INTERFERENCE CANCELLATION SYSTEM

As a means of providing RF compatibility between transmitters and receivers, a new cancellation technique offers an answer for previously unsolvable interference problems. Interference Cancellation Systems (ICS) have been developed that operate with active real-time networks to reduce interference of undesired signals by more than 60 dB. These ICS systems have successfully proven their ability to suppress interference including modulation and spurious frequencies. Existing units protect overlapping and adjacent channels in collocated transmitters and receivers over ranges from audio frequencies through the lower portion of "J" Band.

As the interference signal travels from its source antenna to the antenna that provides inputs to the receiver, the signal is altered in two ways: The amplitude decreases because of losses within the medium (propagation loss). Also, the interference signal detected by the receiver antenna is delayed in time because of the physical separation between the interference antenna and the receiver antenna. Therefore, an amplitude ratio and time delay factor K/τ defines the characteristics of the propagation path. If a second propagation path is constructed and controlled so that it has the same time delay factor, and with the same amplitude ratio factor with reversed polarity; then a cancelling signal would be synthesized. Interference signals traveling through both the natural and the synthesized paths would be identical, except for their reversed polarity. The summing of these two signals would in effect cancel the interfering signal in the receiver antenna line.

The technical approach implemented consists of synthesizing a network equivalent to the propagation path between the interference source antenna and the receiver antenna. A coupler or a reference antenna feeds a sample of the interference of the synthesizing network. The interference signal is divided into two channels in the signal controller to drive quadratured control mechanisms. One channel controls the sine characteristics and the other channel controls the cosine characteristics. This, in effect, provides a complete 360° phase control function. The sine and cosine components are independently amplitude adjusted and summed to control the amplitude and phase time-delay of the resulting signal. Thus the resulting signal is effectively subtracted in a passive coupler from the signals detected by the receiver antenna. The desired signals will not be cancelled, because their propagation paths are different from the interference path and/or samples of the desired signals are not included in the sample applied to the signal controller.

Because it is difficult to determine the exact parameters of the propagation path of the reference signal and such parameters may vary the time, a close loop servo arrangement is provided. This arrangement, which utilizes synchronous detectors, allows for continuous automatic adjustment of the amplitude and time delay parameters. When the time delay parameters are controlled in the proper fashion, they also become phase parameters. If the amplitude is controlled to one percent in the time delay or phase response to .057 electrical degrees, a cancellation of 60 dB can be approached with the use of this technique. Figure 1 provides a block diagram of the interference cancellation system as described with the reference shown applied to the synchronous detector, the key parameter for the close loop control. A synchronous detector is essentially a double balanced mixer. Its operational characteristics are similar to those obtainable when the signal at the input port from the sampling coupler is switched synchronously with the signal at the reference port as if it were done by double throw switch. When the signals at these two ports are spectrally synchronous (coherent), the output error signal is essentially DC. The DC output is amplified, integrated and fed to the signal controller to adjust the ratios which control the phase (and time-delay) and amplitude ratio of the synthesized interference signal path. Properly implemented, this system will successfuly suppress all of the interference signals including the modulation sidebands and spurious outputs because the ICS is effectively duplicating the interference signal path. In addition, the closed loop technique described can provide a remedy for multipath and stability problems in many installations; and since it is a nulling approach that continuously drives the interference signal to a null.

