Suppressing Multipath Interference

Electronically variable time delay can be used to suppress multipath and other interfering signals on the basis of their difference-in-time-of-arrival at two spatially separated antennas. Up to 40 dB of suppression of wideband interferers was obtained when the desired and interfering signals differential arrival times differed by only 30 picoseconds.

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In communications and electronic surveillance applications, it is often important to reduce the level of interfering signals prior to amplification, frequency conversion and subsequent signal processing. For example, in mobile communications multipath interferers can cause "dead spots' in certain areas, while in direction-finding, in-band interference signals act to reduce the effective signal-to-noise ratio and degrade the overall system accuracy.

In this paper we describe an interference suppression circuit that uses electronically variable time delay elements in conjunction with two spatially separated antennas[1, 2]. This circuit is able to suppress a number of interfering signals without degrading the desired signal.

Circuit Description

A schematic diagram of the interference suppression circuit is shown in Figure 1. Operation of the circuit is illustrated by the series of phasor diagrams in Figure 2. A selected signal is received at two spaced antennas with a small time difference due to the angle-of-arrival. The earlier signal is delayed by a time-delay element and set to equal the time-of-arrival difference. Signals arriving from most other directions will not be time balanced in the two paths from the antennas resulting in an electrical phase offset of phi = omega x *t*, where omega is radian frequency and *t* is the time difference between a selected interference signal from Antenna A and the samesignal from Antenna B (Figure 2a).

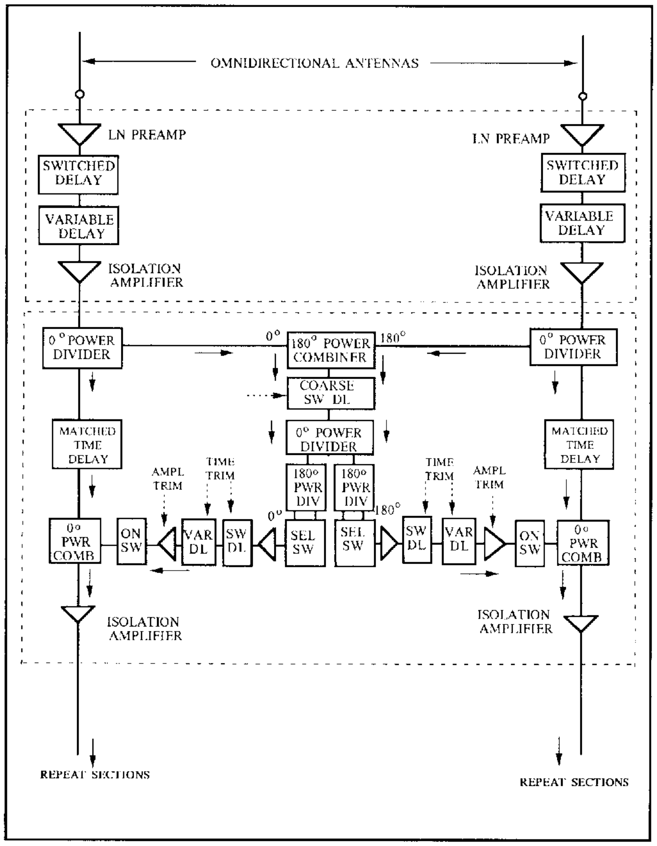


Figure 1. Interference suppression circuit.

This remains true at the output of the following 180 degree combiner, which splits the selected interferer into equal signals that are 180 degrees apart (Figure 2c). These signals are amplified to match the level of their counterparts in the bypass paths (Figure 2d) and time-delayed to bring them into an antiphase condition (Figure 2e). In both cases, the required phase shift is 90 - phi/2, but in one case it is leading and in the other case it is lagging. In order to provide a means of applying the leading phase shift, some quiescent time delay (td=phi/2) must be provided that can be removed when required. The lagging phase can be obtained by adding more time delay of up to phi/2. The total time delay required to produce the opposing phase offsets is t = phi/omega (radians) or t = 360/f (degrees) where f is the frequency in hertz.

