see Fig. 3: We recognize the main response in a narrow peak around t = 67 ns (about 20 meters) and a long tail in the time-domain with various signal components due to reflections and scattering on the roof platform superimposed. Separate portions of the composite time-domain signal were gated out and re-transformed back into the frequency-domain, so that signal delay and amplitude for each signal path over the frequency range and in particular, at a frequency of 430 MHz (our intended frequency of operation with the interference cancellation circuit) could be evaluated.

Analysing the first peak in the time-domain response, it is clearly seen that the peak can not be separated into two separate signals of the direct path and the roof skin ground reflection path in the time-domain; however, the retransformed frequency response of the gated main-peak, see Fig.4, shows a quasi-periodic variation over about 600 MHz frequency band which clearly indicates a delay path length of about 50cm, which coincides approximately with the geometrical path difference (at 20 m direct path and antennas at about 2 m height). Although two different path length requirements thus have been established, in order to save in the effort of the equalizer circuit, the response was modelled merely as one single signal of –49 dB at 20.22 m average delay. As can be seen from Fig.4, this simplification can be tolerated over the limited bandwidth of the intended operation over 10 MHz around 430 MHz with the penalty of a variation of the insertion loss on the order of below 1 dB (and a few degrees in angle).
Although the time delay “tail” is not distinctly structured, two other signal components were gated out in the time-domain and retransformed into the frequency-domain to yield signals with –55 dB at 26.7 m average delay and –83 dB at 45 m average delay. However, it must be warned that the separating of individual signal components (signal paths) is not a unique operation due to the rather distributed character of the time-domain function, so that some arbitrariness resides in the present method with respect to the choice of the number of time-domain gates and their positions and widths.
The total delay of signals from the transmitter to the receiver included two connecting transmission lines with a resulting electric length of 48 m, yielding a total delay length of 68 m for the direct path. From such long time-delay, the phase of the received unwanted signal changes steeply with frequency and signal cancellation using a constant phase shift compensating signal would work only over extremely narrow band (20 dB cancellation over about 0.3 MHz). Thus, only by using equivalent lengths delay lines in the compensating signal paths, a broad bandwidth cancellation can be expected.

Cancellation Demonstrator System

Our initial experimental cancellation circuit provided only two delay lines in order to compensate the first two identified signal paths. The lengths of the delay lines and the power divider ratios were fixed to the corresponding values of the measured signals, including the directional coupler amplitude and phase responses. Although failing a satisfactory representation of the real scenario (direct- and ground reflection path not discriminated and only one further path represented), after a fine-tuning adjustment of the delay and amplitude settings for the time-delay equalizer circuit, a flat cancellation by about 20 dB over a bandwidth of 30 MHz was achieved or, with a different adjustment, a deep cancellation over 5 MHz, see Fig.5. In part, the limitation in the cancellation ratio (broad-band) or the bandwidth of cancellation (narrow-band) is due to the residual frequency variation of the first signal component which is cancelled using a signal of constant amplitude over frequency: Instead of employing an extra delay branch in the equalizer circuit to represent the ground reflection signal and thus improve cancellation, it should be possible to represent the frequency

behaviour by a suitable R-L-C equalizer network at least over the limited band used in this system.
In principle, performance can be further improved by using additional delay-sections in the equalizer circuit, to better match the signal response "tail" but short-term and long-term degradation of signal cancellation due to aging, temperature and humidity- effects and even wind have been noticed during the experiments. Thus, such an additional effort was found to be of little value, unless an adaptive component is added to the canceller loop, as has been demonstrated by adaptive power canceller circuits for CW-radar systems /2/. In that case, the merit of the equalizer circuit would be that the adaptive canceller loop agility requirements could be much relaxed as compared to the critical loop requirements in a canceller without pre-equalization.

Conclusion

It has been shown that the antenna-to-antenna coupling in communication systems may be reduced by a cancellation circuit which employs transmission lines to mimic the phase progress in the coupling signals. Separation of the coupling response into individual signal components and representation of each component by individual transmission line lengths and amplitude allow the design of a equalizer-type cancellation circuit. Cancellation to 20 dB was found realistic over a 5% bandwidth using a simple two-path equalizer, but much higher cancellation will require some form of adaptiveness.