COLLOCATED SYSTEM, BLOCK DIAGRAM

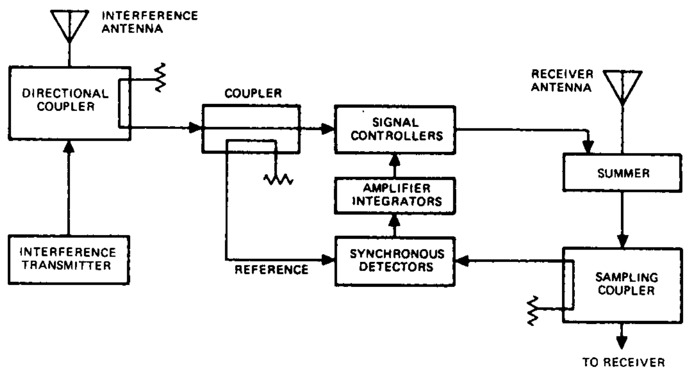


Figure 1

REMOTE TRANSMITTER, BLOCK DIAGRAM

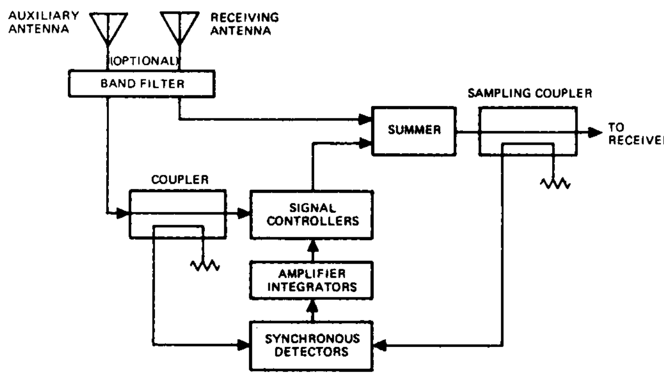
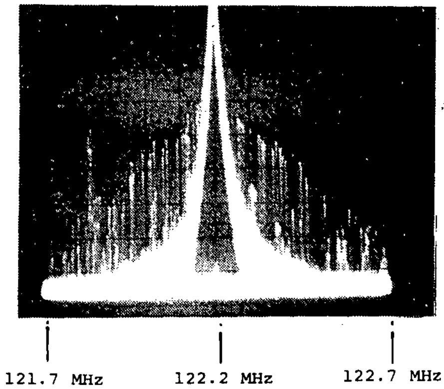


Figure 2

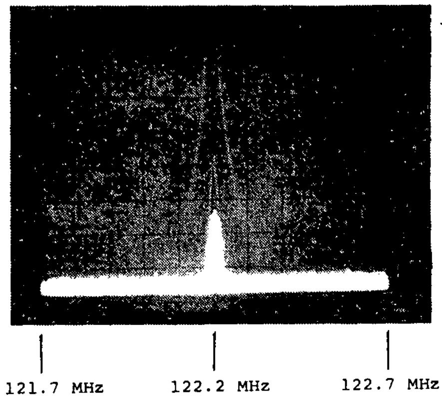
For applications where the intereference source is remote from the receiver antenna, it is possible to utilize this technique with a directional antenna. The use of directional antennas can provide adequate samples for the reference inputs of the synchronous detectors and the cancellation loops. The Interference Suppression System block diagram of Figure 2 shows the arrangements for this type of system. The directional antenna or auxiliary antenna is used in place of the hardline directional coupler sample. In some dense signal environments, preselectors may be required for this type of installation. The installation of an Interference Cancellation System requires some care and consideration, since the path lengths must be approximately the same for the signal time delays. This match provides the ability of the system to provide wideband cancellation. The desired characteristics for Interference Cancellation Systems are as follows:

- Truly linear processor - Degradation of S/N even for weak signals must be negligible.
- Will not require transmitter or receiver modification.
- Self tuning - Automatically track the interference frequency over an octave or larger band.
- Reduce the interference by 60 dB or more, or to the noise level.
- Be unaffected by propagation multipaths and their variations with time.
- Cannot degrade normal receiver performance when suppression system is inoperative.
- Employ no moving parts - capable of withstanding shocks and vibrations typical of aircraft.
- Interchangeable passive or solid-state component modules. Require negligible maintenance.
- Multichannel capability to allow multiple transmitter operation.

Figure 3 provides a presentation of cancellation of an interference signal with spurious noise on a VHF transmitter as viewed by the receiver antenna.