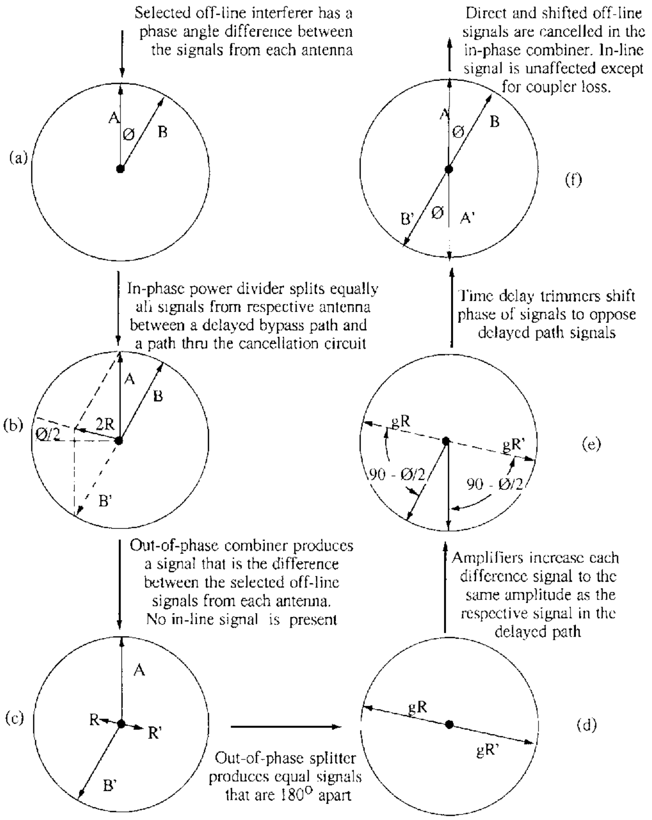


Figure 2. Phasor diagram illustrating the operation of the multi-stage interference suppression circuit of Figure 1.

The direct and processed signals are summed in their respective in-phase power combiners (Figure 2f). The selected interferer is suppressed to an extent determined by how well the amplitudes are matched and how close to 180 degrees the phase differences are offset. The desired signal is attenuated by the combiner and divider coupling factors. These losses are known and can be restored by amplification. The desired signal is unaffected by the gain and time delay adjustments of the circuit.

A key feature of this circuit is that it preserves the amplitude and phase relations between the desired signals in each path for further signal processing provided there is a very accurate match between the delays and losses in each path. This makes it possible to sequence several stages of interference suppression without significant alteration or degradation of the wanted signal. When multiple stages of interference suppression are used, it is preferable to sequence the suppression such that the interferer canceled by the lowest gain amplifier setting is processed in the first stage to minimize the amplification of the other interferers.

Electronically Variable Delay Lines

The interference suppression circuit of Figure 1 uses switched delay lines in series with continuously variable delay lines. The switched delay lines consist of two, five-step switchable delay line sections that provide a zero to 3100 picosecond relative delay in 100 picosecond steps. Figure 3 shows a plot of delay versus frequency for one of the switched delay lines, with delays ranging from 100 to 1600 picoseconds.

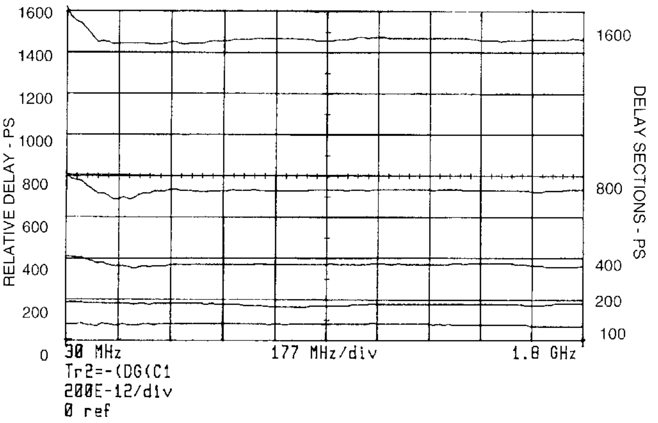


Figure 3. Delay versus frequency of the switched increment delay line.

The performance of one of the continuously electronically variable delay lines is illustrated in Figure 4, and a photograph of these packaged delay lines is shown in Figure 5.

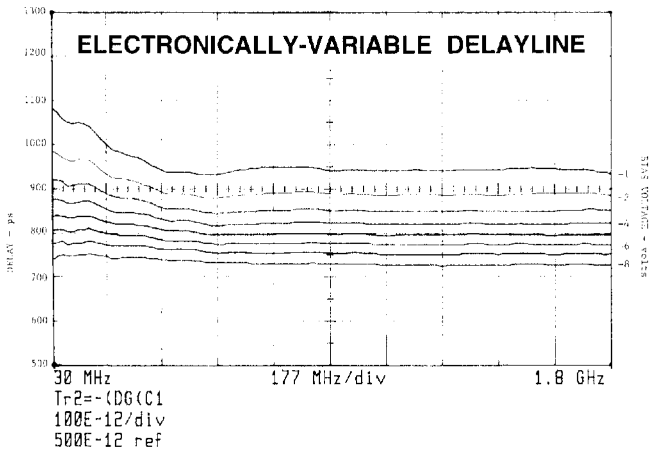


Figure 4. Delay versus frequency of the variable delay line.

