SELF-TRACKING DUPLEX COMMUNICATION LINK USING INTEGRATED RETRODIRECTIVE ANTENNAS

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ABSTRACT

A new type of active retrodirective antenna array for full duplex transceiver applications is presented in this paper. The architecture of a dual frequency retrodirective array normally used only for returning an encoded signal to its originating source has been modified to now include a receive function. The usefulness of this new architecture is demonstrated by constructing a bi-directional communication link based on two identical architectures operating in conjunction with a single pilot signal.

INTRODUCTION

Recent advances in mobile wireless communication technology has generated considerable interest in low cost novel antenna architectures which can combine more than one function and can be integrated with rest of the system. A conventional retrodirective antenna reflects incident signal back in the direction of its originating source without a-priori knowledge of its position. The best known example of such an antenna is the corner reflector where the geometry of the structure results in retrodirective beam formation. Retrodirectivity is a result of phase conjugation of the incident signal at each element before retransmission. Van Atta [1] proposed a planar retrodirective antenna using interconnecting transmission lines for phase conjugation. Pon [2] used a mixer such that the conjugated mixing product was used to obtain retrodirectivity. All these architectures essentially act like reflectors sending back the incident signal towards its source and do not simultaneously support the conventional array receive function.

In this paper a new type of retrodirective antenna is presented which retains the functions of the retrodirective transmitter while simultaneously permitting operation as a receiver array whose characteristics are those of a classical passive array. A communication link based on the new array is also presented. The link uses a pilot tone as a phase reference for initiating the synchronisation of the co-operating retrodirective arrays which forms mutually self-tracking polar patterns. In a mobile communication environment ultimately this means that highly directional antennas could be made to stay automatically aligned so that the need for omnidirectional antennas, hence multipath interference problem could potentially be eliminated.

RETRODIRECTIVE TRANSCEIVER ARRAY

Figure 1 shows the circuit diagram for the two element retrodirective transceiver array. For compactness dual polarised microstrip patch antennas are used as the radiating elements in the array. These act to provide polarisation isolation between transmit and receive signals. The received signal from each element in the array is divided using power dividers. Outputs from one port of each divider is summed to form the receive section of the array. The output from the other divider port is amplified and mixed with a local oscillator signal operating at approximately twice the frequency of incoming signal. The phase conjugate signal available at the mixer output [3] is further amplified and fed to the transmit port of the respective dual polarised patch antenna element. Because of the narrow bandwidth of the patch antenna only the difference product, which bears the phase conjugate relationship with respect to the incident signal is retransmitted and the sum product is filtered out, thus eliminating the need for additional filtering components. Due to the phase conjugation operation on the signal applied to each element the retransmitted signals add in phase only in the direction of the originating source thereby forming a re-radiated beam in that direction.

Figure 2 shows monostatic radar cross section measurement of the transmit beam and radiation pattern of the received beam for this architecture. The transmit beam being retrodirective tracks the source, which is moving in azimuthal plane. This results in a flat amplitude response at all the source positions. Here the measured 3 dB beamwidth is 130^0. This performance characteristics is preserved for the communication link experiments carried out in figure 4, using the arrangement of figure 3a.

The measured receive radiation pattern is that of the passive two element array with measured 3dB beamwidth of 60^0 .

DUPLEX RETRODIRECTIVE COMMUNICATION LINK

A communication link can be formed using a pair of the retrodirective transceiver antennas described above and a pilot signal. Figure 3 shows the layout for the link. Here for ease of measurement one unit is held stationary, the base unit, while the other unit is allowed to roam, the mobile unit. However, in general the base station can also be mobile. The base station houses a separate microstrip patch antenna for the transmission of the pilot signal. In our experiments this is required in order to initiate co-operative retrodirective action. Synchronised retrodirective action has been once established the pilot tone can be switched off, although in our work it is left on. The base station retrodirective transceiver antenna transmits the signal with a vertical polarisation and receives it in horizontal polarisation. At the mobile unit the signal is received in the vertical polarisation and transmitted in horizontal polarisation.

Mutual self tracking communication is initiated by switching-on the 1GHz signal from the pilot antenna. This signal can be removed once synchronisation has been acquired, in our work it is left on throughout the experiment. The retrodirective transceiver array at the mobile unit receives this signal. The retrodirective section of the array mixes received signal with a local oscillator signal at 1.990GHz, and the difference product at 990MHz is retransmitted back in the direction of the pilot signal, i.e. to the base station. The retrodirective transceiver antenna at the base station, in turn, receives the signal at 990MHz. The receiver section of the base station array operates in the conventional way as for a passive array. The retrodirective section of the base station array mixes the signal with its local oscillator signal at 1.990GHz. The difference product at 1GHz is retransmitted back in the direction of the mobile unit. In this way the transmit beams from base station and mobile unit always track each other without a-priori information of their respective positions. Thus in principle directive antennas can be made to track each other in a mobile wireless environment. Although not implemented in the prototype described here, the retransmitted signal from each unit can be suitably modulated to bi-directionally communicate encoded information between the units.