(a)
Sample as received at receive antenna



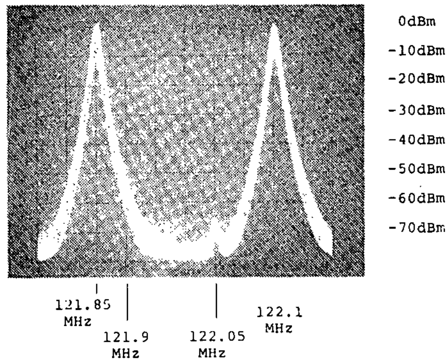
(b)
After ICS Cancellation

Figure 3. Spurious Cancellation of the ICS with an Extremely Noisy Transmitter (TUQ)

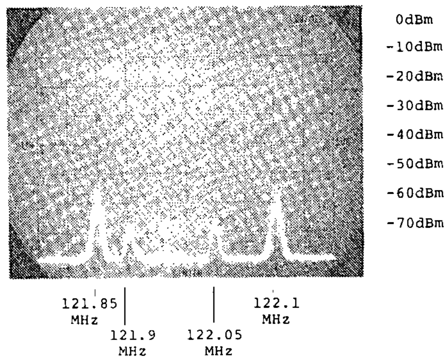
Once the receiver antenna line has been cleared of the interfering source, the receiver front end is unloaded to the extent that it can search for and lock-on to signals in the fashion and environment for which they were designed. The interference cancellation techniques are essentially unaffected by different types of modulation. Systems in the field have been used for pulse, amplitude, and frequency modulation and combinations of the above with successful cancellation as high 85 dB in some installations. Interference Cancellation Systems have also been flight proven on a number of aircraft installations where the interfering source antenna is moving due to the flexure of the airframe.

The systems have demonstrated their ability to maintain cancellation while tracking those variations present when the antennas are subject to movement. The items necessary for specifying an interference cancellation system include the number of interfering transmitters and whether the interfering sources are collocated or remote. The power level of each interfering signal at the receiver antenna must be perferably measured or calculated in dBm. Identification of the number of receivers which require protection is helpful. Typically, the interference cancellation technique is applied to a single antenna and multiple receivers are then fed from this one protected antenna. The frequency bands, involved receiver sensitivity and degree of suppression required should also be provided. Although there is no inherent limitation in the interference suppression systems described from a power handling power standpoint, economic considerations dictate the use of different types of components for different power ranges. The typical power handling capability of the systems described have been provided with up to +20 dBm as a nominal power handling capability. In the design of these systems, it is also possible to design for minimum insertion loss. Typically, insertion loss can be as high as five dB in a relatively low cost installation or with a moderate investment in coupling capability. The insertion loss can be held to less than 1 dB.

Interference Cancellation Systems are also available with multiple channel capability. Multiple channel means an ability to provide cancellation for multiple interfering sources and protection of one or more receivers from these sources. Sixteen channel systems have been constructed and flight tested in applications for reduction of 400 cycle harmonics from receiver antenna systems. In multioctave applications of this nature, the degree of cancellation is considerably more modest. Twenty dB cancellation has been achieved.



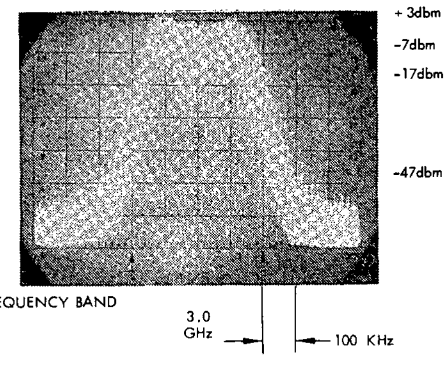
Before cancellation (undesired and desired signals as seen at the receiver input without processing by the ICS.)



After cancellation (reduced interference signals and desired signals as seen at the input to the receiver after being processsed by the ICS.)

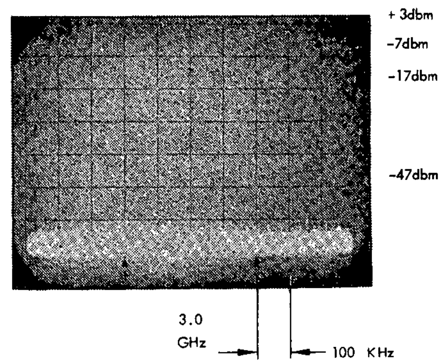
Figure 4

(a)



OPERATING FREQUENCY BAND
2-4 GHz
MODULATION
AM: 7KHz
FM: 7KHz RATE
300KHz DEV.

(b)



Suppression characteristics of a combined AM-FM Jamming Signal: a) Spectral characteristics before suppression
b) Spectral characteristics after suppression

Figure 5

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