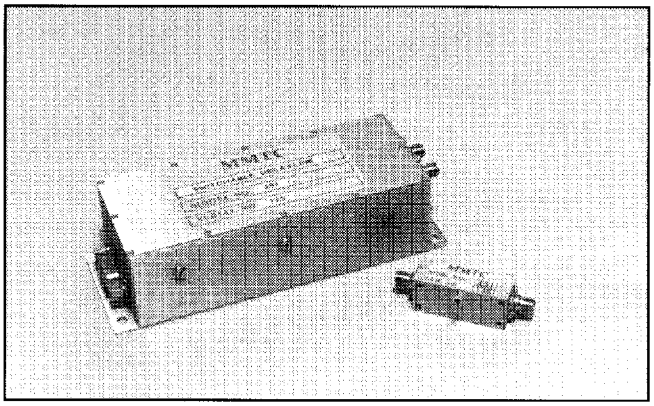
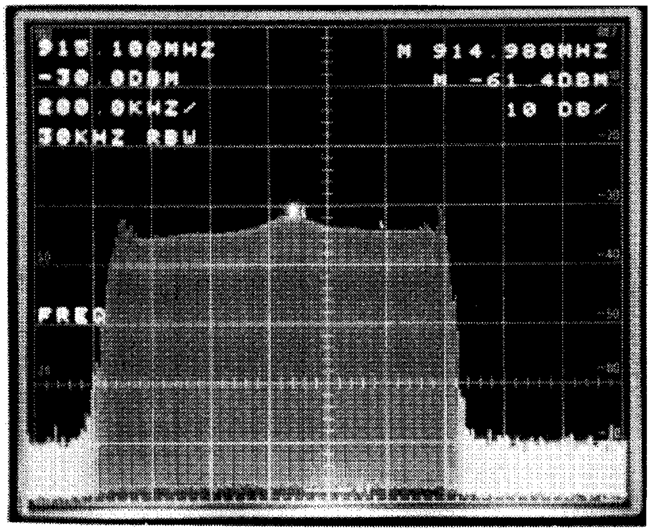
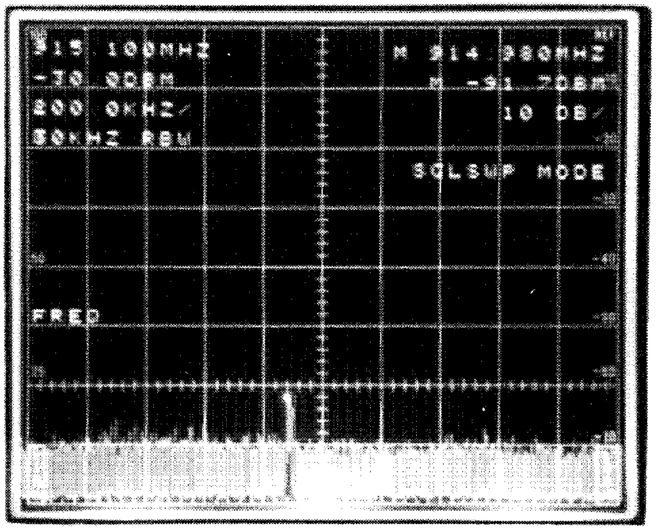


Figure 5. Photograph of packaged delay lines.



(a) No cancellation.



(b) Full cancellation.

Figure 6. Demonstrating wideband input interferer at same center frequency as desired signal with angle of arrival difference of approximately 0.4 degrees. The interferer amplitude is approximately 30 dB above the narrowband desired signal amplitude, and the narrowband signal is about 10 dB above the noise level.

Results

The performance of a single section of the interference suppression circuit is illustrated in Figures 6-8 for the case of a large wideband interferer whose frequencies overlap that of a small, desired, narrowband signal. Figures 7 and 8 respectively show the experimental setup and the observed television pictures for the case of two different television signals (ghosting) appearing in the same channel.