Literature

/1/ R.N.Ghose, Interference Mitigation, IEEE Press, 1996

/2/ F.J.O'Hara, G.M.Moore,"A high performance CW receiver using feedthru nulling", Microwave Journal, Sept.1963, 63-71

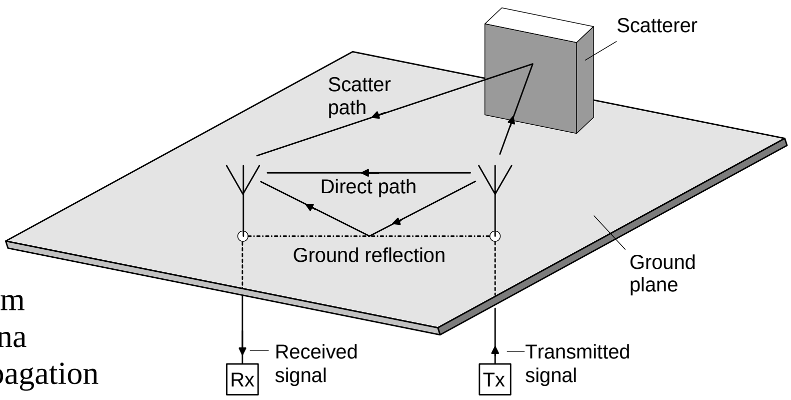

Fig.1 Scenario of interference from co-located transmitter antenna under multi-path signal propagation

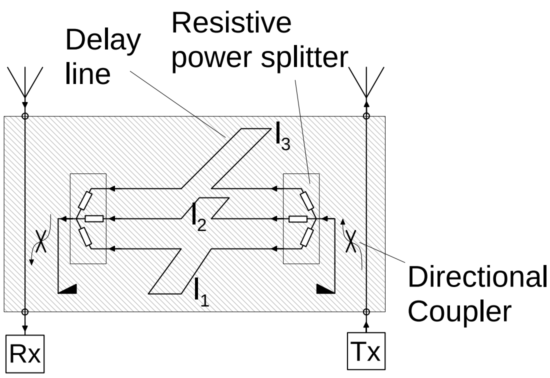

Fig.2 Unwanted-signal canceller circuit using time-delay equalization (3 paths shown, with equivalent time delays l_1 , l_2 , l_3)

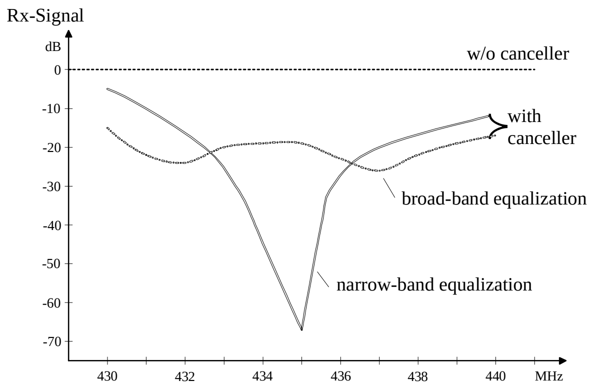

Fig.5 Cancellation ratio achieved with two-element time-delay equalizer

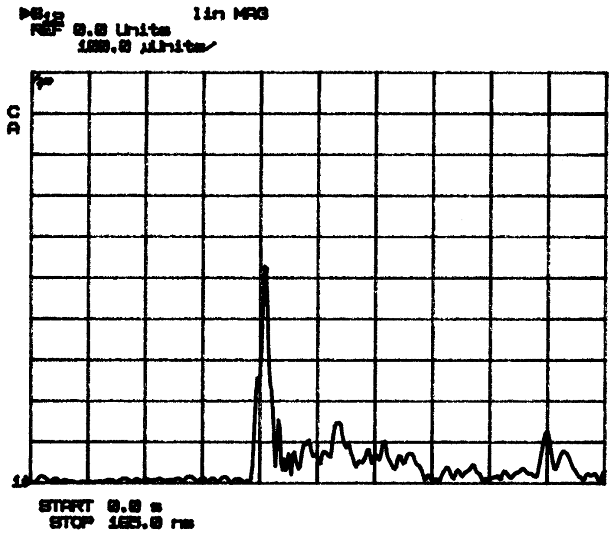

Fig.3 Time-domain response of coupling between antennas(main peak at about 67 ns)

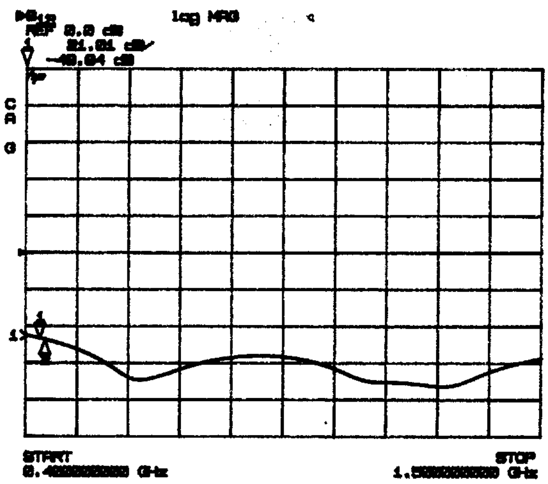

Fig.4 Re-transformed response of the main peak antenna-to-antenna coupling