MEASUREMENTS

Measurements on the link were obtained by keeping the base station stationary and moving the mobile unit around it in an azimuthal plane as shown in figure 4. To evaluate the performance of the system a reference measurement was also performed on a separate communication link constructed using passive elements arranged as in figure 3b. During the measurement on the passive link the nominal boresight of the mobile unit was always kept parallel to the nominal boresight of the base station array (figure 4a). In this situation the radiation patterns of both arrays comes into play and the measured radiation pattern represents a multiplication of each respective array radiation pattern. Hence in this case the received power decreases rapidly as the array moves away from the boresight position. Measurement shown in figure 4b was carried out for the retrodirective link and results in the transmit beam characteristics in figure 2. In this case, although both the arrays have relative movement parallel at all azimuthal positions, because of retrodirective nature their transmit beams are always locked to each other. This configuration was used in preference to an arrangement with mobile and base station unit nominal boresights aligned so that a less than optimal situation could be systematically tested.

Figure 5, shows the measured receive radiation patterns at the mobile unit and the base station. Figure 5a shows the receive radiation patterns for the mobile unit. Here it can be seen that the physical array orientation performed for the retrodirective link and the passive link, figure 4a and 4b, respectively are identical. The results for the measurement of the received power of the retrodirective link shows an improvement in excess of 10dB at the $\pm 70^0$ azimuthal positions when compared to the power received in the case of passive link at the same positions. This occurs since the power received at the passive link (figure 3b) is the product of the multiplication of radiation patterns of the receive beam at the mobile unit and the transmit beam at the base station, both of which are that of a two element passive array. In the case of the retrodirective link, the received power is the product of the radiation patterns of the receive beam at the mobile unit and the transmit beam at the base station. In this situation the receive beam is that of the passive two element array and the transmit beam is retrodirective in nature and remains relatively flat with azimuthal positions (see figure 2).

Similarly the received power at the base station for the retrodirective link in figure 5b shows improvement in the excess of 12dB at $\pm 70^0$ azimuthal positions when compared to the power received in the case of passive link at these positions.

CONCLUSION

A new type of active retrodirective transceiver antenna array with inherent receive function is presented in this paper. Its usefulness is demonstrated by implementing a retrodirective communication link using these arrays for simultaneous transmit/receive communication. Results for the prototype retrodirective transceiver antenna array element and the communication link are discussed. It is shown that such a communication link gives superior performance when compared to a link constructed using passive arrays. The approach outlined in this paper may find application in mobile communications where directional antennas could be made to automatically track each other.

ACKNOWLEDGEMENTS

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REFERENCES

1. Van Atta L. C., "*Electromagnetic reflector*", U.S. patent No. 2,908,002, Oct. 6, 1959.
2. Pon, C. Y., "Retrodirective array using the heterodyne technique", *IEEE trans. on Antenna and Propagation*", Mar 1964, pp, 176-180
3. Karode S. L. and Fusco V. F., "*Frequency Offset Retrodirective Antenna Array",* Electronic Letters, July 31, Vol. 33, No 16, 1997 pp 1350-1351