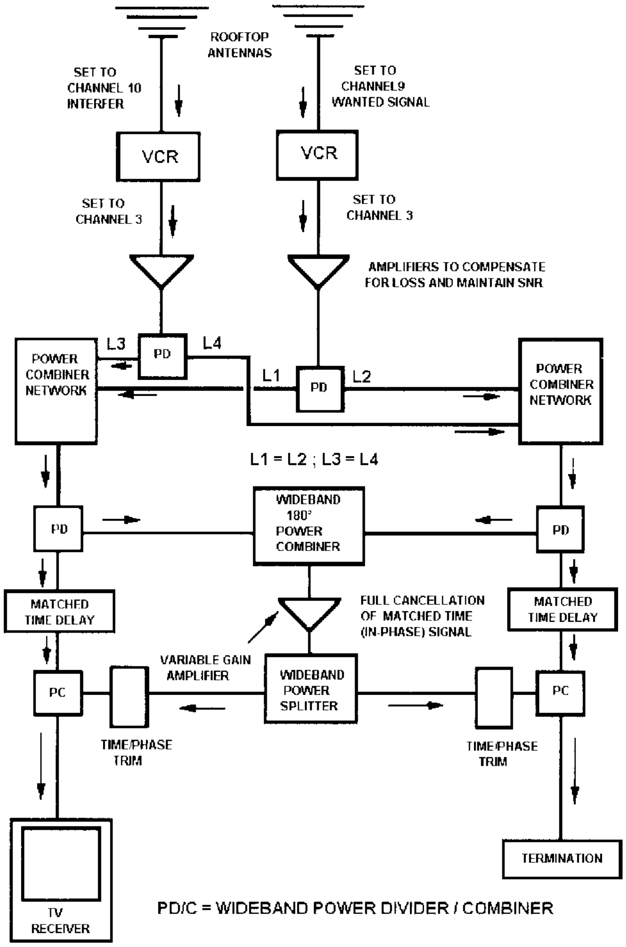
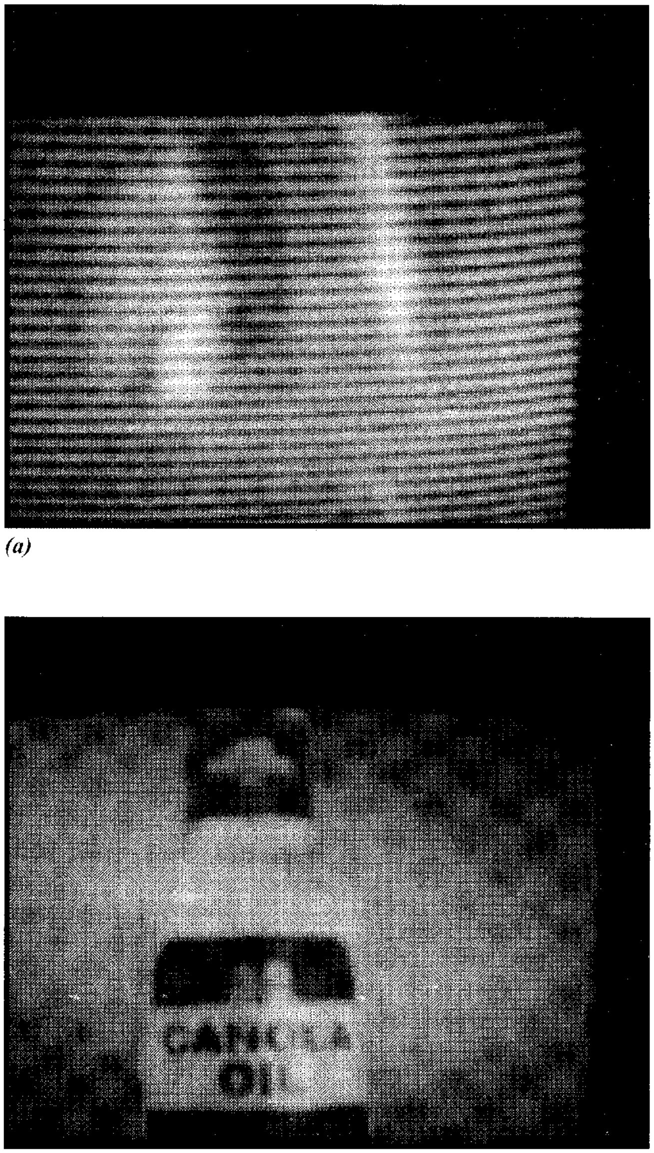


Figure 7. Diagram of the experimental setup used to demonstrate suppression of interfering TV signals which occupy the same TV channel as the desired signals.

As these results demonstrate, the use of multiple antennas and variable time delays can suppress undesired signals without significantly affecting wanted signals. In these tests the technique spells the difference between a comfortably viewable TV picture and an all but useless one. As continuing growth occurs in wireless communications, the limited radio spectrum will be taxed by multiple interfering signals. Suppression methods such as this can be expected to find ever increasing application.



(a)

(b)

Figure 8. TV pictures received with and without the use of the interference suppression circuitry of Figure 7. (a) Picture without using the interference suppression circuitry. (b) Picture using the interference suppression circuitry.

References

[1] Fred Sterzer, "Difference-in-Time-of-Arrival Direction Finders and Signal Sorters", United States Patent 5,260,711, November 9,1993.

[2] Robert E. Askew, Daniel D. Mawhinney and Fred Sterzer, "Suppression of Multipath and Other Interferers using Electronically Variable Time Delay Elements," IEEE MTT-S International Microwave Symposium Digest, 1994, pp 1671-1674.

Robert E. Askew was awarded a BSEE Degree from Newark College of Engineering (now New Jersey Institute of Technology) in 1963, where he also attended graduate courses.

He joined RCA's Microwave Tube Operations in 1961 where he was engaged in the Pencil Tube Design and Applications Group. Subsequently he collaborated on microwave solid-state design projects as part of the Advanced Development activity, and developed solid-state oscillators for radiosonde applications and projectile telemetry transmitters. In 1972 he transferred to the RCA Solid State Division where he supervised the fabrication and testing of microwave power amplifiers for military and space applications.

From 1977-1978 he was engaged at Microwave Semiconductor Corporation after which he returned to the David Sarnoff Research Center's Microwave Technology Center where he designed a cooled low-noise amplifier for a ground-based satellite terminal, a low-noise amplifier for a Ku-band down converter for a geostationary satellite, a state-of-the-art microwave rotary joint, a high-dynamic-range channelized receiver and other advanced microwave components.

He is currently involved in the development of a direction finding receiver for electronic warfare applications at MMTC, Inc.

In 1985 Robert Askew was a co-recipient of the David Sarnoff Award for Outstanding Technical Achievement, RCA's highest honor, for the design, development and space qualification of the first commercial cooled, low-noise microwave amplifier.

He has published several papers on microwave solid-state components, and holds three U.S. Patents. He is a Senior member of the Institute of Electrical and Electronics Engineers and of its Professional Group on Microwave Theory and Techniques.

Daniel Mawhinney received a BEE Degree, magna cum laude, from Polytechnic Institute of Brooklyn and an MSEE Degree from Newark College of Engineering.

While serving in the military he was assigned to the Evans Signal Laboratory and the Naval Research Laboratory. Subsequently he joined the RCA Microwave Operations in Harrison, NJ where he contributed to the design and fabrication of frequency multiplier units for the Lunar Module landing and rendezvous radars and developed a tunnel-diode amplifier subsystem used in a commercial aircraft radar system. As Manager of Solid State Product Design, he was responsible for product development and transfer to manufacturing of microwave solid state devices, with emphasis on military subsystems.

In 1975 he transferred to the Technical Staff of the Microwave Technology Center at RCA Laboratories (now the David Sarnoff Research Center) Princeton, NJ where he continued his work on advanced microwave devices and subsystems for ECM applications as well as various small radar systems for industrial and medical applications. He developed hand-held heart rate monitors for specialized military applications, and miniaturized arterial pulse sensors for use in aerospace physiological monitoring.

Currently at MMTC he is involved in development of DF subsystems, recrossed time delay devices, radiometers, and noninvasive vital signs monitors for medical applications and remote sensors for industrial uses.

Daniel Mawhinney has been awarded 26 U.S. Patents and has published approximately 20 papers. He is a member of the IEEE and a licensed Professional Engineer in the State of New Jersey.

Fred Sterzer received a BS Degree in Physics from the City College of New York in 1951, and M.S. and PhD Degrees in physics from New York University in 1952 and 1955, respectively. The subject of his Ph.D. thesis was microwave spectroscopy.

In 1954 he joined RCA, where he was engaged in the development of traveling-wave tubes, optical components, gigabit logic, microwave solid state devices and circuits, and medical applications of microwaves. He ultimately became Director of the Microwave Technology Center at the David Sarnoff Research Center, Princeton, NJ, at which he led a group of over 85 scientists, engineers and technicians in developing new microwave technologies. In 1987 he formed and is the president of MMTC, Inc. a company specializing in the utilization of microwave technologies in industrial, medical, military, and space applications.

Dr. Sterzer is a member of the National Academy of Engineering, a Fellow of the IEEE and a member of Phi Beta Kappa, Sigma Xi, and the American Physical Society. He received the New York University Founders Award and the IEEE Centennial Medal. He has written over 90 papers and was awarded more than 35 patents.