FIGURES

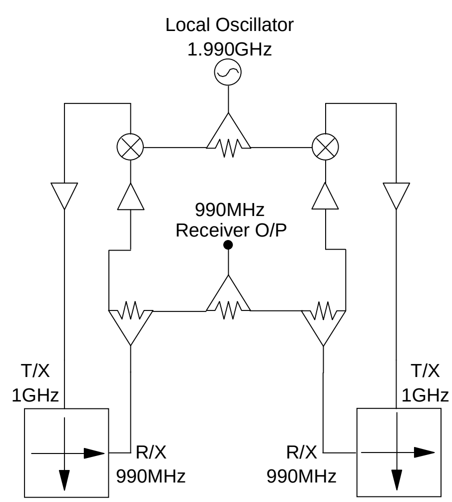

Figure 1 Retrodirective transceiver array

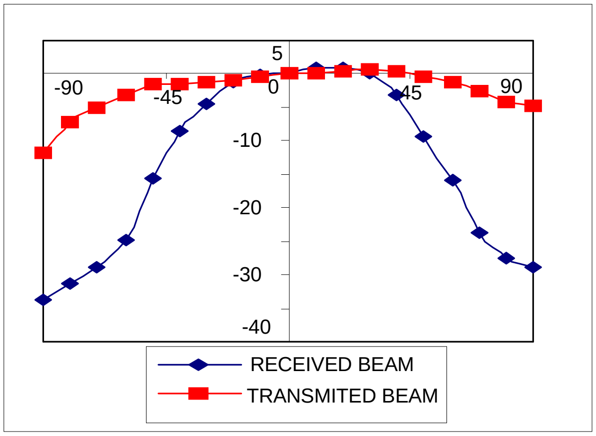

Figure 2 Measured radiation patterns for the retrodirective transceiver array

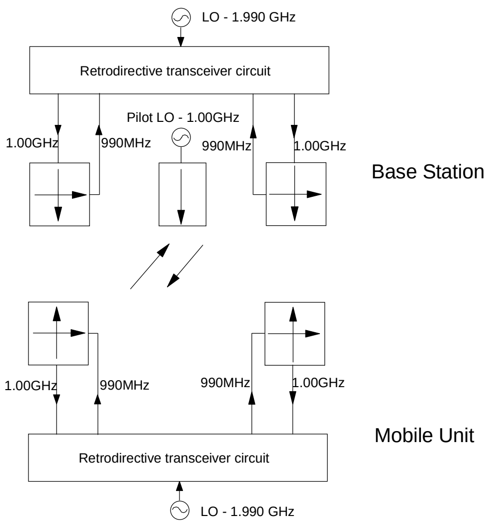

Figure 3a Self tracking communication link

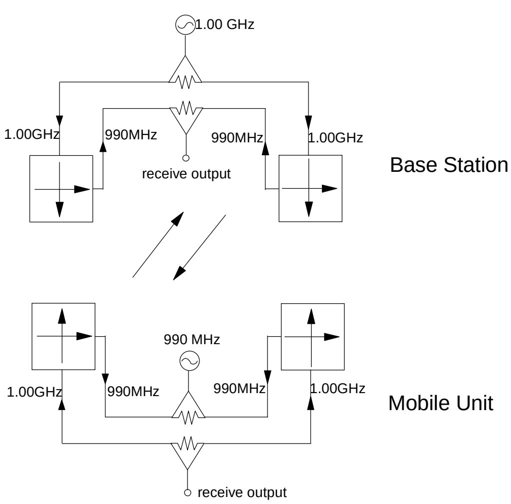

Figure 3b Passive array communication link

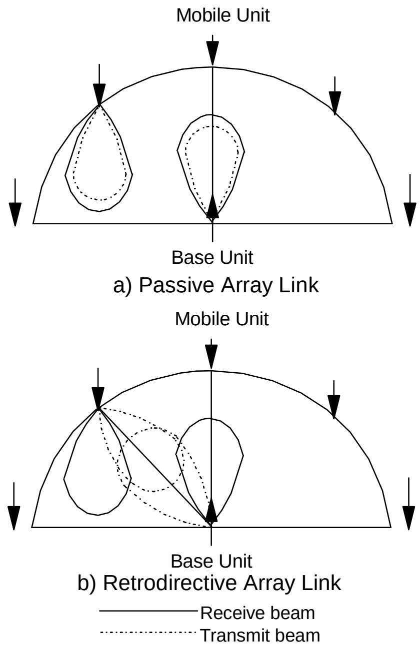

Figure 4 Measurement set-up

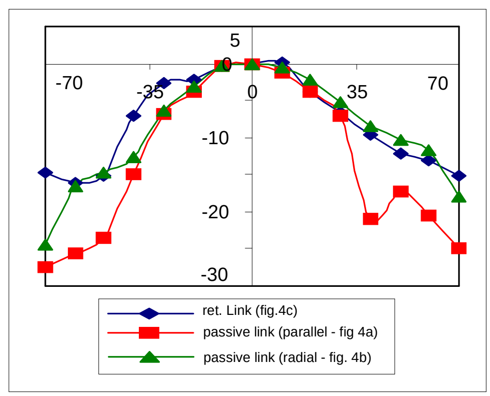

Figure 5a Radiation patterns at receive port of the mobile unit

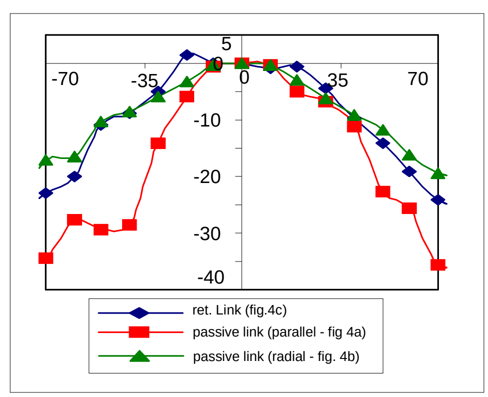

Figure 5b Radiation patterns at receive port of the base station